1983 PROGRESS REPORT

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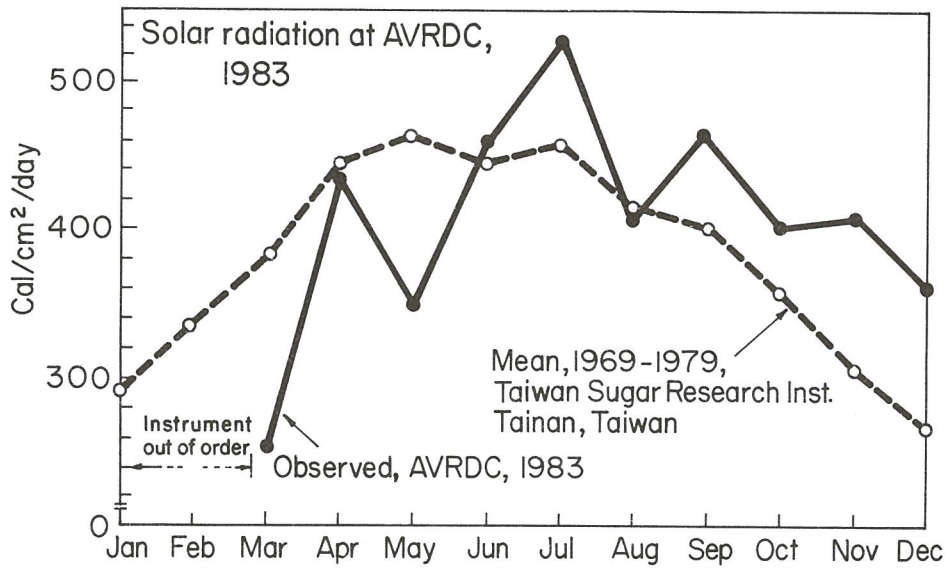
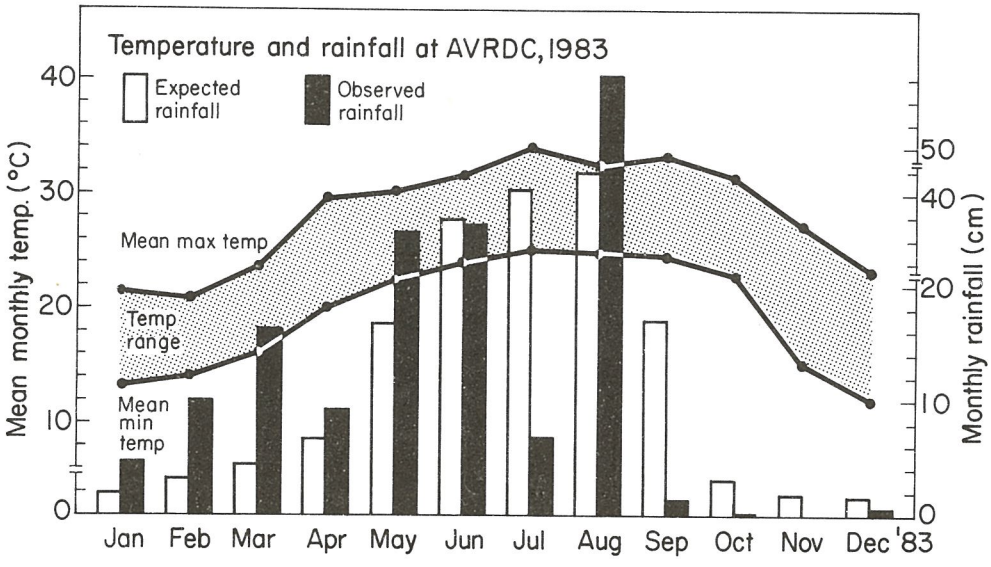
Foreword

This publication provides detailed reports on the research conducted at the Asian Vegetable Research and Development Center (AVRDC) during the 1983 calendar year. Because of the expense involved in its production, it will be distributed free charge only to libraries; personal copies can be purchased for US $10.00 (please see the "Publications" section for instructions.) Readers who need only general information about AVRDC research are invited to request a complimentary copy of the Center's 1983 Progress Report Summaries.

All requests should be sent to the AVRDC Office of Information Services, P.O. Box 42 Shanhua, Tainan 741, Taiwan.

Weather Conditions





Abbreviations and Acronyms

a.i.	- active ingredient
ARRT	- advanced rust tolerance trial
AYT	- advanced yield trial
AzMV	- adzuki bean mosaic virus
BARI	- Bangladesh Agricultural Research Institute
BCMV	- bean common mosaic virus
BGMV	- bean golden mosaic virus
BlCMV	- blackeye cowpea mosaic virus
BlMV	- blackgram mottle virus
BlCMV	- blackeyed cowpea mosaic virus
BW	- bacterial wilt
BYMV	- bean yellow mosaic virus
CAMV	- cowpea aphid-borne mosaic virus
CAT	- combining ability trial
cc	- cubic centimeter
CCMV	- cowpea chlorotic mottle virus
CFU	- colony forming units
CGR	- crop growth rate
cm	- centimeter
CMV	- cucumber mosaic virus
CMV-Y	- cucumber mosaic virus-Y
CPA	- 4-chlorophenooxyacetic acid
CPMV-S	- cowpea mosaic virus-S
CPMV-Y	- cowpea mosaic virus-Y
CV	- coefficient of variance
cv	- cultivar
CMS	- cytoplasmic male sterility
DAE	- days after emergence
DAP	- days after planting
DAT	- days after transplanting
DNP	- dinitrophenol
ELISA	- enzyme-linked immunoabsorbent assay
EYT	- elite yield trial
FAO	- UN Food and Agriculture Organization
FMV	- feathery mottle virus
g	- gram
HGR	- height growth rate
HI	- harvest index
HR	- highly resistant
HS	- highly susceptible
ha	- hectare
IARI	- Indian Agriculture Research Institute
IBPGR	- International Board for Plant Genetic Resources
i.d.	- inside deameter
IMN	- International Mungbean Nursery
INRA	- Institute National de la Recherche Agronomique
INTSOY	- International Soybean Program
IRRI	- International Rice Research Institute

IRTT - intermediate rust tolerance trial
ISEM - immunosorbent electron microscopy
IYT - intermediate yield trial
kg - kilogram
LAD - leaf area duration
LAI - leaf area index
LER - leaf area expansion rate
m - meter
min - minute
ml - milliliter
mm - millimeter
MR - moderately resistant
MS - moderately susceptible
NAR - net assimilation rate
NT$ - New Taiwan Dollar
NTU - National Taiwan University
OYT - observational yield trial
PDA - potato dextrose agar
PMV - peanut mosaic virus
PPM - parts per million
PRTT - preliminary rust tolerance trial
PSV - peanut stunt virus
psi - pounds per square inch
PSV-B - peanut stunt virus B
PVX - potato virus X
PVY - potato virus Y
PYT - preliminary yield trial
PeMV - pepper mottle virus
R - resistant
RB - reddish-brown
RCB - randomized complete block
RDA - recommended daily allowance
RDW - root dry weight
RGR - relative growth rate
RH - relative humidity
S - susceptible
SBMV - southern bean mosaic virus
SHAM - hydroxamic acid
SLW - specific leaf weight
SMV - soybean mosaic virus
SPD - split plot design
SPV-A - sweet potato virus A
SPV-N - sweet potato virus N
SSV - soybean stunt virus
t - metric ton
TARI - Taiwan Agricultural Research Institute
TEV - tobacco etch virus
ToMV - tomato spotted wilt virus
TYDV - tomato yellow dwarf virus
TLCV - tomato leafcurl virus
TYLCV - tomato yellow leafcurl virus
TuMV - turnip mosaic virus

USAID	- United States Agency for International Development
USDA	- United States Department of Agriculture
VAM	- vesicular arbuscular mychorrhizae
WAP	- weeks after planting
WAT	- weeks after transplanting
WP	- wettable powder

Horticultural Crops Program

Tomato Breeding

Crossing Program and Segregating Populations

The development of improved tropical tomato lines is a progressive, step-by-step process. Although advanced lines are now available which combine heat tolerance, bacterial wilt resistance, and the $Tm2^a$ gene for resistance to Strains 0 and 1 of tomato mosaic virus, they still require further improvement of other horticultural traits essential for the tropics. A number of them are being improved by the addition of such characters as nematode resistance, firmness, and large fruit size (Table 1).

Many of the 127 crosses made in the fall of 1983 were attempts to improve the heat tolerance of tropical lines, either by using a heat tolerant accession identified in 1983's summer test (see Table 6) or by using the genetic parthenocarpic trait, which allows fruit to develop without being pollinated. Because more outstanding tropical lines have already been identified, future emphasis will shift to backcross breeding. This should ensure the effective recovery of previous gains without making it necessary to handle large populations, even when dealing with such complex traits such as wilt resistance and heat tolerance.

Table 1. Number of crosses made in 1983.

Characters[z] under transfer	Tropical parent stocks		Number intended for backcross
	HT,BWR,$Tm2^a$	HT,BWR[y]	
Mi, with or without firmness, large fruit size, etc.	51	3	18
Improved heat tolerance	6	-	6
Dark green shoulder	10	-	10
Improved BW resistance	8	-	
Parthenocarpic fruit set	45	-	3
Mi and $Tm2^a$	-	4	3
Total	120	7	40

[z] Mi = nematode resistance gene; $Tm2^a$ = resistance to Strain 0 and 1 of ToMV; HT = heat tolerant; BWR = bacterial wilt resistant.
[y] Crosses made with widely adapted tropical line CL143.

The generations of crosses made in 1982 and early 1983 were advanced in 1983. Most of them were described in AVRDC's 1982 Progress Report, and many of them are presently in the DC_3 generation (the third

generation after the initial double cross). Whenever appropriate, they have been subjected to early generation screening for ToMV resistance (mainly for presence of $Tm2^a$ gene), either through inoculation or, since the ah gene is closely linked to the $Tm2^a$ gene, by selecting only ah (anthocyaninless) plants. In 1984, lines homozygous for $Tm2^a$ will be selected from various populations before being finally screened for more complex traits such as bacterial wilt resistance and heat tolerance. The results from the handling of these segregating populations are part of the routine development of the breeding program, and will not be reported here.

Two double crosses (CL5915 and CL5916) have also been advanced by the single seed descent method (SSD) for three generations, and promising ToMV-resistant DC_5 lines selected in the spring of 1983 were screened in the summer for resistance to bacterial wilt. Lines with high survival rates were transplanted to the field for heat tolerance screening. In bacterial wilt tests, each individually potted seedling received via soil injection 2 ml of TBW #1 inoculum. An RCB design was used with two replications and 48 plants per replication.

The bacterial wilt incidence and selected horticultural characteristics of the DC_5 lines which compared well with the highly resistant check L285 are shown in Tables 2 through to 5. Relatively large-fruited types with wilt resistance as good as or better than that of L285 were noted in the first 51 indeterminate lines screened (Table 2). Some of them were also firm and displayed cracking resistance, two important tropical traits. At best, fruit setting of most lines during the unusually hot and dry summer of 1983 was rated as moderate. Nonetheless, the heat tolerance of the lines which yielded further selections was considered superior to that of older breeding lines such as CL1131-38-4 or CL1131-43-8-1. Selections from the best DC_5 lines are now being multiplied for preliminary evaluation in the summer of 1984.

Table 2. Bacterial wilt incidence (%)[z] of SSD DC_5 lines (Indeterminate Group I) whose resistance levels comproved favorably with that of resistant (HR) check L285; AVRDC, 1983.

Line no./Acc.	BW incidence		Fruit size	Fruit set[x]		Cracking	Firmness
	Transformed[y]	Actual (%)	(g)	Spring	Summer		
5915-206-2	24.9	18	119	H	M	none	good
5915-330-3	24.6	17	55	VH	P	none	moderate
5915-39-2	23.9	16	79	H	M	severe	good
5915-39-1	19.2	11	83	H	M	none	soft
5915-402-3	17.9	10	85	H	M	slight	soft
5915-396-1	17.4	9	37	H	P	slight	soft
5915-364-2	17.2	9	40	VH	M	slight	good
5915-330-2	7.5	2	50	VH	M	none	moderate
L285 (HR check)	7.3	2	8	-	-	-	-
CV (%)	25.6	-	-	-	-	-	-
LSD (5%)	17.6	-	-	-	-	-	-

[z] Twenty-five day-old seedlings were inoculated on June 6, using the soil injection method. Two readings made between June 22 and 29 resistant lines were transplanted to the BW field nursery.

[y] Original values (%) transformed to arcsin $\sqrt{\%}$ prior to analysis.

[x] H = high; VH = very high; M = moderate; P = poor; F = fair; G = good

Some of the 60 determinate lines tested were also observed to have wilt resistance as good as or better than that of L285 (Table 3). However, their fruits were generally smaller, than those of the best indeterminate lines from the first screening. These lines again exhibited selectable variation for crack resistance and firmness, but most had fruit set no better than that of CL1131-38-4. Selections from this group are also being multiplied for preliminary evaluation in the summer of 1984.

A number of the 33 indeterminate lines screened at a later date showed less BW incidence than did L285, but the differences were insignificant (Table 4). Because this test was conducted during the hottest and driest part of August, even L285 was heavily infected. Lines in this screening generally had smaller fruits than did those in the first group, but some had better fruit set. Selections from the best lines in this group were also saved for further evaluation in 1984.

Table 3. Bacterial wilt incidence (%)[z] of SSD DC_5 lines (Determinate Group I) whose resistance levels compared favorably with those of highly resistant (HR) check L285; AVRDC, 1983.

Line no./Acc.	BW incidence		Fruit size	Fruit set		Cracking	Firmness
	Transformed	Actual (%)	(g)	Spring	Summer[y]		
L390 (susceptible check)	74.5	93	50	-	-	-	-
L285 (HR check)	25.5	19	8	-	-	-	-
5915-452-1	25.3	18	29	M	G	none	soft
5915-455-2	24.0	17	54	M	F	slight	good
5915-204-1	21.2	13	33	H	F	slight	good
5915-455-3	20.6	12	49	M	P	slight	moderate
CV (%)	18.3	-	-	-	-	-	-
LSD (5%)	18.1	-	-	-	-	-	-

[z] Twenty-one day-old seedlings were inoculated on June 24 using the soil injection method. Three readings were made between July 1 and 8 before resistant lines were transplanted to the BW field nursery.
[y] Relative to CL1131-38-4 (heat tolerant parent).

Table 4. Bacterial wilt incidence (%)[z] of SSD DC_5 lines (Indeterminate Group I) whose resistance levels compared favorably with that of highly resistant (HR) check L285; AVRDC, 1983.

Line no./Acc.	BW incidence		Fruit size	Fruit set		Cracking	Firmness
	Transformed	Actual (%)	(g)	Spring	Summer[y]		
L390 (susceptible check)	69.7	88	50	-	-	-	-
L285 (HR check)	43.4	47	8	-	-	-	-
5915-553-3	42.8	46	36	H	G	slight	moderate
5915-384-1	40.1	42	57	M	-	slight	good
5915-314-1	40.0	42	34	M	G	slight	moderate
5915-314-2	39.5	41	38	M	G	slight	moderate
5915-172-2	36.8	36	31	M	-	-	good
5915-553-2	36.5	35	40	M	G	slight	good
5915-165-1	31.8	28	39	M	P	-	moderate
CV (%)	16.6	-	-	-	-	-	-
LSD (5%)	17.1	-	-	-	-	-	-

[z] Twenty-seven day-old seedlings were inoculated on August 17 using the soil injection method. Four readings were made between August 22 and September 1 prior to transplanting resistant lines to the BW field nursery.

The second batch of 21 determinate lines again showed generally high levels of wilt incidence. The highly resistant check L285 was no exception. A number of lines had resistance levels comparable to that of L285 (Table 5). Most had fruit weighing about 50 grams, and fruit set levels were usually no better than those of CL1131-38-4. The best lines were selected for crack resistance and relative firmness, and these selections are being multiplied for further evaluation in 1984.

Table 5. Bacterial wilt incidence (%)[z] of SSD DC_5 lines (Determinate Group I) whose resistance levels compared favorably with that of highly resistant (HR) check L285; AVRDC, 1983.

Line no./Acc.	BW incidence		Fruit size	Fruit set		Cracking	Firmness
	Transformed	Actual (%)	(g)	Spring	Summer[y]		
L390 (susceptible check)	69.7	88	50	-	-	-	-
5915-225-1	52.2	62	54	M	G	slight	good
5915-310-1	51.9	62	41	M	F	slight	soft
5915-93-3	51.7	62	54	H	F	slight	good
5915-381-1	51.5	61	44	M	F	-	soft
5915-281-1	49.3	58	52	M	F	slight	good
5915-310-2	46.1	52	48	M	F	slight	soft
L285 (HR check)	43.4	47	8	-	-	-	-
CV (%)	11.5	-					
LSD (5%)	13.2	-					

[z] Twenty-seven day-old seedlings were inoculated on August 17 using the soil injection method. Four readings were made between August 22 and September 1 prior to transplanting resistant lines to the BW field nursery.

[y] Relative to CL1131-38-4 (heat tolerant parent).

Evaluation of Germplasm for Heat Tolerance and Bacterial Wilt Resistance

Introduction

Breeders continued in 1983 to evaluate new, possibly useful germplasm. Stocks which had previously been identified as heat tolerant or wilt resistant were retested to confirm their resistance or tolerance, and to identify any other useful horticultural characteristics they might possess.

Materials and Methods

In the summer of 1983 ninety-seven untested accessions were grown for preliminary observation of heat tolerance. Each occupied a 4.8 m single-row plot, with 40 cm between plants. Entries were not replicated. Plants were sown on May 6 and seedlings were transplanted on June 2. Heat sensitive line TK-3 and heat tolerant lines L3690 and CL1131-43-8-1 and were included as checks. On July 29, fruit set was rated on a scale of 0 (no set) to 5 (heavy fruit load).

Two other plantings tested a few newly acquired stocks and several old accessions reported by donors as potentially heat tolerant. The first set comprised 12 entries and two checks, L4964 (heat tolerant) and L387 (heat sensitive). The second consisted of 24 entries tested against two checks. Sowing and transplanting dates for these sets were the same as in the above experiment. Plots were the same size, but entries were replicated twice in an RCB design.

Five accessions rated heat tolerant in a preliminary 1982 summer test were re-evaluated against heat tolerant checks L3690 and CL1131-43-8-1. Each entry occupied a 4.8 m double-row bed with 40 cm between plants and 80 cm between rows. Seeds were sown on April 19, and seedlings were transplanted on May 17. An RCB design was used with four replications. Data were collected for descriptive cataloguing purposes on fruit set, and on such component traits as stigma exertion, antheridial cone splitting, and fruit size.

Fifty-one new and old accessions reported by their donors to be bacterial wilt resistant were screened for resistance and evaluated for horticultural traits. Seeds were sown on July 28, and on August 26 each individually potted plant received a soil injection of 2 ml of inoculum. Each entry had 48 plants per plot. An RCB design was used with two replications. Resistant line L285 and susceptible line L390 were included as checks.
from tropical line CL143 at Mauritius was tested to compare their resistance levels with those of the original source. Resistant and susceptible checks L285 and L390 were included. Seeds were sown on September 14, and seedlings were inoculated on October 6. Design, plot specification, and inoculation technique were similar to those described above.

Six other old accessions were included with F_6 breeding lines in a separate screening. Seeds were sown on August 12 and seedlings were inoculated on September 9. These materials were handled in a manner similar to that described in the above experiments.

Results

The summer of 1983 was unusually hot and dry, and almost all accessions had very low fruit setting rates (Table 6). Only eight of the new accessions in the observational test (Trial I) set any fruit. Except for L5153, which was rated 2, all the others had fruit set ratings comparable to that of CL1131-43-8-1 but lower than that of L3690. Heat sensitive check TK-3 did not set any fruit in this trial.

Of the old and new stocks in trial II, only L4043 (Baytay) and BL183 or 823158 (TH-318) set fruit as well as heat tolerant check L4964. All entries, including the check, had fruit set ratings of 1. The heat sensitive check L387 did not set fruit.

One entry (L3957 or Canada BL6807) did very well in Trial III, and had an average fruit set rating of 3.5. Heat tolerant check CL1131-43-8-1 set few fruit, with a rating of 1. Heat sensitive check TK-3 did not set any fruit. Line L3957 had an average fruit set of 44%, compared to an average of only 19% for CL1131-43-8-1 in several summer trials (see "Advanced Trials of Tropical Breeding Lines"). Line L3957 is a determinate line with little foliage. It bears fruits that weigh an

Table 6. Distribution of accessions tested for heat tolerance on the fruit setting scale; AVRDC, 1983.

Scale	Trial set		
	I[z]	II[y]	III[x]
0 (no set)	89	10	21
1 (very light)	7	2	2
2 (light)	1	0	0
3 (medium)	0	0	1[w]
4 (medium-heavy)	0	0	0
5 (very heavy)	0	0	0
Total accessions	97	12	24

[z] Heat tolerant (HT) checks and fruit setting score: L3690 = 2.5 and CL1131-43-8-1 = 1.0
[y] HT check and fruit setting score: L4964 = 1.0
[x] HT check and fruit setting score: CL1131-43-8-1 = 1.0
[w] Score is slightly higher at 3.5

average of 16 g, and are uniform-shouldered, plum-shaped, soft, and relatively free of cracking. Two other entries, L3956 and L4719, had fruit set ratings similar to that of CL1131-43-8-1.

Two the five accessions reevaluated for heat tolerance had significantly higher fruit setting rates than the checks (Table 7). One (L4964) is a small-fruited type averaging only 4 grams per fruit, and the other (L4841) had fruits similar in size to those of CL1131-43-8-1. Heat tolerant accessions generally had exserted stigmas, but this component's high coefficient of variation makes it an unreliable indicator of heat tolerance. Levels of antheridial cone splitting (ACS) were minimal for most of the five entries, but L4841 showed moderate levels of ACS. Covariance analysis showed ACS to have a highly significant negative correlation (r = -0.55) with fruit set; it alone accounted for 30% of this experiment's total variation in fruit set.

In a screening trial of 51 accessions, the wilt resistance level of new Sri Lankan accession BL170 (T-62) compared favorably with that of highly resistant check L285 (Table 8). Self-pruning, it bears fruits that are oblate, soft, and uniform-shouldered, with a maximum size of 5.2 x 4.3 cm. Eight other accessions had levels of wilt incidence significantly lower than that of susceptible check L390, but still considerably higher than that of L285. Some cultivars or breeding lines which had been released as wilt resistant in their countries of origin were found susceptible: Chancellor (derived from an AVRDC SSD line in Papua New Guinea), Seeda (Thailand), L22 (Thailand), Pope (Philippines) and Caraibe (French West Indies).

None of the lines released in Mauritius compared well with L285, but BL190 or MST 20/13 showed significantly lower levels of wilt incidence than the original CL143, which was susceptible in this test (Table 9).

None of the six accessions included in a separate test proved as resistant as L285. Four of them showed levels of wilt incidence significantly lower than that of susceptible check L390, but even the most resistant of them (L1 or VC48-1) had rates of wilt incidence as high as 71%.

Table 7. Fruit setting rate (%) and other characteristics of the best heat tolerant accessions; AVRDC, 1983.

Entry	Fruit size[z]		Fruit size (g)	Stigma exsertion[y] (m)	Antheridial Cone Splitting[x]
	Transformed	Actual(%)			
L4964	37.4	36.9	4	0.1	2.1
L4841	36.6	35.6	32	0.7	2.8
CL1131-43-8-1 (HT check)	30.2	25.3	31	0.1	1.8
L3690 (HT check)	29.3	24.0	2	1.1	2.2
CV (%)	14.1	-	16	110	18.9
LSD (5%)	5.2	-	6	0.3	0.7

[z] Original data (%) transformed into arcsin % prior to analysis.
[y] Exsertion above the lip of the anther cone.
[x] Based on rating scale of 0 = no splitting, to 5 = severely split.

Table 8. Bacterial wilt incidence of selected accessions; AVRDC, 1983.

Accession number	BW Incidence[z]	
	Transformed	Actual (%)
L390 (susceptible check)	71.7	90
L4798	56.1	69
BL171A	55.8	68
L4799	55.0	67
L4782	54.9	67
BL169	54.8	67
BL174	46.7	53
L3983	46.2	52
L4038-1	42.5	46
BL170	29.0	24
L285 (resistant check)	26.7	20
CV (%)	11.4	-
LSD (5%)	15.5	1

[z] Original values (%) were transformed to arcsin $\sqrt{\%}$ before analysis.

Table 9. Bacterial wilt incidence of lines derived from CL143; AVRDC, 1983.

Accession/line	BW Incidence[z]	
	Transformed	Actual (%)
L390 (susceptible check)	66.8	84
CL143	60.4	76
BL192 (MST 21/23)	60.4	76
BL191 (MST 32/1)	48.6	56
BL190 (MST 20/13)	35.7	34
L285 (resistant check)	11.4	4
CV (%)	10.2	-
LSD (5%)	12.4	-

Conclusions

Patative heat tolerant accessions set few fruit during the exceptionally hot, dry summer of 1983. Even tropical breeding line

CL1131-43-8-1, by far the most heat tolerant in 1982 trials, had at best only light fruit set. Under these extreme conditions accession L3957 (BL6807) proved outstanding. It had not been used previously, but is now being utilized in the 1983-84 hybridization program. One of the accessions screened for bacterial wilt resistance, (T-62) from Sri Lanka, had as high a resistance level as did small-fruited, highest resistant accession L285. Although its fruit is still rather small, it should be more useful for breeding than L285. Its high levels of resistance will be further tested and confirmed in 1984.

Evaluation of Bacterial Wilt Resistant Stocks as Parents

Introduction

Although genetic materials may perform similarly, some are more able than others to transmit their desirable characteristics to their offspring. To identify bacterial wilt resistant stocks with such characteristic, a diallel analysis was made of a group of parents and all their possible hybrids.

Materials and Methods

Six BW resistant accessions and one highly susceptible check were chosen for this experiment. These included the highly resistant but small fruited accession L285, breeding lines CL1351-1-9-10 and CL1219-0-12, and accessions L96 (Saturn), L366, and L4670 (PI 406994). The highly susceptible check L390 completed the seven-parent diallel set. All possible F_1's (excluding reciprocals) and their controlled selfs were made during the 1982-83 cool season.

All 28 entries (21 crosses and 7 parents) were pre-germinated in petri dishes on July 4, 1983. Later individual seedlings were planted in plastic pots, and allowed to grow until inoculation. Each plot totalled 48 seedlings.

An RCB design was used with two replications. On July 20, each seedling received a soil injection of 2 ml of TBW #1 inoculum. The number of wilted seedlings was recorded five times between August 8 and 17.

The percentage wilting of each plot was converted to arcsin times $\sqrt{\%}$ prior to the general analysis of variance. A subsequent analysis of combining ability used the means of parents and all the possible F_1's arranged in a diallel array, following Griffing's Method Four analysis (see Griffing, B. 1956. Australian J. Biol. Sci. 9:463-493).

Results

The general analysis of variance showed highly significant differences among entries. The coefficient of variation, which is usually rather high when using clip inoculation, was an acceptable 26% for the soil injection method.

Line L285 had the highest estimate of GCA effect (-7.3), but this value is not significantly different from that of CL1351 or L96 (Table 10). Estimates for all three accessions were significantly higher than for the rest. The high positive estimates for CL1219 and L390 indicate that they impart BW susceptibility to their progeny. It should be noted that CL1219 had originally been bred as a wilt resistant line.

Table 10. Estimates of general combining ability effects and associated variances among parental stocks in a seven-parent diallel set.

Parental stock	Effect[z] ($\hat{g}i$)	Variances[y]	
		(S^2g)	(S^2s)
L285 (highly resistant)	-7.3	47	6
CL1351-1-9-10	-5.9	28	29
L96	-5.6	24	≈ 0
L4670	-2.3	≈ 0	13
L366	-0.8	≈ 0	6
CL1219-0-12	8.6	68	13
L390 (highly susceptible)	13.3	169	12
Standard error ($\hat{g}i-\hat{g}j$)	3.0	-	-

[z] Negative effects imply transmission of BW resistance to progeny; positive effects imply transmission of susceptibility.

[y] Variances that are approximately zero were small negative values.

Of the stocks which showed high negative GCA effects, and are thus able to transmit high levels of resistance to their progenies, L96 appears to be most able to uniformly transmit resistance, as indicated by its low variance for specific combining ability (S^2s). L285 also did well but its variance for general combining ability (S^2g) is higher than that of L96. CL1351's high variance for specific effect ($S^2s = 29$) indicates that it exhibited high levels of BW resistance in some combinations but not in others.

Conclusions

L96 (Saturn) has much better potential as a breeding stock for BW resistance than do accessions L366 and L4670, both of which had previously been used in AVRDC's breeding program. As they seldom impart high levels of resistance to their progeny, these two lines should not continue to be used a parental stocks.

Although L285 was also able to consistently transmit its resistance to its progeny, its value as a breeding line is limited by its small fruit size.

Similar studies should be extended to other BW resistant stocks. The same approach could also be used to evaluate heat tolerant parental stocks, streamlining AVRDC's breeding program even further.

Tropical Breeding Line Yield Trials

Introduction

Three advanced lines selected from the 1982 trials were re-evaluated in 1983. In 1982, trials transplanted after July were of little value in screening for high temperature fruit set, thus all 1983 trials were transplanted before the end of July.

Materials and Methods

Lines CL1131-7-2, CL1131-13-0-6, and CL1131-43-8-1, were compared with checks CL1131-38-4 and CL143 in the plantings listed below:

Trial	Sowing date	Transplanting Date
I	May 27	June 21
II	June 3	June 30
IV	June 27	July 21

Trial III suffered from poor germination, and no data was obtained.

Each 16 m^2 plot consisted of two double-row beds, with 40cm between plants and 80 cm between rows. An RCB design was used with four replications.

Each trial was analyzed individually for yield and other horticultural characters. A combined analysis of all three trials was carried out after testing for homogeneity of variances in individual experiments.

Results

Unusually hot, dry weather in the summer of 1983 caused all lines and checks to perform very poorly (Tables 11 and 12). Low yields could be traced to small fruit size and poor fruit set.

The best performance was observed in Trial IV, which had an average marketable yield of 7.8 t/ha (Table 11). In contrast, Trials I and II averaged less than 2 t/ha. Plant stand in the earlier trials was significantly higher than in Trial IV; poor fruit set was the main reason for the low yields. Trial IV averaged 31% fruit set, two to three times that of Trials I and II. Lower fruit weight and earlier maturity could also have contributed to the depressed yields of these trials, but the differences in these traits were not as nearly pronounced as were the differences in fruit set.

Lines CL1131-13-0-6 and CL1131-7-2-0 significantly and consistently outperformed all other entries, especially in yield and fruit set (Table 12). Their superiority was apparent even in the earlier trials, when they and all other entries gave unusually low yields. Their best mean marketable yields were obtained in Trial IV, where they averaged 13

and 11 t/ha, respectively. These yields were significantly higher than those of all other lines.

Table 11. Selected horticultural characteristics of three advanced trials held at AVRDC in 1983.

Trial	Stand	DF	DM	Fruit set (%)	Marketable yield (t/ha)	Cull Yield (t/ha)	Total Yield (t/ha)	Fruit size (g)
I	37a	15b	54c	16b	1.0b	0.6b	1.6b	16c
II	37a	17a	62b	11c	1.4b	0.8a	2.2b	19b
IV	35b	16a	64a	31a	7.8a	0.4b	8.3a	21a

[z] Figures are averages of five entries; means followed by same letters are insignificantly different.

Table 12. Selected horticultural characteristics of entries in three advanced trials held at AVRDC in 1983.

Trial	Stand	DF	DM	Fruit set (%)	Marketable yield (t/ha)	Cull Yield (t/ha)	Total Yield (t/ha)	Fruit size (g)
1131-7-2-0	37	18b	61b	25a	5.2a	1.1a	6.4a	19
1131-43-8-1	36	15c	61b	19b	2.9b	0.7b	3.5b	20
1131-13-0-6	36	14c	53c	24a	5.7a	1.0a	6.7a	20
1131-38-4 (check)	36	19a	62ab	17b	1.9bc	0.2c	2.1c	17
143-10-3 (check)	35	14c	64a	13c	1.4c	0.2c	1.6c	18

Lines CL1131-13-0-6 and CL1131-7-2-0 had the highest fruit setting rates in Trial IV, averaging 38% and 30%, respectively. Again, both values were significantly different from those observed for all other entries.

Fruit size did not seem to contribute to yield differences among lines. Significant line x trial interactions were found for all characters, except fruit size, indicating that most entries did not perform similarly in all trials. This trend may not necessarily apply, however, to CL1131-13-0-6 and CL1131-7-2-0, both of which significantly and consistently outperformed other entries.

Conclusions

Generally low yields in the summer of 1983 indicated that the present tropical breeding lines cannot easily adapt to hot, dry conditions. The best marketable yield obtained was a mere 13 t/ha. As

in 1982, lines CL1131-13-0-6 and CL1131-7-2-0 consistently outperformed all other entries. Already included in AVRDC's current seed distribution list for the tropics, these lines are currently being improved for other characteristics such as nematode resistance, firmness, and fruit size. To widen their adaptability however, their heat tolerance levels need even further improvement. This problem has already received some attention in 1983's hybridization program.

Incorporation of Genes for ToMV Resistance into Tropical and Processing Tomatoes

Introduction

Of all the viruses infecting tomato, tomato mosaic virus (ToMV) is the most common. ToMV has been widely studied since resistance breeding first began in Hawaii in 1958, and today it is the best understood of all virus diseases infecting tomato. Although most of the varieties grown in the temperate zones have been bred for resistance to ToMV, such is not the case with those grown in the tropics. This project was designed to incorporate genes for ToMV resistance into wilt resistant tropical breeding lines and high yielding processing lines.

Materials and Methods

In 1982 studies, the best recurrent and donor parents were shown to be the following AVRDC lines and ToMV resistant accessions:

Recurrent parents:

Tropical tomato:
- CL 143-0-10-3-1
- CL 1104-0-0-71-4-3-0
- CL 1131-0-0-38-4-0
- CL 1131-0-0-43-8-1

Processing tomato:
- CL 1561-6-0-5-1-3 (Tainan selection no. 2)
- CL 1591-5-0-1-2-0

ToMV-resistant donor parents:

Tm^2/Tm^2 genotype	: Moperou
Tm^2a/Tm^2a genotype	: Moperou, Delisa
Tm/Tm^2a homozygous genotype	: Mocimor
heterozygous genotype	: Tanit and 79W177
Tm/Tm^2 heterozygous genotype	: (GCR 237 x Moperou)

AVRDC lines grown between March and June of 1982 were crossed with ToMV-resistant donors, and F_1's grown between July and September of 1982

were backcrossed to their respective recurrent parents. Only 20 backcrosses from 30 combinations were selected for resistance screening between December of 1982 and March of 1983. More detailed information about the early history of this program can be found in AVRDC's 1982 progress report.

Lines were screened for ToMV resistance using the same procedure as in 1981. Both soil and seeds were sterilized before planting. At the first true leaf stage, cotton with carborundum was used to inoculate each plant with 0.5 ml of inoculum. Plants were observed for symptoms 14 days after inoculation. Only symptomless seedlings were selected and transplanted to the field.

Results

Introduction of Tm/Tm^{2a} genes from F_1 cultivars Tanit and 79W177(I):

Tanit is the highest yielding ToMV-resistant line available, and bears fruits of moderate size. Although 79W177 had slightly lower yields, it had larger fruits than any other ToMV-resistant accessions. Breeders hoped to introduce the good horticultural characteristics of these lines, and along with them the Tm/Tm^{2a} resistance genes they carried.

The F_1 progenies resulting from crosses between these two cultivars and AVRDC lines segregated for ToMV resistance after inoculation with strain 1 are shown in Table 13. Except for Walter/79W177, all segregations failed to fit the expected monohybrid ratios. Because CL1131-0-0-38-4-0 already carries Tm^{2a} linked with the ah (anthocyaninless) gene, crosses between it and Tanit showed no symptoms whatsoever.

Table 13. Results of screening test for ToMV resistance among F_1's.

Combination	Total no. of seedlings	Mosaic %	Symptomless %	Chi-square (1 : 1)
CL 143/Tanit	73	63	37	5.0
CL 1131/Tanit	77	0	100	77.0
CL 1561/Tanit	69	68	32	9.1
CL 1591/Tanit	80	64	36	6.1
CL 1561/79W177	82	71	29	10.0
Walter/79W177	66	56	44	1.0

When crossed with Tanit, AVRDC lines segegated into determinate and indeterminate plant types. One of Tanit's parents was presumed to be determinate. Segregation ratios for growth habit closely fit the expected monohybrid ratio. Determinate tropical tomatoes can be easily selected from selfings of indeterminate (sp+)F_1 plants.

When Tanit was the donor parent, yield was positively correlated with the number of fruits per plant whereas fruit size was not. However, when 79W177 was the donor parent, both yield and fruit size were negatively correlated with the number of fruits per plant. In both

cases, fruit weight correlated poorly with yield, and was negatively correlated with the fruit number (Table 14). Fruit size should thus be kept in mind when planning breeding strategies.

Table 14. Correlation of yield, number of fruits per plant and mean fruit weight.

Combination	No. of fruits vs. yield	Fruit weight vs. yield	Fruit weight vs. no. of fruits
CL 143/Tanit	0.97	-0.24	-0.45
CL 1131/Tanit	0.93	-0.22	-0.50
CL 1561/Tanit	0.98	-0.06	-0.25
CL 1591/Tanit	0.97	-0.37	-0.56
CL 1561/79W177	0.94	-0.05	-0.29
Walter/79W177	0.95	-0.21	-0.32

Introduction of Tm^2, Tm^{2a}, Tm/Tm^{2a} and Tm/Tm^2 genes (I) - B_1 generation:

In the B_1 generation, backcrosses with CL 143, CL 1561 and CL 1591 showed over 50% susceptibility, but backcrosses made with CL1131 showed only 2% susceptibility. This means that the former's B_1 populations inherited ToMV resistant genes through independent monohybrid or dihybrid segregation. On the other hand, the B_1 generation of CL 1131 showed complete resistance and possessed both ah-Tm^{2a} and Tm^{2a} genes. A lower percentage of infection in the B_1 generation of CL 1104 B_1 suggested the presence of the ah-Tm^{2a} gene in its recurrent parent.

The B_1 progeny of CL 143, unlike those of CL1131, had high yields and a high fruit setting rate (Table 15). The B_1 progeny of CL 1104 developed larger fruit than did those of other lines. Backcrosses with Moperou as the donor parent had the largest fruit size (67g), followed by Mocimor (60g) and Momor (50g).

Table 15. Yield and selected horticultural characteristics of B_1 families of $Tm^2/+$ genotype.

Combination	Genera-tion	Original population					Selected population			
		Yield (g)	No. of fruits	Fruit wt.(g)	sp+/ sp	Selec-tion rate[z]	Yield (g)	No. of fruits	Fruit wt.(g)	sp+/ wp
CL 143/Moperou	B_1	497.3	7.6	69.5	10/12	5/22	534.0	8.0	68.4	2/3
CL 1104/Moperou	"	541.1	6.2	88.8	14/8	3/22	426.7	4.7	93.2	2/1
CL 1131/Moperou	"	196.5	4.4	35.5	7/15	3/22	367.5	8.5	44.0	1/2
GCR 237/Moperou/ CL143	"	982.0	17.2	57.6	20/0	3/20	1193.3	18.3	65.4	3/0
CL 1561/Moperou	"	743.0	11.6	65.8	14/9	2/23	1745.0	18.0	97.3	2/0
CL 1591/Moperou	"	890.5	14.0	66.4	10/21	4/21	1272.5	17.8	73.5	1/3
GCR 237/Moperou/ CL 1591	"	795.0	14.3	54.3	15/0	3/15	1123.3	18.0	63.1	3/0
CL 143-0-10-3-1	P	840.0	18.0	46.7	sp					
CL 1561-6-0-5-1-3	"	510.9	8.3	61.8	sp					

[z]No. of selected plants/total no. of plants.

To simultaneously introduce both Tm and Tm^2 genes, the F_1 progeny of the cross between GCR 237 (Tm/Tm) and Moperou (Tm^2/Tm^2) was used as donor. Triple crosses (Tc) between F_1 and CL 143 showed superior

performance, but those crossed with CL 1131 performed poorly.

A 95.5% infection rate indicated that the B_1 generations of CL 1591 and Momor or Tanit were probably miscrossed. The B_1 progeny of CL 1561 averaged 16 fruits per plant and had a mean fruit weight of 86 g. The B_1 progeny of CL 1591 produced more but smaller fruits.

Introduction of Tm/Tm^{2a} genes from Tanit and 79W177 (II) - B_1 and F_2 generations:

Many B_1 lines showed a higher infection rate than was expected, and even some of the B_1 plants from CL 1131 showed symptoms.

Each B_1 and F_2 generation was separated into indeterminate (sp+) and determinate (sp) types. Yields are shown in Table 16.

The B_1's generally showed a higher yield potential than the F_2's, but fruits were smaller. Determinate plants yielded more than indeterminate plants, but their fruits tended to be smaller. A triple cross of Walter, 79W177, and CL 1131 increased fruit size from the 41.3 g mean of the B_1's of CL 1131 to 62.3g in the original population and from 53g to 92.7 g in the selected population. Increased fruit size contributed little to yield.

Introduction of Tm^2, Tm^{2a}, Tm/Tm^{2a} and Tm/Tm^2 genes (II) - the B_1S_1 generation:

One of the B_1S_1 families was grown at the Puli Branch Farm of the Taichung District Area Agricultural Improvement Station for adaptability testing and generation advance. Only the determinate type was tested for highland cultivation.

High rainfall during the cropping season amplified many foliage diseases. The B_1S_1 of CL 1131, though, showed high resistance and good fruit set. Fruits of the two combinations were similar in size (Table 17).

The other B_1S_1 families were grown at AVRDC during mid-summer. Severe damping off was observed in all B_1S_1 families but those of CL 1131. Mechanical damage or reaction to ToMV after inoculation were probably not causal factors. Some susceptible plants could have been included among the diseased plants, and, since B_1S_1 plants with the homozygous $Tm2^a$-ah/Tm^{2a} genotype showed less disease infection, many heterozygous plants (Tm^{2a}/+ or Tm^2/+) could have reacted with necrotic symptoms (Table 18).

Anthocyaninless plants occured in the B_1S_1 of CL 1131 at a frequency of 26.9%, not far from the expected 25%.

The B_1S_1 lines of CL 143 and CL 1104 bore little fruit; only 28.4% of the plants bore more than 2.1/plant (Table 19). In contrast, 47.4% of the B_1S_1 lines of CL 1131 bore more than 4.5 fruits/plant.

Forty-three heat tolerant plants which produced higher yield and more fruits than average were selected from the B_1S_1 populations of CL 1131. Plants from B_1S_1 (CL 1131/Moperou)-19 and B_1S_1 (CL 1131/Mocimor)-02 second selected line had especially high fruit set at high temperatures. Unfortunately, many of the fruits were pathenocarpic. The relationship between parthenocarpy and heat tolerance should be further explored.

Table 16. Yield and selected horticultural characteristics of B_1 and F_2 families

Combination	Original population						Selected population				
	Genera-tion	Plant type	Yield (g)	No. of fruits	Fruit wt.(g)	sp+/ sp	No. of plants	Yield (g)	No. of fruits	Fruit wt.(g)	sp+/ sp
CL 143/Tanit	B_1	sp+	732.8	16.0	50.9	11/7	4/18*	1040.0	19.0	55.3	3/1
CL 143/Tanit	B_1	sp	1178.6	24.4	38.4	0/7	2/7	1480.0	34.7	43.9	0/2
CL 143/Tanit	F_2	sp+	665.2	10.1	66.0	20/2	5/22	938.0	14.4	98.0	5/0
CL 143/Tanit	F_2	sp	713.9	19.1	37.9	0/31	5/31	1304.0	30.6	46.6	0/5
CL 1131/Tanit	B_1	sp+	550.6	15.6	37.0	11/27	6/38	938.3	20.3	47.5	2/4
CL 1131/Tanit	B_1	sp	628.6	20.2	32.4	0/28	2/28	730.0	16.5	44.4	0/2
CL 1131/Tanit	F_2	sp+	552.7	10.4	53.7	17/16	7/33	758.6	11.3	68.3	5/2
CL 1131/Tanit	F_2	sp	556.2	13.0	42.2	2/31	5/35	1022.0	19.6	52.1	0/5
Walter/79W177/ CL 1131	Tc	sp+	503.0	8.6	62.3	31/18	4/49	822.5	9.0	92.7	3/1

* 4/18: No. of selected plants/total no. of plants.

Table 17. Yield and selected horticultural characteristics of B_1S_1 families.

Combination	Gene ration	Genotype	Total plants	Selected population			
				No. of plants	Yield (g)	No. of fruits	Fruit wt.(g)
CL 143/Delisa	B_1S_1	+/+ Tm^{2a}/	41	8	158.0	4.6	34.4
CL 143/Delisa	F_3	+/+ TM^{2a}/	41	-	-	-	-
CL 143/Moperou	B_1S_1	+/+ TM^2/	41	9	238.9	9.0	33.2
CL 143/Momor	B_1S_1	+/+ TM^{2a}/	42	10	279.2	10.4	27.3
CL 1131/Moperou	B_1S_1	+/+ TM^2/	42	14	522.0	19.4	32.0
CL 1131/Momor	B_1S_1	+/+ TM^{2a}/	42	13	392.8	13.2	29.9

Table 18. Results of screening test for ToMV resistance among B_1S_1

Combination	Gene ration	Genotype	Total	Symptom-less	ah	Disease	Mosaic	M%
CL 143/Moperou	B_1S_1	+/+ Tm^2/	87.3[z]	35.8	0	43.0	8.5	9.7
CL 143/Momor	B_1S_1	+/+ Tm^{2a}/	91.0	34.8	0	38.5	17.8	19.6
CL 143/Mocimor	B_1S_1	Tm/ Tm^{2a}/	90.8	32.0	0	38.5	20.3	22.4
CL 1104/Moperou	B_1S_1	+/+ Tm^2/	80.0	64.0	12.5	1.5	14.0	17.5
CL 1104/Momor	B_1S_1	+/+ Tm^{2a}/	93.0	42.5	2.5	38.5	12.0	12.9
CL 1131/Moperou	B_1S_1	+/+ Tm^2/Tm^{2a}-ah	93.3	77.0	26.0	16.3	0	0
CL 1131/Momor	B_1S_1	+/+ Tm^{2a}/Tm^{2a}-ah	93.5	95.7	24.8	0.3	0	0
CL 1131/Mocimor	B_1S_1	Tm/+ Tm^{2a}/Tm^{2a}-ah	85.0	82.0	22.7	0.7	0	0

[z] All data are means of 4 lines.

Table 19. Yield and selected horticultural characteristics of B_1S_1 families.

Combination	Gene-ration	Original population			Selected population				
		Yield (g)	No. of fruits	Fruit wt.(g)	No. of plants	Yield (g)	No. of fruits	Fruit wt.(g)	SP+/P
CL 143/Moperou	B_1S_1	53.6[z]	1.9	27.8	4/96	125.0	4.3	29.6	2/2
CL 143/Momor	B_1S_1	58.4	2.5	23.8	6/89	109.2	5.6	33.7	0/6
CL 143/Mocimor	B_1S_1	59.5	2.0	28.7	2/69	150.0	4.5	33.3	0/2
CL 1104/Moperou	B_1S_1	41.9	1.5	30.4	9/48	0	0	0	0
CL 1104/Momor	B_1S_1	103.4	3.4	30.9	7/46	257.5	7.6	33.4	0/7
CL 1131/Moperou	B_1S_1	135.4	5.4	25.6	9/81	307.2	12.3	25.4	0/9
CL 1131/Momor	B_1S_1	85.9	3.2	27.2	13/125	207.8	7.9	26.2	2/11
CL 1131/Mocimor	B_1S_1	153.1	5.4	28.0	21/79	250.1	8.9	27.9	2/19

[z] Mean of 4 to 2 lines.

Introduction of Tm^2, Tm^{2a}, Tm/Tm^{2a} and Tm/Tm^{2a} genes (III) - the B_2 generation:

More severe necrotic reactions to ToMV were noted in the B_2 population of CL 1131 than in those of CL 143. One reason is the heterozygosity of the B_2 population of CL 1131 for the ToMV resistant gene. The "B_2" seeds of CL 1131 were produced by crossing the B_1 with a different line, CL 1131-0-0-43-8-1, which does not carry a ToMV resistant gene, but is apparently more heat tolerant than the originally intended recurrent parent, CL 1131-0-0-38-4-0. As a result, B_2 plants shifted in genotype from Tm^{2a}/Tm^{2a}-ah to Tm^{2a}-ah/+, and many of the heterozygous (Tm^{2a}/+) plants reacted with necrotic symptoms at high temperatures (Table 20). Screening for ToMV resistance during the summer could thus mean the loss of many desirable plants among heterozygous genotypes in the segregating population.

Because of extremely high temperatures, most B_2 progenies did not bear fruit. Temperatures from July to September 1983 were generally 34-35°C maximum, 25-26°C minimum, with a mean of 29-30°C. Nonetheless, 94% of the B_2 CL 1131 progenies bore fruits, with an average of eight fruits per plant (Table 21). Generally, CL 1131/Moperou and CL 1131/-Momor showed better fruit set than did CL 1131/Tanit. CL 1131-0-0-38-4-0 and its sister line CL 1131-0-0-43-8-17 were the most heat tolerant AVRDC lines in this experiment.

Table 20. Results of B_2 screening test for ToMV resistance.

Combination	Generation	Genotype	Total	Symptomless	Mosaic	Necrosis	% of M+N
CL 143/Moperou	B_2	+/+ Tm^2/+	53	37	14	2	30.2
CL 143/Momor	B_2	+/+ Tm^{2a}/+	75	45	3	15	40.0
CL 143/Tanit	B_2	Tm/+ Tm^{2a}/+	108	70	15	16	28.7
CL 1131/Moperou	B_2	+/+ Tm^2/+	95	52	6	37	45.3
CL 1131/Momor	B_2	+/+ Tm^{2a}/+	78	24	2	52	66.6
CL 1131/Tanit	B_2	Tm/+ Tm^{2a}/+	79	36	2	41	54.4
CL 1561/Moperou	B_2	+/+ Tm^2/+	128	120	8	0	6.3
CL 1561/Momor	B_2	+/+ Tm^{2a}/+	115	79	3	33	31.3
CL 1561/79W177	B_1F_2	Tm/+ Tm^{2a}/+	91	76	3	12	16.5

Table 21. Yield and selected horticultural characteristics of B_2 families.

Combination	Generation	Original population			Selected population				
		Yield (g)	No. of fruits	Fruit wt.(g)	Setting[z] (%)	No. of plants	Yield (g)	No. of fruits	Fruit wt.(g)
CL 143/Moperou	B_2	44.0	2.0	22.0	5/12				
CL 143/Momor	B_2	38.0	1.6	23.8	5/12				
CL 143/Tanit	B_2	49.6	3.1	23.7	7/24				
CL 1131/Moperou	B_2	158.8	10.0	15.9	27/30	6	266.7	17.5	15.2
CL 1131/Momor	B_2	174.5	10.0	17.4	17/18	5	316.7	17.6	17.8
CL 1131/Tanit	B_2	46.6	3.2	14.9	24/24	7	81.7	5.2	15.9
CL 1561/Moperou	B_2	25.5	1	25.5	2/24				
CL 1561/Momor	B_2	45.1	1	45.0	1/24				
CL 1561/79W177	B_1F_2	0	0	0	0				

[z] Setting percentage: No. of fruit bearing plants/total no. of plants.

Introduction of Tm^2, Tm^{2a}, TM/Tm^{2a} and Tm/Tm^2 genes (VI) - the B_3 and other generations:

As in the B_2 generation, severe necrotic reaction occured in B_3 and B_2S_1 of CL 1131, and only a few plants survived. Apparently the heterozygous form of CL 1131-0-0-43-8-1 is more sensitive to ToMV than is that of CL 1131-0-0-38-4-1. Several lines were found which segregated for ToMV resistance. Several B_1S_2 lines of three tropical tomatoes are already stabilized for the Tm^2 gene; B_1S_2 lines of CL 143 and CL 1131 are now homozygous for Tm^{2a} gene (Table 22). In the case of the B_1S_2 of CL 1131, the ah-Tm^{2a} gene originating from CL 1131-0-0-38-4-1 has now been converted to the Tm^{2a} gene introduced from Momor.

Table 22. Present state of ToMV stabilization among B_1S_2 lines of tropical tomatoes.

Combination	Genotype	Total no. of lines	Hymogygous			Heterozygous		Susceptible
			ah+	ah+/ah	ah	ah+	ah	
CL 143/Moperou	+/Tm^2	8	2	0	0	5	0	1
CL 143/Momor	+/Tm^{2a}	11	2	0	0	9	0	0
CL 143/Delisa	+/Tm^{2a}	5	2	0	0	3	0	0
CL 143/Mocimor	Tm/Tm^{2a}	1	0	0	0	1	0	0
CL 1104/Moperou	+/Tm^2	3	1	0	0	0	0	0
CL 1104/Momor	+/Tm^{2a}	4	0	0	0	4	0	0
CL 1131/Moperou	+/Tm^2	13	2	6	5	0	0	0
CL 1131/Momor	+/Tm^{2a}	15	3	4	8	0	0	0
CL 1131/Mocimor	Tm/Tm^{2a}	2	0	1	1	0	0	0
GCR 237/Moperou// CL 1131	Tm/Tm^2	2	0	1	1	0	0	0

Conclusions

Three tropical tomatoes (CL 143-0-10-3-1, CL 1104-0-0-71-4-3-0 and CL 1131-0-0-38-4-0) and two processing tomatoes (CL 1561-6-0-5-1-3 and CL 1591-5-0-1-2-0) were selected for the introduction of ToMV resistant genes.

Moperou (Tm^2/Tm^2), Momor (Tm^{2a}/Tm^{2a}), Mocimor (Tm/Tm, Tm^{2a}/Tm^{2a}) and GCR 237 x Moperou (Tm/+, Tm^{2a}), Mocimor (Tm/Tm, Tm^{2a}) and GCR 237 x Moperou (Tm/+, Tm^{2a}), Mocimor (Tm/Tm, Tm^{2a}) and GCR 237 x Moperou (Tm/+, $Tm^{2a}/+$) were the principal ToMV resistant gene donors.

The F_1's were not as heat tolerant as the tropical parents and had small fruits. These characteristics are governed by polygenes, and further improvement will be relatively difficult.

Backcross progenies of CL 143 performed well during the cool season, and were expected to have larger fruit. They did not, however, adapt well to high temperatures.

All backcross progenies of CL 1131 had a high degree of heat tolerance. Shifting the recurrent parent from CL 1131-0-0-38-4-0 to CL 1131-0-0-43-8-1 improved heat tolerance and maturity.

The fruit size of tropical tomatoes can be increased by crossing them with large fruited varieties, but fruit size was negatively correlated with fruit number; the progeny of large fruited plants selected from segregating populations may produce only a few fruits, and their yields may actually be lower. Therefore, a fruit size that maximises yields should be sought.

Since many backcross progenies using Moperou or Mocimor as donors showed good performance, superior plants may perhaps be selected from B_1S_1's or from the B_2 generation. It should be possible to recover heat tolerant types from the early backcross generations of these materials.

Many plants with high levels of heat tolerance produced seedless fruits under extremely hot, dry conditions. The relationship between heat tolerance and parthenocarpy should be further investigated.

Many problems occured during the summer screening. A foliage disease severely damaged the segregating populations. The possible interaction between the ToMV resistance genes and ToMV strain cannot be entirely ruled out. Backcrosses between CL 143 and Moperou or Momor contained plants heterozygous for the Tm^2 or the Tm^{2a} gene. $Tm^2/+$ or $Tm^{2a}/+$ genotypes often showed necrotic lesions at high temperatures.

Screening for ToMV resistance is best done during the cool season; in the summer many desirable characters could be lost from segregating populations as a result of eliminating the heterozygotes for ToMV resistance.

Several lines already homozygous for ToMV resistance have been found in B_1S_2 populations. Although they have already been selected for heat tolerance, further pedigree selection could achieve an even higher degree of heat tolerance and even better horticultural characters. Anthocyaninless (ah) line CL 1131-0-0-38-4-0, which carries ah-Tm^{2a}, has now been converted to ah+ condition (Tm^{2a} only).

After further selection, these lines could replace many of the ToMV susceptible cultivars presently being grown in the tropics.

Development of Inbred Processing Tomato Lines

Introduction

Processing tomato is one of southern Taiwan's most important cash crops. Over 7,000 hectares were planted in 1982/83, and its US$ 40 million export value was exceeded only by that of other canned products such as asparagus and mushroom. Production is limited, however, to the cool season after the second rice crop. High temperatures are a major limiting factor, as are root knot nematode, tomato mosaic virus, and bacterial wilt. Because present cultivars such as TK 70, Tainan #2, and Known You 209 lack resistance to these soil-borne pathogens, tomato is presently grown only in the cool season following paddy rice.

Root-knot nematode, which is especially a problem when tomato is grown after sugarcane, can reduce yields by up to 32%. Bacterial wilt is a serious problem during Taiwan's warm season. Both pathogens are difficult to control by chemical means, and genetic resistance is the most effective way to control them.

Described here is an attempt made in 1983 to incorporate resistance to root-knot nematode and bacterial wilt into processing tomato cultivars. In order to develop superior inbreds with multiple disease resistance, lines with improved horticultural and processing characteristics were also selected for use in future breeding programs.

Materials and Methods

The project used 21 families derived from crosses with the following parental cultivars: 1) root-knot nematode resistant cultivars Hawaii 7795, Kewalo, VFN-8 and No. 498-VFN F_1, 2) processing tomato cultivars such as UC82, UC Mass 99, TK-70, KY 209 F_1, Merit, and UC134-61D, and 3) heat and bacterial wilt resistant cultivars such as Tamu Chico III, Venus, Saturn and VC lines (Table 23).

Selection procedures:

F_2:

The F_2 seeds of all 21 families were sown on September 21, 1982. Selections within each family were made on the basis of horticultural characteristics.

F_3:

On March 3, a total of 200 F_3 seeds of each family were sown directly into a nematode-infested hotbed. The soil was composed of equal proportions of soil, sand, and compost. Temperature was maintained at 25°C. Seedlings were rated for resistance on April 16, and those selected were transplanted to a nematode infested field near AVRDC. Seeds were later collected from single plants chosen on the basis of horticultural characteristics, root-knot nematode resistance, and fruit set.

F_4:

All F_4 seeds were sown on August 4, 1983. Plants were inoculated

with root-knot nematode on September 5 and October 12. Meanwhile, three seedlings from each line were transplanted in the field for generation advance. Seeds were collected from single plants on the basis of horticultural characteristics and responses to inoculation in the progeny test.

F_5:

On January 6, 1984, 48 seedlings of each line were inoculated with bacterial wilt and placed in controlled growth rooms. A replicated trial was conducted in the field to evaluate the yield and horticultural characteristics of these F_5 lines.

Table 23. Pedigrees of the selected families.

AVRDC Selection no.	Pedigree
CL 1820	No. 498-VFN-FI/(VC9-1-2-9B/Venus)-0-2-2-0-0
CL 1822	No. 498-VFN-FI/(VC48-1/Tamu Chico III)-0-4B-(HY)-1-0
CL 4180	UC/82//FAR 6-3 F_6///Peto 5028/Kewalo
CL 4181	UC/99 Mass-1 F_7//Peto 5028/Kewalo
CL 4182	UC/99 Mass-2 F_7//Peto 5028/KewaloKewalo
CL 4183	UC/99 Mass-3 Peto 5028/Kewalo
CL 4184	UC/ii Mass-3//VFN-8
CL 4189	Merit/VFN-8
CL 4190	TK 70//Peto 5028/Kewalo
CL 4191	Campbell 34//Peto 5028/Kewalo
CL 4192	CL 4102-E_1/Hawaii 7795
CL 4193	KY 209/Hawaii 7795
CL 4528	TK 70-4/[(TR/VC8-1)-5-4-2-F_5//T3800///VC11-1UG/Kewalo// VC11-1UG/Kewalo]-6
CL 4529	TK 70-4/[UC82A//(VC48-1GS/Tamu Chico III)-0-10-3-0-0/// VC11-1UG/Kewalo//VC11-1UG/Kewalo]-6
CL 4532	TK70-4/[UC82C/Peto 110///VC11-1UG/Saturn//Saturn/Kewalo]-1
CL 4638	(UC134-61D/TK 70)-6-0-19-1-4/[(TR/VC8-1)-5-4-2F_2//T3800/// VC11-1UG/Kewalo//VC11-1UG/Kewalo]-1
CL 4641	(UC134-61D/TK70)-6-0-19-1-4/[UC82A//(VC48-1GS/Tamu Chico III)-0-10-3-0-0///VC11-1UG/Kewalo//VC11-1UG/Kewalo]-6
CL 4653	(UC134-61D/TK70)-6-0-5-1-3/[(TR/VC8-1)-5-4-2F_2//T3800/// VC11-1UG/Kewalo//VC11-1UG/Kewalo]-2
CL 4655	(UC134-61D/TK70)-6-0-5-1-3/[(UC82A//(VC48-1GS/Tamu Chico III)-0-10-3-0-0///VC11-1UG/Kewalo//VC11-1UG/Kewalo]-6
CL 4656	(UC134-61D/TK70)-6-0-5-1-3/[TK T-1/VC-9-1-2-9B/Venus)-0-2-1-0-1//CAL 5///VC11-1UG/Saturn//Saturn/Kewalo]-2
CL 4657	(UC134-61D/TK70)-6-0-5-1-3/[UC82A//(VC48-1GS/Tamu Chico III)-0-10-3-0-0///VC11-1UG/Kewalo//VC11-1UG/Kewalo]-9

Results

F_2:

Three of the 21 F_2 families were discarded because of small fruit size and poor color. Seeds were bulked from three to ten superior plants of each of the remaining families. This helped to avoid losing favorable genes for bacterial wilt and heat resistances in the early generations; both are known to be polygenic traits. To obtain homozygous nematode resistant lines for the subsequent progeny test, single plant selections were also made within each family.

F_3:

When the F_3 generation was evaluated for resistance to root-knot nematode, a high correlation was observed between the resistance shown in seedling inoculation and that shown in field screening. When the egg inoculation method was used, the seedling population's expression of susceptibility was quite uniform. A total of 91 single plants from 9 families were selected on the basis of horticultural characteristics and root-knot nematode resistance (Table 24).

Table 24. Susceptibility of F_3 tomato lines to seedling inoculation[z] of root-knot nematode.

AVRDC selection no.	Plant no.[y]				Percent infection
	Total	no symptom	little	many	
CL 1820-0-0	218	43	62	113	51.8
CL 1822-0-0	190	13	31	146	76.8
CL 4183-0-0	194	22	29	143	73.7
CL 4184-0-0	196	46	46	104	53.0
CL 4189-0-0	196	75	62	59	30.1
CL 4641-0-0	209	38	23	148	70.8
CL 4641-0-0	181	15	28	138	76.2
CL 4656-2-0	204	20	29	155	75.9
CL 4657-9-0	192	22	16	154	80.2
TK70 (susceptible control)	147	0	21	126	85.7
Cal-Mart (resistant control)	197	131	66	0	0
LSU 447 (resistant control)	22	4	18	0	0

[z] No symptom: completely free
little : minor infection
many : plants with clear symptom (galls)

[y] Seeds were sown and inoculated on March 3, 1983, and were rated on April 15, 1983.

F_4:

Because tomato's resistance to root-knot nematode is controlled by a single dominant gene, all segregating families were discarded in the F_4 generation. Twenty single plants from 18 homozygous families were selected on the basis of genotype and horticultural characteristics (Table 25).

Bacterial wilt resistance is horizontal, with multiple recessive genes acting additively. Environmental factors such as temperature, soil moisture, and rainfall have been found to influence its development and expression. To avoid such environmental variables, and to allow favorable recombinations, screening for bacterial wilt resistance was not begun until the F_5 generation. Of the 15 F_5 lines chosen for bacterial wilt seedling inoculation screenings, five appeared to have the same level of resistance to bacterial wilt as resistant control line CL1069-0-5-4-0-1A. Of these five, CL4657-9-0-1R-1NR had the highest level of resistance. The resistance of all five lines will be confirmed in the field in 1984.

Lines CL4184-0-0-2R-1NR, CL4181-0-0-19R-1NR, CL4656-2-0-3R-1NR, CL4656-2-0-5R-1NR, and CL4657-9-0-4R-1NR were found to be promising in terms of general performance. Most of them had good horticultural

characteristics, and most were homozygous for resistance to root knot nematode (Table 26).

Table 25. Classification of the nematode resistance genes of 19 single-plant families subjected to seedling inoculation.

AVRDC selection no.	Probability of heterozygosity	Genotype
C11820-0-0-14R	-	segregating[z]
CL1822-0-0-2R	-	segregating[y]
CL1822-0-0-5R	0.13533	(homo.res.)[y]
CL4183-0-0-2R	0.00001	homo.res.
CL4184-0-0-2R	0.00002	homo.res.
CL4184-0-0-11R	0.00033	homo.res.
CL4184-0-0-19R	0.3184	(homo.res.)[y]
CL4656-2-0-1R	0.00018	homo.res.
CL4656-2-0-2R	0.00001	homo.res.
CL4656-2-0-3R	0.00006	homo.res.
CL4656-2-0-4R	0.07642	(homo.res.)[y]
CL4656-2-0-5R	0.31890	(homo.res.)[y]
CL4657-9-0-1R	0.00001	homo.res.
CL4657-9-0-2R	0.00139	homo.res.
CL4657-9-0-4R	0.04315	homo.res.
CL4657-9-0-13R	0.01800	homo.res.
CL4657-9-0-16R	0.18000	(homo.res.)[b]
CL4657-9-0-17R	0.04315	homo.res.
CL4657-9-0-18R	-	segregating
TK 70	-(susceptible)	-
Tainan Sel. No. 2	-(susceptible)	-

[z] Probability for heterozygosity was larger than 0.05.
[y] All plants were resistant in both seedling and field tests, but the small number of seedlings tested meant that the probability of heterozygosity was still larger than 0.05.

Table 26. Characteristics of selected F_5 nematode-resistant lines.

AVRDC selection no.	fruit weight (g)	fruit color	fruit set	fruit firmness	Plant size
CL1820-0-0-14R-1	57	M	M	M-firm	S
CL1822-0-0-2R-1	45	VG	G	firm	M-L
CL1822-0-0-5R-1NR	35	VG	VG	soft	VS
CL4183-0-0-2R-1NR	73	G	G	firm	VS
CL4184-0-0-2R-1NR	150	G	M	very firm	S
CL4184-0-0-11R-1NR	155	G	N	soft	S-M
CL4184-0-0-16R-1	117	G	VG	very firm	S
CL4184-0-0-19R-1NR	120	VG	VG	M-firm	S
CL4656-2-0-1R-1NR	108	G	G	soft	M
CL4656-2-0-1R-2NR	140	G	G	soft	M
CL4656-2-0-2R-1NR	137	G	G	M-firm	M
CL4656-2-0-3R-1NR	100	M	VG	firm	S-M
CL4656-2-0-4R-1NR	80	G	G	soft	S
CL4656-2-0-5R-1NR	95	G	VG	very firm	S-M
CL4657-9-0-1R-1NR	83	G	G	M-firm	S-M
CL4657-9-0-1R-2NR	60	G	G	M-firm	S-M
CL4657-9-0-2R-1NR	93	G	G	soft	S-M
CL4657-9-0-4R-1NR	153	G	M-G	firm	M
CL4657-9-0-13R-1NR	122	G	G	soft	S-M
CL4657-9-0-14R-1	55	G	G	firm	S
CL4657-9-0-16R-1NR	48	G	G	soft	M
CL4657-9-0-17R-1NR	55	G	G	soft	M
CL4657-9-0-18R-1	63	G	G	firm	M
TK 70	70	G	P	soft	S
CL1561-6-0-5-1-3	90	G	G	firm	M

G : good M : medium P : poor S : small VG: very good VS: very small

Conclusions

The egg inoculation method recommended by AVRDC pathologists was able to effectively identify nematode resistance in early segregating populations. Single plant selections and progeny tests showed 20 F_5 lines to be homozygous for nematode resistance. These lines also exhibited good horticultural characteristics; all had firm, well-colored fruits of 40-150 g. More importantly, most were more heat tolerant than control cultivars TK 70 and Tainan Selection No. 2. Lines CL4184-0-0-19R-1NR, CL4656-2-0-3R-1NR, CL4656-2-0-5R-1NR, and CL4657-9-0-4R-1NR appeared to be the most promising, and in 1984 will be further evaluated for yield and horticultural traits.

Development of ToMV and Bacterial Wilt Resistant F_1 Processing Tomato Cultivars

Introduction

Local cultivar TK 70, which presently occupies more than 85% of the hectarage planted to processing tomato in Taiwan, is lacking in heat tolerance and disease resistance. This limits production to the cool-dry season, usually a period of less than 100 days between December and March. Cultivars which could be grown at other times would allow processing facilities to operate throughout the year. The development of such cultivars would also be a boon to farmers in the highlands of Thailand, Indonesia, and the Philippines, where night temperatures around 23°C necessitate similar levels of heat tolerance. Such areas would require, too, the same sorts of disease resistance as does southern Taiwan in the late summer.

Materials and Methods

Introduction of genetic materials:

As sources of resistance to tomato mosaic virus (ToMV) and root knot nematode, 180 inbreds of various genetic backgrounds were introduced in 1981 and 1982 from the USA, France, Japan, and Holland. In addition, about 100 commercial processing cultivars and breeding lines were introduced from the US, New Zealand, Europe, and South America.

Evaluation of genetic materials:

In cooperation with AVRDC's plant pathology unit, the disease resistant traits of the collected genetic stocks were re-evaluated in separate inoculation tests for resistance to ToMV, bacterial wilt, or nematode, depending upon their genetic backgrounds. Inbreds found resistant to two or more diseases were selected as parental materials.

AVRDC tropical tomatoes with high levels of resistance to bacterial wilt and ToMV were evaluated and selected for hybridization.

Commercial open-pollinated cultivars or introduced inbreds were

evaluated in two separate trials conducted in both the warm and the cool seasons of 1982-83. Elite cultivars exhibiting characteristics lacking in AVRDC's tropical tomatoes (i.e. uniform maturity and large and firm fruits) were selected for use as major parental lines in the combining ability test.

Combining ability test and evaluation of F_1 hybrids:

To determine the best combiner for incorporating heat tolerance and bacterial wilt resistance, a total of 190 F_1 hybrids of 14 combinations were tested for specific combining ability during 1982 and 1983.

The F_1 hybrids from the above crosses were rescreened for disease resistance at the seedling stage and in multilocational disease nurseries. Fruit characteristics and heat tolerance were also evaluated in the field in mid-summer of 1983. Because this project's goal was to develop cultivars which could set fruit at night temperatures as high as 23°C, cultivars able to set some fruits at mid-summer's night temperatures of 25°C were considered satisfactory. Preliminary selections were based on 1) reaction to diseases, 2) fruit set, and 3) fruit characteristics (primarily size, firmness, and color). The selected hybrids were then evaluated for yield and processing qualities.

Evaluation of adaptability and processing quality:

Eleven promising F_1 cultivars selected from previous trails were evaluated for adaptability in the Regional Yield Trial coordinated by the Provincial Department of Agriculture and Forestry (PDAF). In 1983, trials were conducted at three locations in southern Taiwan, with three planting dates (August 3, October 15, and December 15) at each location. In all nine trials an RCB design was used with four replications. Plot size was 14.4 m^2. Only the results of the three trials planted in August are reported here. The two best entries from 1983's trials will be advanced to the 1984 Demonstrational Trials.

Results

Sources of heat tolerance and resistance to ToMV, nematode, and bacterial wilt were introduced, purified, and tested. Some of these materials can be used in the hybridizaton program without further improvement.

Elite cultivars were selected for improving the horticultural traits of the AVRDC lines. Both they and the resistance sources were tested for combining ability for various traits. The best combiners for heat tolerance and resistance to bacterial wilt, ToMV, and nematode are shown in Table 27.

Eight promising F_1 hybrids were evaluated for heat tolerance in the late summer of 1983. Unusually high temperatures during anthesis in September and October provided an excellent opportunity for evaluating the heat tolerance of these entries (Fig. 1); night temperatures were consistently over 23°C during the anthesis of early clusters (early September to late October). Although some of the control cultivars set no fruit whatsoever during this period, the F_1 hybrids were able to

Table 27. Best combiners for heat tolerance and resistance to bacterial wilt, ToMV, and nematode.

AVRDC selection no.	Major traits	General characteristics of resulting F_1 progeny
CL1131-0-0-38-4-0-1A	ToMVR, heat tolerant tolerant of bacterial wilt	excellent fruit set, small and soft fruits, susceptible to bacterial wilt, resistant to ToMV
CL1104-0-0-71-4-0-1A	ToMVR, heat tolerant, bacterial wilt resistant	good fruit set, medium sized but soft fruits, resistant to bacterial wilt and ToMV
CL9-0-0-1-3	ToMVS, heat tolerant, tolerant of bacterial wilt	good fruit set, medium sized but soft fruits, susceptible to bacterial wilt and ToMV
CL1069-0-5-4-0-1A	ToMVR, heat tolerant bacterial wilt resistant	good fruit set, soft and medium to large fruits, resistant to bacterial wilt and ToMV
CL4657-9-0-1R-1NR	heat tolerant, nematode and bacterila wilt resistant	good fruit set, resistant to nematode, tolerant to bacterial wilt, firm medium-sized fruits

*ToMVR=resistant to Tobacco Mosaic Virus (ToMV); ToMVS=susceptible to ToMV.

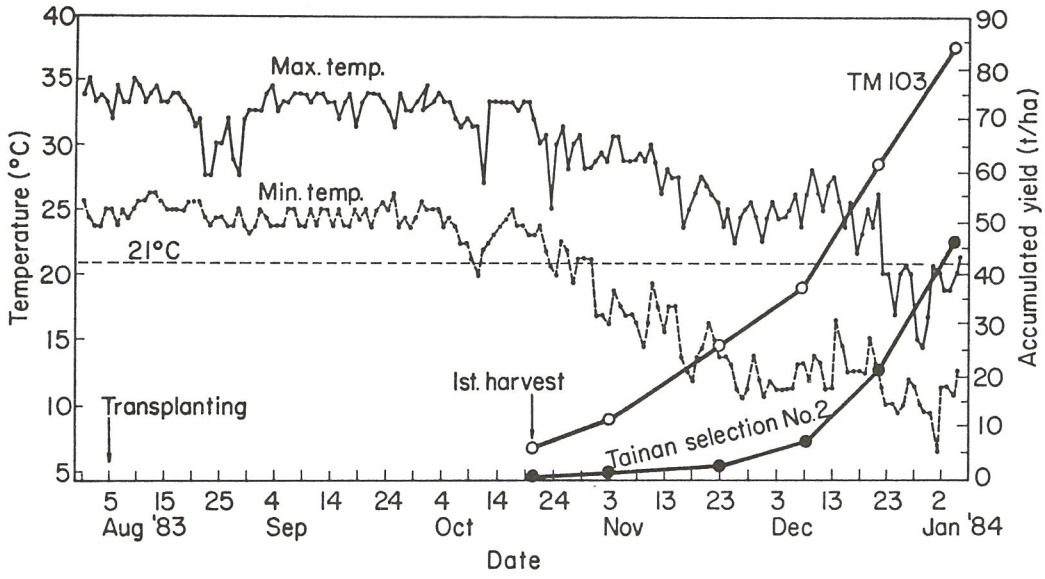


Fig. 1. Daily temperatures and accumulated fruit yield of two processing tomato cultivars transplanted, late summer 1983.

produce normally. The accumulated fruit yield of the first three harvests of TM 103 was 26 t/ha, compared with only 0.9 t/ha for TK 70 and 2.5 t/ha for Tainan #2 (Table 28). The F_1 hybrids, then, were better able to set fruits at high night temperatures. When transplanted at least one month earlier than is feasible with local cultivars, they still produced fruit yields ranging from 52 to 81 t/ha, and all five hybrid selections outyielded local cultivars TK 70 and Tainan Selection No. 2 (Table 29). AVRDC's new open-pollinated selection CL2815-1-1-1-0-12 produced a mean yield of 58 t/ha, significantly more than TK-70, but still less than Tainan Selection No. 2. This selection's fruits were too small (62 gm) for Taiwan's hand-picked harvest.

Table 28. Accumulated yield of processing tomatoes in regional yield trials held at AVRDC in late summer, 1983.

Entry	Accumulated Yield (t/ha)		
	Nov. 23, 83[z]	Dec. 9, 83[y]	Jan. 6, 83[x]
TM103 F_1	26.0a	37.9a	81.2a
PT679 F_1	19.9b	39.0a	79.7ab
PT857 F_1	19.0b	31.7ab	72.1abc
PT678 F_1	23.1ab	37.5a	71.3abc
PT862 F_1	20.6b	29.6b	66.4abc
PT858 F_1	13.6c	24.9b	65.5bcd
TM102 F_1	9.0cd	15.9c	61.1cde
PT577 F_1	5.3de	13.4cd	42.7de
CL2815-1-1-1-0-14	3.5e	6.8de	49.9def
TK 10 F_1 (CK)	9.7cd	17.1c	62.3cde
Tainan Selection NO. 2 (CK)	2.5e	7.6de	46.5ef
TK 70 (CK)	0.9e	5.5e	85.8f

[z] Transplanted on August 3, 1983 and harvested six times between October 20 and January 6. Replicated 4 times.
[y] Minimum day and night temperatures during the anthesis period of these harvests were over 24°C and 21°C, respectively.
[x] Sum of 6 harvests.

Table 29. Marketable fruit yield of processing tomato selections and control cultivars in regional yield trials held in the summer of 1983 at AVRDC, Tungshih, and Suilin[z].

Entry	Marketable fruit yield (t/ha)				Index
	AVRDC	Tungshih	Suilin	Mean	
TM102 F_1	61.1cde	73.0abc	49.0c	61.0bc	138
TM103 F_1	83.2a	84.3ab	63.3ab	76.9a	174
PT857 F_1	72.1abc	89.4a	46.9c	69.5ab	158
PT858 F_1	65.5bcd	74.1abc	66.6a	68.7ab	156
PT862 F_1	66.4abcd	63.7cd	52.6bc	60.9bc	138
CL2815-1-1-1-0-12	49.9def	68.5bcd	55.7abc	58.0cd	131
TK-10 F_1 (CK)	62.3ced	64.4cd	48.4c	58.4cd	132
Tainan Sel #2 (CK)	46.5ef	54.4ce	53.9abc	51.6de	117
TK-70 (CK)	35.8f	52.6d	44.0c	44.1e	100
CV %	17.7	17.6	15.1	17.1	-

[z] Transplanted on August 3-5, 1983 at 3 locations, replicated 4 times.

After being artificially inoculated at the seedling stage and being field tested in infected soil, seven hybrids selections (TM103, PT677, PT679, PT858, PT862, PT867, and PT873) were rated as resistant (R) to bacterial wilt (Table 30). All seven showed levels of resistance similar to those of AVRDC resistant breeding lines CL1069-0-5-4-0-1A, CL1069-0-5-6-0-1A, and CL1080-0-4-10-0-1A. Four other hybrids (TM102, PT678, PT857, and PT870) were rated as moderately resistant (MR), and showed levels of resistance similar to those of control cultivar L96GS (Saturn).

Table 30. Reaction of F_1 hybrids and control cultivars to bacterial wilt in disease nursery and seedling inoculation tests, 1983.

Entry	Field screening[z] % survival	Seedling inoculation[y] Days to 50% killed	Summarized[x] rating
TM102 F_1	20*	10	MR
TM103 F_1	50	12	R
PT677 F_1	60*	> 13	R
PT678 F_1	60*	10	MR
PT679 F_1	20*	> 13	R
PT857 F_1	20*	11	MR
PT858 F_1	20*	12	R
PT862 F_1	40	12	R
PT867 F_1	50	12	R
PT870 F_1	40	9	MR
PT873 F_1	40	12	R
TK-70 (Susceptible CK)	0	0	S
Tainan Sel. No. 2 (Susceptible CK)	0*	8	S
K.Y. 301 F_1 (Susceptible CK)	0*	4	S
CL1131-0-0-38-4-0 (Resistant CK)	-	9	-
L285 (Resistant CK)	100	>13	HR
L96 (GS) (Resistant CK)	100	9	MR

[z] Conducted in disease nursery at Taiwan Seed Improvement Service, Taichung from July 7 through August 31, and at Taichung DAIS's highland farm in Puli from July 10 through September 20. Asterisks indicate that data is from the Puli trial.

[y] Means of 2 seedling inoculation tests conducted from May 25 to Aug 26 at AVRDC.

[x] R = resistant; MR = moderate resistant; S = susceptible

Five F_1 hybrids possessed ToMV resistant gene $Tm2^a$ (Table 31). Although all five were still in a heterozygous form, no ToMV symptoms were observed on them or detected by serological test when they were grown in the field during the cool season. Artificial inoculation with Strain 1 of ToMV caused necrotic symptoms to appear on the hybrids when they were grown at high temperatures.

Most of the hybrids had larger fruits than did TK 70 or Tainan Selection No. 2. In Taiwan, where farmers harvest by hand, cultivars with fruits smaller than TK-70's are considered unacceptable. PT858 hybrid was as firm as TK-70, and all other F_1 hybrids were firmer than TK-70 but softer than Tainan Selection No. 2. Fruit pH of the new selections was in the range acceptable (below 4.5) for processing. Soluble solids (Brix) ranged from 4.6 to 5.3, similar to that of TK-10 and Tainan Selection No. 2 but lower than that of TK-70. Hunter color readings (a/b) of the hybrids were also similar to those of the three control cultivars, and ranged from 2.5 to 2.8 (Table 31).

Table 31. Genotype, fruit size, and quality of F_1 processing tomato selections and control cultivars in regional yield trials in late summer, 1983[z].

Entry	Genotype	fruit size (gm)	Quility			
			firmness[y]	pH	Brix	Hunter color (a/b)
TM102	$Tm2^a/+$	65	2	4.2	5.0	2.6
TM103	$TM2^a/+$	75	2	4.2	4.6	2.6
PT857	$Tm2^a/+$	69	2	4.2	5.1	2.6
PT858	$Tm2^a/+$	93	1	4.2	4.6	2.5
PT862	$Tm2^a/+$	81	2	4.3	5.3	2.8
CL2815-1-1-1-0-12	+/+	62	3	4.2	4.6	2.6
TK-10	+/+	62	2	4.2	5.0	2.6
Tainan Sel. No. 2 (CK)	+/+	69	3	4.2	4.8	2.9
TK-70	+/+	59	1	4.3	5.5	2.6

[z] Transplanted on August 3. Samples collected at second and/or fifth harvests (Nov. 3, and Dec. 23).
[y] Rated on a scale of 1 to 3, with 1 being soft.

Conclusions

Several promising F_1 hybrids developed in 1982 and 1983 are resistant to bacterial wilt and tomato mosaic virus. They are also able to set fruit at relatively high night temperatures (23°C), and can be planted about one month earlier in southern Taiwan than can any local cultivar. In regional yield trials conducted in three locations, hybrid TM103 produced up to 78 t/ha of marketable fruit when planted in early August - 74% more than TK 70, the most commonly grown local cultivar, and 48% more than newly released AVRDC cultivar Tainan #2 (CL1561-6-0-5-1-3). In 1984 these selections will be advanced to demonstration trials in Taiwan. They should also have a great deal of potential in the highlands of Thailand, Malaysia, Indonesia, and the Philippines, since the environments and endemic diseases (primarily bacterial wilt) in these countries are similar to those which have proven growth constraints in southern Taiwan's late summer.

Selection of Cherry Tomatoes for Freezing

Introduction

Fresh-market cherry tomato is very popular in Taiwan, and has recently begun to be frozen for the rapidly increasing export market. In southern Taiwan's late summer, however, farmers who grow local cultivars in salty soils must use laborious hormone treatments to increase fruit set. In response to the requests of the Taiwan Provincial Department of Agriculture and Forestry (PDAF) and local processors, a project was initiated in 1981 to develop better cherry-type tomato cultivars. Its objectives were to develop cultivars with attractively colored, juicy, and flavorful fruit, and, most importantly, with resistance to tomato mosaic virus (ToMV) and the ability to set fruits at relatively high night temperatures.

Materials and Methods

In 1981, AVRDC heat tolerant lines were crossed with local or introduced cultivars to combine heat tolerance with better plant vigor and ToMV resistance. Two F_1 cultivars (PT912 and PT913) resulting from crosses between heat tolerant and parthenocarpic tomato lines (Ventura-0 x CL 1131-0-0-38-4-0 and Ventura-1 x CL1131-0-0-38-4-0) were selected from 1982 observational trials.

Yield trials conducted at AVRDC from June 5 to September 12, 1983 featured cherry-type lines and cultivars (including PT912 and PT913) selected from AVRDC germplasm collection and breeding materials. An RCB design was used with two replications. Two rows of 12 plants were planted in each plot. One row was treated with hormones [Sodium-4-chloro-2(hydroymethyl) phenoacetate, 9.8%, 1000X] on July 22 and 29.

Five lines selected from this trial were evaluated by the Tainan District Agricultural Improvement Station (Tainan DAIS) against local checks at AVRDC and Tung-Shih. In both locations an RCB design was used with three replications. No hormone treatment was used in the regional trials.

Results

Mid-summer was unusually hot and dry in 1983. Minimum night temperatures during anthesis were consistently over 25°C. Most of the 33 entries, including AVRDC heat tolerant line CL1131-0-0-38-4-0, did not set any fruit under natural conditions. Only hybrid selections PT912 and PT913 produced any fruit at all, and they yielded only 7 to 10 t/ha (Table 32). In the hormone treated plots, L123 (TK 3) produced 20.5 t/ha and L4128A (RV 31) 17.7 t/ha of marketable fruits (Table 32). These two accessions responded favorably to hormone treatments at mid-summer.

Regional yield trials were conducted at AVRDC and Tungshih from September of 1983 through January of 1984. Night temperatures during early anthesis were about 24°C, two to three degrees higher than normal

for October. This provided an excellent opportunity to screen for heat tolerance. In the AVRDC trial, hybrid selections PT912 and PT913 provided the highest fruit yields of all entries. They produced 75 and 78 t/ha of marketable fruits, respectively, compared with only 3.5 t/ha for local cultivar Golden Citrus and 59 t/ha for AVRDC heat tolerant selection CL1131-0-0-38-4-0 (Table 32). Without hormone treatments, Golden Citrus, usually cannot set fruit when planted in late summer.

Similar results were obtained from the regional yield trial at A-lien. Hybrid PT912 had bilocational mean yields 53% higher than those of superior control cultivar Known You 209 (Table 33). AVRDC heat tolerant selection CL1131-0-0-38-4-0 yielded about the same as Known You 209, but significantly more than Golden Citrus.

Hybrids PT912 and PT913 both appear superior to local control cultivars. In late summer plantings both are able to yield up to 70 t/ha without hormone treatments.

Table 32. Marketable yields of various tomato cultivars and selections with and without hormone treatments during the summer and fall of 1983.

Entry	Without hormone (t/ha)		With hormone[x] (t/ha)
	Summer[z]	Fall[y]	Summer[a]
PT 912	6.19	47.87	11.95
PT 913	9.78	78.09	5.82
L 123 (TK 3)	0.07	34.55	20.48
L 4128A (RV 31)	0.01	30.61	17.71
CL1131-0-0-38-4-0	0.00	59.35	0.00
K. Y. 209 (CK 1)	0.02	53.82	1.68
Golden Citrus (CK 2)	0.00	3.49	0.00
LSD (5%)	11.34 (NS)	11.10 (**)	17.44 (NS)

[z] Transplanted on June 5, 1983 and harvested from August 29 to September 12. Replicated twice.
[y] Transplanted on September 14, 1983 and harvested from January 5 through January 16, 1984. Replicated three times.
[x] Hormone was sprayed on each cluster on July 22 and June 29. [Sodium-4-Chloro-2-(hydroxymethyl) phenoxyacetate 9.8% a.i.; 1000x].

Table 33. Marketable fruit yields of cherry tomato in regional yield trials held at two locations in the fall of 1983.

Entry	Marketable yield (t/ha)			
	A-Lien[z]	AVRDC[y]	Mean	Index
PT912	61.6a	74.9a	68.3a	153
PT913	54.6a	78.1a	66.4a	148
L123	23.3d	34.6c	29.0c	65
L4128A	25.3cd	30.6c	28.0c	63
CL1131-0-0-38-4-0	32.5bc	59.4b	46.0b	103
Known You 209 (CK1)	35.7b	53.8b	44.8b	100
Golden Citrus (CL2)	18.1d	3.5d	10.8d	24

[z] Transplanted on September 13, 1983 and harvested from November 24, 1983 through January 22, 1984. Replicated three times.
[y] Transplanted on September 13, 1983 and harvested from January 5 through January 16, 1984. Replicated three times.

Although selections PT912 and PT913 carry only the heterozygous form of the ToMV resistance gene, $Tm2^a$, no ToMV symptoms were detected in the serological test of field-grown samples (Table 34). In the same test, however, local check Golden Citrus was found to be 100% infected by ToMV. All entries were found to be susceptible to Cucumber Mosaic Virus (CMV), another prevalent virus in southern Taiwan. Serological tests showed all entries but L4128A (RV 31) to also be susceptible to Potato Virus Y (PVY).

Both PT912 and PT 913 matured about two weeks earlier than the control cultivars. Both were determinate and had medium to large vines. Improved plant vigor was a major factor contributing to their high yields. Fruit shape was globe for PT912 and deep globe for PT913 (Figs. 2 and 3). Both had better color but softer fruit than Golden Citrus (Table 35). Soft fruit was a major defect, but their flavor was also inferior to that of the control cultivars. Fruit brix and total solids were only 4.4 and 5.7-5.8 compared to 5.9 and 7.5 for Golden Citrus. Other quality parameters, such as pH, titratable acid, and Hunter's color reading, were similar to those of the control cultivars (Table 36).

Table 34. Percentages of tomato cultivars or selections infected with ToMV, CMV, or PVY under field conditions[zy].

Entry	Genotype (%)	ToMV (%)	CMV (%)	PVY (%)
PT912	$Tm\text{-}2^a/+$	0	82	18
PT913	$Tm\text{-}2^a/+$	0	46	46
L123 (TK 3)	+/+	91	73	36
L4128A (RV 31)	+/+	64	64	0
CL1131-0-0-38-4-0	$Tm\text{-}2^a/Tm\text{-}2^a$	0	46	36
Known You 209 (CK1)	+/+	82	73	46
Golden Citrus (CL2)	+/+	100	100	100

[z] Transplanted on September 14, 1983 and harvested from January 5, through January 16, 1984. Replicated three times.

[y] Eleven samples from each entry were collected randomly from one replication on December 3 were that same day subjected to serological test by ELISA.

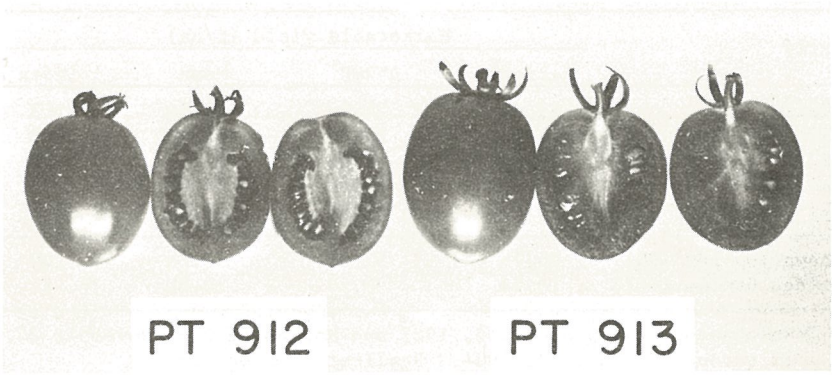


Fig. 2. Fruits of F_1 hybrid tomato selections PT 912 and PT 913.

Fig. 3. Plant type of F_1 hybrid PT 913.

Table 35. Horticultural characteristics of selected tomato cultivars and selections, Fall, 1983[z].

Entry	Days to[y] Flowering	Growth habit	Vine size	Fruit color	Fruit shape	Fruit firmness
PT 912	20	Det	M-L	G	Globe	Soft
PT 913	24	Det	M-L	G	Deep globe	Soft
L 123 (TK 3)	36	Semi	M	G	Pear	Medium
L 4128 A (REV 31)	36	Det	M	G	Pear	Soft
CL1131-0-0-38-4-0	36	Det	M	G	Globe	Soft
Known You 209 (CK 1)	32	Det	M	G	Pear	Firm
Golden Citrus (CK 2)	38	Semi	L	P	Deep globe	Medium

[z] Transplanted on September 14, 1983 and harvested from January 5 through January 16, 1984. Replicated three times.
[y] Days after transplanting to 50% plant flowering.

Table 36. Quality analysis of various tomato cultivars or selections. Fall, 1983[z].

Entry	pH	°Brix	Total Solid (%)	Titratable Acidity (% citric acid)	Hunter's color (a/b)
PT 912	4.37abc[y]	4.4cd	5.70c	0.395a	2.49a
PT 913	4.32bc	4.4cd	5.80c	0.362ab	2.46ab
L 123 (TK 3)	4.33abc	4.5cd	6.09c	0.337ab	2.16b
L 4128 A (REV 31)	4.45a	5.2b	6.85ab	0.342b	2.27ab
CL1131-0-0-38-4-0	4.27 c	4.2 d	5.62c	0.369ab	2.30ab
Known You 209 (CK 1)	4.42ab	4.8bc	6.20ab	0.282c	2.37ab
Golden Citrus (CK 2)	4.30bc	5.9 a	7.50a	0.389ab	2.18ab

[z] Transplanted on September 14, 1983 and harvested from January 5 through January 16, 1984. Replicated three times.
[y] Numbers followed by the same letters are not significantly different at the 5% level.

Conclusions

After two years of trials, hybrid selections PT912 and PT913 were found superior to commonly grown local cultivars Golden Citrus and F_1 hybrid Known You 209 in terms of yield, heat tolerance, and resistance to tomato mosaic virus. In late summer both can produce up to 70 t/ha of marketable fruits under natural conditions, without laborious hormone treatments. Before being released, both will be further evaluated in 1984 demonstration trials by the Tainan DAIS.

International Trials

In 1983, AVRDC distributed a total of 1,606 seed packets to 218 cooperators in 83 countries. Cooperators in the following countries filed these reports:

Bangladesh

Dr. M. Rashid, Director of BARI (The Bangladesh Agricultural Research Institute) reported the selection of two tomato lines, CL143-0-10-3 and CL11d-0-1, both of which have been found suitable for growing during the off-season. There is a good chance that they will be officially released.

Barbados

Mr. A. Joseph of Hygro Gardens, Ltd. grew seven AVRDC lines in hydroponic culture during the height of the hot, rainy season (June - September). He selected lines CL1131-43-8-1 and CL1131-38-4, which were reportedly strong, vigorous, and free of diseases. Their fruits, slightly larger than those of cherry tomatoes, were extremely tasty, of even-size and shape, beautifully colored, and in high demand for salads. Fruit set was described as excellent, and this at a time when local cultivars were unable to set any fruit whatsoever. Additional seeds were provided for commercial production to meet the special market demand that had been created. These lines can be considered as already released to growers.

Brazil

Dr. S. Cheng of EMBRAPA (Belem) reported the outstanding performance of two F_1 combinations of AVRDC lines and/or accessions in a BW-infested field trial in the Amazon basin. Line CL5551 (L22/L336) was singled out for potential release because of its earliness (harvestable in 70-90 DAP), and high resistance to cracking, a very important character in such a climate. Fruit weight varied from 30 to 60 grams, and the average of 45 g was acceptable to local consumers. Estimated yield was 35-40 t/ha. Another breeding line, CL1131-0-0-38-4-0, was

found highly resistant to biovar 3 of the wilt pathogen, and has done well during the heavy rain season. Its fruit size, however, was still well below the market standard of 60 grams per fruit.

Brunei

Mr. R. Santiago of the Sinaut Agricultural Training Centre tested seven breeding lines at 5°N latitude and 21 meters above sea level. Plot size was 12.4 m^2, without replication. Mean maximum and minimum temperatures during the trial were 33.6 and 22.1°C. Entries varied in yield from 3 to 11 t/ha, with the last harvest 64 days after trans-transplanting. AVRDC lines CL9-1-3 and CL1131-38-4 were the best performers, with yields of 11 and 8 t/ha, respectively.

Cook Island

Mr. K. Turepu of the Tokoitoku Research Station tested nine AVRDC breeding lines against three commercial hybrids from Yates Seed Company (Australia). Seeds were sown on July 21 and seedlings were transplanted August 19, 1982.

An RCB design was used with four replications. Each plot measured 6 m^2. Mean maximum and minimum temperatures during the trial were 27.1 and 18.1°C. The characteristics of the four entries selected for release to growers are shown in Table 37.

Table 37. Performance[z] of AVRDC lines selected in 1982 for release to growers on Cook Island.

Entry	DF[y]	Marketable yield (t/ha)	Fruit size (g)	Leaf mold[x]	Cracking
CL11d-0-2-2-0-3-0	38a	67a	56cd	0 c	none
CL9-0-0-1-3-0	38a	31cd	62b-d	1.5b	slight
CL143-0-10-3-0-1-1-0	32b	46b	41e	1.5b	none
CL1104-29-1-0	38a	27cd	68bc	1.5b	none
YR 809 (check)	37a	35bc	62b-d	1.8ab	moderate
YR 815 (check)	36a	25cd	92a	2.2a	moderate
LFYR 813 (check)	38a	28cd	73b	1.5b	moderate
CV (%)	7	27	14	32	-

[z] Means followed by same letters are insignificantly different.
[y] DF = days to flowering of 50% of each plot.
[x] Based on scale of 0 = healthy to 3 = severely diseased.

Fiji Island

Mr. M. Iqbal, Senior Horticultural Research Officer of the Sigatoka Research Station, reported the release of another selection from AVRDC

line CL8d-0-7-1. It is named "Sada Bahar", meaning "evergreen" or "always in fruit" in Hindustani, and is heat tolerant, resistant to bacterial wilt, and high yielding (up to 35 t/ha). Its sweet, uniform-shouldered fruit weighed an average of 80 grams. Alton (AVRDC # CL143-0-4B-1) was released in 1979, and is now reportedly yielding as much as 65 t/ha in farmers' fields.

Gabon

Professor K. Kjomboya tested five breeding lines in an unreplicated trial at Mimongo, which is located at 1° south and 800 m above sea level. Plot size was 10.88 m^2. Temperatures during the trial ranged from 22°-29°C. CL1131-38-4 and CL9-1-3 were the best performers, with estimated marketable yields of 86 and 83 t/ha, respectively. Both were reportedly resistant to bacterial wilt and resistant to moderately resistant to early blight, but both were infected in varying degrees by leaf curl and nematodes.

A three-replicate trial of 11 bacterial wilt resistant AVRDC accessions and breeding lines was conducted by FAO/CIAM in one of their stations (unspecified) in 1982. Individual 6 m^2 plots had a population density of 33,000 plants per hectare. The following entries were selected for further trials against cultivars Caraibe, Carette, and Xeewet in 1983: CL1219-0-8, L4670 (PI406994), L96 (Saturn), and L15 (VC8-1-2-7). Their yields and other horticultural characteristics are shown in Table 38.

Table 38. Yield and other horticultural characteristics of the best entries selected by FAO/CIAM in Gabon; 1982.

Entry	Marketable Yield (t/ha)	Fruit size (g)	Days to Harvest
CL1219-0-8	45	53	63
L15	61	40	61
L96	46	48	66
L4670	44	58	70

Indonesia

Dr. J. Fitzgerald, University of Sriwijaya, Sumatra, conducted two trials of AVRDC breeding lines. Both were located at 5° S latitude and 5 meters above sea level. The first, involving nine AVRDC lines and local variety "Ranti", was replicated three times, and was sown on July 31 and transplanted on September 16, 1982. The second consisted of ten AVRDC breeding lines; the local check proved inferior in the first trial and was not included. This trial was also replicated three times, and was sown on September 8 and transplanted on October 7, 1983. Mean min/max temperatures during the first trial were 22.2 and 33.9°C.

The best line in the first trial, CL143-10-3, had a marketable yield of 10 t/ha, good fruit set, and smaller fruit but less cracking than CL9-1-3 (Table 39). Much higher yields were obtained in the second trial (Table 40). CL1131-17 gave the highest yield of 33 t/ha, but did not significantly differ from that of other high-yielding entries. Bacterial wilt incidence was considered negligible in both trials.

Table 39. Performance[z] of the best AVRDC tomato lines and the local check at Palembang, Sumatra, Indonesia; 1982.

Entry	Fruit set Rate[y]	Marketable Yield (t/ha)	Fruit size (g)	Cracking[x]
CL9-1-3	5a	11a	33a	3.0a
CL143-10-3	5a	10ab	20c	1.7bc
Ranti (check)	2b	6c	4e	2.0bc
CV (%)	0	21	12	9

[z] Means followed by same letters are insignificantly different.
[y] Based on scale of 1 = no fruit set to 5 = heavy set.
[x] Based on scale of 1 = none to 3 = heavy.

Table 40. Performance[z] of the best AVRDC tomato lines in a second trial at Palembang, Sumatra, Indonesia; 1983.

Entry	DF	DM	Marketable yield (t/ha)	Fruit size (g)	Fruit set Rate
CL1131-17	23e	64	33	41bc	4.0a
L4841	20g	64	29	33bc	3.3ab
CL1104-63-3	24d	64	24	52b	3.0b
CV (%)	0	2	44	29	23

[z] Means followed by same letters are insignificantly different; DF = days to flowering; DM = days to maturity.

Malawi

Dr. W. Stephens of the Kasinthula Research Station reported a three replicate trial of seven AVRDC breeding lines and three commonly grown cultivars during the hot, wet season. The trial was located at roughly 16° south latitude and 70 meters above sea level, and was sown on January 13 and transplanted February 2, 1983. Mean minimum and maximum temperatures during the trial were 18.4° and 37°C. Table 41 shows the performance of the best AVRDC lines and highest yielding check Moneymaker. The best AVRDC lines had better fruit set but smaller fruit. The fruits of line CL1131-43-10-1 also showed a greater tendency to crack.

Table 41. Performance[z] of the best AVRDC lines and the best yielding check at Kasinthula Research Station, Malawi; 1983.

Entry	Fruit set rate[y]	Marketable yield (t/ha)	Fruit size (g)	Late Blight[x]	Cracking[x]
CL1131-43-10-1	4ab	22	15	1.0	1.7a
CL1131-43-4-12	5a	20	16	1.3	1.0b
Moneymaker (check)	3d	18	25	1.3	1.0b
CV (%)	13	35	-	26	40

[z] Means followed by the same letters are insignificantly different.
[y] Based on scale of 1 = no set to 5 heavy set
[x] Based on scale of 1 = mild to 3 = heavy

Nepal

Three trials were conducted by AVRDC cooperators. One featured ten AVRDC lines and local check Pusa Ruby in a three-replicate trial, and was carried out at Dhankuta by Mr. B. D. Pathak from March through July of 1982. The second trial, planted at Khumaltar by Mr. I. R. Pandey, had eleven entries (ten AVRDC lines and local check Monprecos), was replicated three times, and conducted from January through July of 1982. The third, conducted by Mr. P. Dahal at Sarlahi, tested ten AVRDC entries without a local check, and was grown from September 1981 through to March 1982.

The best performers at the Dhankuta trial were lines CL9-0-0-1 and CL143-10-3 (Table 42), which yielded 25 and 20 t/ha, respectively, not significantly more than Pusa Ruby.

Although the fruit set and fruit size of these entries were significantly better than the check's, CL143-10-3 showed a blotchy ripening fruit defect.

At Khumaltar and Sarlahi, none of the AVRDC lines tested proved to be outstanding.

Table 42. Performance[z] of the best AVRDC lines and the local check at Dhankuta, Nepal; 1982.

Entry	Marketable yield (t/ha)	Fruit set rate	Fruit size (g)	Blotchy Ripening	DF
CL9-0-0-1	25	5a	84ab	1c	34
CL143-10-3	20	5a	50d	3a	30
Pusa Ruby (check)	17	3c	20e	1c	35
CV (%)	26	0	18	0	10

[z] Means followed by the same letter are insignificantly different.

Tanzania

Mrs. E. Meela of the Uyole Research Center reported the results of a three-replicate trial comparing five AVRDC lines with Moneymaker. Seeds were sown on February 3, 1983, and seedlings were transplanted on March 11. Climate during the trial was relatively dry (except during the first two months of growth) and cool (mean minimum and maximum temperatures were 8.7° and 24.5°C). The best performing line was CL143-10-3-1, which gave total yields of 100 t/ha and marketable yields of 74 t/ha. Both figures were significantly higher than those observed for Moneymaker (Table 43).

However, line CL 143-10-3-1 had smaller fruit than Moneymaker. As had been expected for such cool conditions, no significant difference was noted in their fruit setting abilities.

Table 43. Yield[z] of the best AVRDC tomato line as compared with local check at Uyole Research Station, Tanzania; 1982.

Entry	Marketable yield (t/ha)	Total yield (t/ha)	Fruit size (g)	Marketable Yield (% of check)
CL143-10-3-1	74a	100a	30	151
Moneymaker (check)	49b	68b	88	100
CV (%)	21	17	-	-

[z] Means followed by same letters are insignificant.

Tomato Pathology

Field Screening of Bacterial Wilt Resistant Lines

Introduction

Bacterial wilt is a major disease of tomato in the tropics. Although previous work at AVRDC had focused on identifying resistant lines, present goals involve the development of methods for accurately quantifying resistance. The first step was to evaluate the relative performance of tomato lines under field conditions without additional seedling inoculation. The results of this experiment could then be compared with the results of other screening methods.

Materials and Methods

Pathology

A field was infested with a single isolate of Pseudomonas solanacearum isolated from fields in central Taiwan. The field, designated TBW 1, was planted with susceptible tomato cultivar Nan-Tzu according to standard AVRDC cultural practices. All plants were then clip inoculated in the field. Although this method of inoculation does not deposit uniform numbers of bacteria into each plant's vascular system, it does wilt them rapidly. Any surviving plants were inoculated a second time. After three weeks, the soil was tilled and new beds formed. At this point, a soil assay indicated bacterial populations of about 6.95×10^3 CFU per gram dry weight of soil. Test lines were transplanted into the new beds, and alternate rows were planted with susceptible check TK-70. Plants were observed at regular intervals, and wilt data was recorded from the 15th to the 60th day after transplanting.

A second planting of the same lines was made in the field on September 25. A soil assay performed at that time indicated population levels of 1.84×10^4 CFU per gram dry soil.

The percentage of wilt increased regularly over time, and then slowly levelled off. Two methods of dealing with this curvilinearity were to use a multiple infection transformation (using the log $(1/(1-x))$ instead of actual disease incidence as the "y" value) and to fit both a linear and quadratic component using multiple regression. These methods of data analysis were compared by using a sign test on the resulting r^2 values.

Results

No tomato line was completely immune to bacterial wilt; at 60 days after transplanting the incidence of wilt ranged from 6.7 to 100 percent (Table 1). Variation in the final amount of wilt indicated that different levels of resistance do exist. The lines chosen for this experiment, however, yielded a very skewed distribution, with most lines being very susceptible. Only 11 of the 41 lines tested had a final wilt incidence below 50%, and 22 of them had a final incidence of 90% or more. Only two showed a wilt incidence of less than 10%. Very little wilt developed in the second planting, and no data were collected.

The polynomial regression had a better fit than the multiple infection transformation in 33 of 41 cases, with seven ties and only one case where it was worse. The sign test showed the fit of the polynomial regression to be significantly better ($P < 0.01$). The predicted maximum wilt agreed well with the observed values, and a chi square test indicated no significant deviations.

Table 1. Tomato lines reported resistant to bacterial wilt; summer, 1983.

Line	Linear plus quadratic analysis				Mult. Inf. Trans.			Abs Wilt	Pred Mx
	Intercept	Slope	Quad.	r^2	Intercept	Slope	r^2		
L 1	-25.56	2.36	-.0192	.99	-0.14	.0147	.96	46.50	47.07
L 8	-43.50	3.82	-.0334	.98	-0.29	.0261	.96	68.70	66.01
L 15	-19.00	1.97	-.016	.98	-0.09	.0121	.94	42.30	42.22
L 95	- 3.34	0.50	-.0029	.95	-0.01	.0034	.94	17.30	18.63
L 96	-14.38	1.27	-.0088	.98	-0.08	.0082	.96	29.30	32.14
L 97	-59.51	6.36	-.0654	.99	-0.61	.0631	.96	92.30	95.52
L 240	-19.92	1.98	-.0176	.98	-0.07	.0103	.93	36.50	36.03
L 245	-49.04	4.41	-.0362	.98	-0.53	.0426	.97	83.10	85.63
L 272	-75.32	7.10	-.0722	.97	-0.95	.0795	.95	97.10	99.53
L 274	-64.10	5.48	-.046	.98	-1.13	.759	.96	96.10	99.43
L 285	- 5.63	.47	-.0042	.95	-0.02	.0021	.89	8.10	7.89
L 315	-68.67	6.93	-.0704	.98	-0.08	.0088	.98	100.00	101.93
L 366	-14.75	1.35	-.0094	.99	-0.02	.0021	.89	33.30	33.96
L 373	-58.11	5.03	-.0427	.98	-0.70	.052	.98	91.40	90.22
L 751	-57.57	4.98	-.0405	.99	-1.07	.074	.96	96.90	95.76
L 755	-57.57	6.31	-.0621	.99	-2.67	.173	.88	100.00	102.85
L 761	-54.83	5.55	-.0515	.99	-0.83	.0672	.98	94.90	95.15
L 766	-66.71	6.81	-.0692	.97	-1.22	.0957	.99	98.90	101.27
L 791	-49.05	5.32	-.0488	.99	-0.82	.0686	.98	94.70	96.08
L 972	-62.02	6.00	-.0583	.99	-0.69	.0594	.99	93.30	92.55
L 794	-62.73	6.89	-.0737	.98	-0.57	.0666	.95	94.70	98.31
L 795	-66.50	6.76	-.0683	.98	-1.29	.0982	.97	99.00	101.09
L 798	-54.59	6.81	-.0736	.98	-0.81	.0898	.95	98.00	103.04
L 990	-64.84	6.73	-.0683	.99	-1.14	.0926	.97	98.10	100.94
L 1477	-68.11	6.05	-.0567	.98	-0.84	.0636	.98	94.60	93.78
L 1629	-34.23	2.52	-.0128	.95	-0.39	.0261	.93	63.00	90.48
L 1737	-61.8	6.60	-.0707	.98	-0.38	.0515	.92	89.70	92.47
L 1822	-65.37	6.52	-.0669	.99	-0.58	.0581	.95	90.90	93.51
L 1937	-21.80	1.74	-.012	.98	-0.14	.0118	.96	37.30	41.86
L 3490	- 4.77	0.68	-.0058	.68	-0.07	.0164	.68	59.20	15.43
L 3560	-41.52	4.99	-.0473	.99	-0.48	.0519	.98	80.00	90.24
L 3638	-69.92	6.83	-.0686	.99	-1.17	.0912	.97	97.50	100.43
L 3690	- 6.66	0.55	-.0055	.91	-0.01	.0019	.79	6.70	7.12
L 3705	-21.62	1.96	-.0192	.96	-0.06	.0081	.85	27.40	28.40
L 3745	-61.90	6.94	-.0724	.99	-0.96	.0853	.98	98.10	100.86
L 3786	-65.05	6.63	-.0502	.97	-0.79	.0591	.97	92.70	92.88
L 3972	-70.48	7.76	-.0856	.97	-1.10	.1059	.96	99.10	105.72
L 4670	-30.39	2.88	-.0312	.94	-0.04	.0101	.75	33.70	36.34
CL-555	-22.91	1.56	-.0065	.96	-0.64	.0387	.92	83.60	71.78
L 3682	-45.02	4.36	-.038	.99	-0.41	.0378	.98	80.40	80.46
TK-70	-20.69	1.83	-.0082	.99	-0.23	.0188	.99	59.20	82.39

Conclusions

Tomato lines previously designated by AVRDC as resistant to BW varied considerably in their reactions. This may be due to varying amounts of resistance, or simply to variations in the methods previously used to test them. Since this experiment was conducted under field conditions and allowed infection to take place naturally, its results are more reliable than those of a seedling or greenhouse test. Although results such as these could vary with the isolate or with weather conditions, they are similar to what a farmer might encounter under real conditions.

Lines from both the multiple infection transformation and the polynomial regression fit the data satisfactorily, and in both cases r^2 values were very high. There are several reasons for favoring the polynomial regression, though. A residual analysis of regressions using the multiple infection transformation showed that it failed to correct at higher levels of wilt, primarily because the "levelling of the line" occurred well below 100%. The multiple infection transformation assumes that the theoretical maximum amount of disease is 100%, and that any disease level less than this is due to the plant having escaped infection. While this model may conform closely to the underlying biological processes involved in infection by some diseases, it does not adequately explain the results of this experiment. It would appear that disease incidence is affected by several factors not considered in the multiple infection transformation. One is that a cultivar's maximum wilt may not always reach 100%. Polynomial regression allowed the calculation of a "theoretical maximum wilt" at which the rate of wilt is no longer increasing, and these values were rarely near 100%, especially with resistant cultivars. As the high r^2 values would suggest, this predicted maximum wilt agreed very closely with the observed maximum value.

In either case, slope appeared to be a good way of comparing resistant lines. Resistant lines had lower slopes, indicating that the rate of disease increase for these lines was less than for the more susceptible ones. Using Spearman's rank correlation to compare the slope from polynomial regression with the observed maximum wilt gave an r_s value of 0.8079 (significant at $P < 0.01$). If testing is not allowed to proceed to maximum wilt, slope may prove to be a valuable parameter.

Artificial Inoculation of Bacterial Wilt Resistant Lines

Introduction

Bacterial wilt resistance is a major goal of AVRDC's tomato breeding program. Although the most accurate data is produced under natural growing conditions, limitations of time and space necessitate a good screening method involving young plants. Measurements of disease resistance are also more easily compared from test to test when plants are grown under controlled conditions. Such a screening method is valid, however, only if there is a high degree of correlation between its results and actual performance in the field. This is the first of

several studies seeking to establish the relationship between the screening of young plants and actual field performance.

Materials and Methods

In this experiment a set of seedlings similar to those grown in the field test were artificially inoculated. Pre-germinated seeds were selected for uniformity and sown on August 18 and 19 in individual pots containing about 100 ml of soil. After 23 days all 96 seedlings of each variety were inoculated with 2ml of an inoculum containing 10^4 to 10^9 bacteria per ml. Plants were observed for symptom development, and wilt incidences were recorded 6, 10, 14, and 18 days after inoculation. Data was analysed by probit analysis (an iterative, maximum likelihood technique for finding the slope and intercept of the probit of wilt as a function of log dose) for each line at each date, and was then compared to the data from the same lines tested under field conditions.

Results

Probit slopes and the corresponding chi-square values for the fitted lines are presented in Table 2. Large chi-square values generally indicated significant deviation from a straight line. Of the 40 cultivars tested six days after inoculation, only 13 had chi-square values under 9.49 (Probability of a larger value equal to .05). On subsequent dates the fits to straight lines became progressively worse, and by day 18 only 2 cultivars showed chi-square values of less than 9.49.

Conclusions

The assumption that the probit of disease incidence and the log of the dose of bacteria would have a linear relationship was not borne out by the results of this experiment. There are several possible explanations for this. Bacteria multiplying within the soil may be responsible for blurring the reactions, and thus progressively worsening the fits over time. Plant age and environmental factors such as irrigation and soil status could also be influencing plant wilt. In some cases the levels of wilt incidence were higher at lower (10^8 or 10^7 cfu/ml) inoculation levels than at higher ones (10^9 cfu/ml). The final explanation, and perhaps the most important, is that the relationship may not be linear at all. Of the 13 lines conforming closely to a linear relationship on day 6, only two were susceptible (wilt over 90% in the field test). The remainder showed an incidence of terminal wilt in the field test of between 8.1 and 83.6%. This may mean that the linear relationship holds for lines with some resistance, but does not hold for susceptible lines.

How well does the probit line serve as a predictor of wilt resistance under field conditions? When the 13 lines giving reasonable fits (chi-square values of less than 9.49) were subjected to Spearman's rank correlation, they showed a reasonable fit with the final wilt of lines

tested in the field (Table 3). Correlation of the probit slope with the linear component of the polynomial regression was much poorer, with an r_s value of only .43.

Table 2. Comparison of field and artificial inoculation, 1983.

Line	Field		Artificial inoculation data							
	Polynomial		6 days		10 days		14 days		18 days	
	Slope	Obs Wilt	Slope	Chi-squ	Slope	Chi-squ	Slope	Chi-squ	Slope	Chi-squ
L 1	2.36	46.50	0.70	9.97	0.49	24.80	0.50	15.59	0.52	19.06
L 8	3.83	68.70	0.66	0.41	0.48	0.98	0.48	1.78	0.49	1.66
L 15	1.98	42.30	0.58	3.51	0.59	28.11	0.59	26.62	0.59	26.58
L 95	0.50	17.30	0.20	6.58	0.17	33.48	0.19	42.88	0.20	40.49
L 96	1.28	29.30	0.39	6.14	0.33	21.68	0.31	31.46	0.30	39.59
L 97	6.37	92.30	1.00	17.31	0.94	19.81	1.00	27.75	0.32	43.59
L 240	1.98	36.50	0.30	16.09	0.31	31.01	0.32	35.82	0.32	37.11
L 245	4.42	83.10	0.68	7.35	0.85	2.44	0.98	7.55	0.88	10.29
L 272	7.11	97.10	0.83	14.76	0.69	30.15	0.73	49.59	0.80	70.39
L 274	5.49	96.10	0.80	23.67	0.72	60.52	0.78	67.02	0.89	62.48
L 285	0.48	8.10	0.34	4.01	0.33	5.36	0.30	8.26	0.30	12.59
L 315	6.93	100.00	0.77	37.27	0.99	34.44	1.10	20.53	1.14	18.88
L 366	1.35	33.30	0.57	10.20	0.46	35.31	0.42	34.26	0.42	41.83
L 373	5.03	91.40	0.52	3.64	0.68	96.30	0.68	111.44	0.70	121.16
L 751	4.98	96.90	0.80	36.80	0.84	35.34	0.78	30.90	0.77	30.13
L 755	6.31	100.00	0.77	44.55	0.75	25.53	0.76	17.32	0.69	18.21
L 761	5.56	94.90	0.57	11.17	0.82	35.18	0.72	41.07	0.72	45.20
L 766	6.82	98.90	0.69	8.63	0.65	16.46	0.71	29.00	0.67	36.17
L 791	5.32	94.70	0.80	18.16	0.67	39.48	0.80	9.81	0.89	7.35
L 792	6.00	93.30	0.88	25.49	1.03	13.18	1.11	12.56	1.13	12.21
L 794	6.89	94.70	0.97	15.06	1.02	16.16	1.12	14.57	1.08	16.32
L 795	6.77	99.00	0.66	39.86	0.70	50.99	0.69	46.16	0.69	48.52
L 798	6.81	98.00	0.77	15.16	0.69	44.50	0.72	36.18	0.70	37.53
L 990	6.73	98.10	0.90	36.22	0.60	14.73	0.58	16.17	0.62	22.23
L 1477	6.06	94.60	0.87	24.15	0.81	19.03	0.79	14.61	0.83	15.82
L 1629	2.53	63.00	0.35	6.32	0.50	36.35	0.54	27.74	0.55	42.12
L 1737	6.61	89.70	0.54	14.10	0.56	14.16	0.60	17.56	0.63	12.32
L 1822	6.52	90.90	0.67	42.89	0.74	72.57	0.73	127.56	0.80	218.58
L 1937	1.75	37.30	0.66	31.74	0.51	10.83	0.56	12.00	0.57	11.46
L 3490	0.68	59.20	0.69	4.78	0.57	23.62	0.61	22.78	0.59	23.13
L 3560	4.99	90.00	0.74	37.44	1.29	38.12				
L 3638	6.84	97.50	0.77	13.19	0.74	23.20	0.81	27.98	0.78	23.70
L 3690	0.55	6.70								
L 3705	1.96	27.40	0.34	9.41	0.35	26.47	0.23	33.51	0.33	33.66
L 3745	6.95	98.10	0.70	45.25	0.59	32.94	0.60	34.02	0.60	29.60
L 3786	5.63	92.70	0.47	9.63	0.40	35.66	0.45	39.56	0.48	53.88
L 3972	7.77	99.10	0.94	12.20	0.99	21.27	1.01	53.54	1.11	10.34
L 4670	2.89	33.70	0.51	6.22	0.44	30.60	0.42	35.23	0.43	34.90
CL-555	1.57	83.60	0.74	7.23	0.68	34.36	0.64	36.52	0.69	71.95
L 3682	4.37	80.40	0.86	21.82	0.68	31.46	0.77	33.59	0.81	34.70
TK-70	1.84	59.20								
L 390			0.59	21.46	0.81	9.23	0.88	41.24	0.83	39.94

While the correlations between the seedling test and actual field performance are "significant", the relationship is not perfect, and seedling performance alone may not be a valid test of field performance. In this experiment almost 600 uniform plants were used to judge relative resistance or susceptibility under field conditions, and even then results were poor. Although subsequent refinements may reduce this number, it is difficult to foresee a single-plant test that will distinguish resistant lines from susceptible ones.

Table 3. Probit lines of 13 tomato lines compared with wilt in the field.

Line	Field Data				Artificial Inoculation		
	Slope	Rank[a]	Max Wilt	Rank[b]	Slope	Rank	Chi-square
L 8	3.82	10	68.7	9	.66	9	0.41
L 15	1.98	7	42.3	6	.57	8	3.51
L 95	0.50	2	17.3	2	.19	1	6.58
L 96	1.28	4	29.3	4	.38	2	6.14
L 245	4.42	11	83.1	10	.68	10	7.35
L 285	0.47	1	8.1	1	.33	3	4.01
L 373	5.03	12	91.4	12	.51	7	3.64
L 766	6.82	13	98.9	13	.68	11	8.63
L 1629	2.53	8	63	8	.34	5	6.32
L 3490	0.68	3	59.2	7	.69	12	4.78
L 3705	1.96	6	27.4	3	.33	4	9.41
L 4670	2.89	9	33.7	5	.50	6	6.22
CL 555	1.57	5	83.6	11	.74	13	7.23

[a] Spearman's r (rank correlation) with probit slope = .43.
[b] Spearman's r (rank correlation) with probit slope = .77.

Evaluation of Bacterial Wilt Inoculation Methods

Introduction

Bacterial wilt is a major disease of tomatoes grown in warm areas. Although the pathogen normally penetrates through the roots of the plant, other techniques have been used to artifically inoculate plants. One recently developed method is to control the number of bacteria injected into the plant, fit a probit line to the data, and assume a linear relationship between the log dose of bacteria and the probit of the resulting wilt. It had been tried elsewhere with both potato and tomato, but this was the first time it was tried at AVRDC.

Materials and Methods

Ten varieties of 30 day old tomato seedling and six concentrations (10^3-10^8 cfu/ml) of bacteria were used in this experiment.

An inoculum of Pseudomonas solanacearum prepared in a fashion similar to that used in other AVRDC pathological studies was diluted to OD_{600} nm = 0.2 (2.17 x 10^8 cfu/ml). The inoculum was then diluted to provide six inoculum concentrations ranging from 10^3 to 10^8 cfu/ml. The concentration of bacteria at each inoculum level was determined by standard dilution planting. A micropipette containing 0.1 ml (100 µl) of inoculum was inserted diagnally into the stem at the third leaf axil from the top. Each plant was thus inoculated with from 10^2 to 10^7 cfu. To facilitate insertion of the micropipette, a sterile wire slightly

larger in diameter than the pipette was first inserted and withdrawn from the stem at the same site. The inoculum was normally taken up after three or four hours, and the pipette was removed. Twenty plants of each variety were tested at each inoculum level. After inoculation the plants were transferred to a growth room and maintained at 28° C night and 38° C day temperatures. Disease index ratings were recorded every day, and the final record was made 21 days after inoculation. These data were then subjected to probit analysis, and a probit line was fitted (probit of incidence of wilt as a function of log concentration).

Results

Probit analysis indicated that varieties 245, 373, 390, and TK-70 were susceptible (Table 4). Most had a poor fit (large chi-square) and high slope (about 0.4), but 373 had a good fit and a low slope. Most had ED_{50} values around 10^2-10^4 cfu/plant.

Table 4. Probit lines of ten tomato lines tested for resistance to bacterial (wilt inoculant injected into the plant).

Line	Intercept	Slope	Chi-square	$\log_{10} ED_{50}$
L 8	3.01	2.69	3.42	7.39
L 15	3.57	0.13	3.50	10.78
L 95	1.09	0.45	1.77	8.73
L 96	3.96	0.03	5.23	28.39
L 245	2.94	0.48	21.36	4.28
L 285	1.49	0.26	2.64	13.34
L 366	3.88	0.14	6.90	7.74
L 373	4.43	0.23	2.83	2.42
L 390	3.37	0.44	18.25	3.66
L 4077	2.82	0.09	13.54	4.43

L285 proved resistant and had a low slope, a low maximum wilt (0-0.05), and an ED_{50} outside of the range of concentrations used. Varieties L 8, L 15, and L 366 were intermediate between the most resistant and the most susceptible. They had a low slope, an intercept greater than 3, a chi-square indicating a reasonable fit, and a level of wilt incidence ranging from 5 to 50%.

Line L 95 had a low intercept, a high slope (about 0.4) and a maximum wilt of 0.2, which means its degree of resistance was correlated with the concentration of the inoculum; it was resistant at low concentrations of bacteria but became more susceptible when concentrations increased.

Line L 96 had an intercept nearly matching that of the susceptible lines, but had a very low slope (only 0.03) and a maximum wilt incidence of only 0.2; it showed little or no correlation between bacterial concentration and the percentage of wilt incidence.

Conclusions

The relationship between the probit of P. solanacearum incidence in tomato and the log of the inoculant dosage is not always linear. Some lines gave reasonably good fits, but susceptible lines did not give good fits at all. As was the case when inoculant was added to the soil, resistant lines responded in a linear fashion and susceptible ones did not. Additional correction may be required before such a method can be used for resistance evaluation.

This method of inoculation, while requiring fewer plants, assumes that inoculant introduced into the above-ground vascular system will have the same effect as would naturally-ocurring bacteria entering through the root. It also requires a large number of plants, and cannot be used to test single plants.

Evaluation of Race-Specific Resistance to Late Blight

Introduction

Resistance to late blight caused by Phytophthora infestans can be race-specific or non-race-specific. At least two races are known to infect tomato, and numerous races are known to infect potato. After successfully isolating P. infestans from central Taiwan in the highlands near Puli, an attempt was made to determine its race.

Materials and Methods

The study included susceptible check TK-70 (AVRDC L 3975) and three tomato lines known to possess gene PH_1, which carries resistance to race T_0. Six pots of each line were started, and after approximately five weeks leaves from each plant were placed in petri dishes with filter paper, inoculated with 20 µl of a spore suspension (20000 sporangia/ml), and incubated in a 15°C illuminated incubator for 7 days. After incubation they were rated as either susceptible or resistant.

Results

All plants were susceptible to the isolate, indicating that it was race T_1 (Table 5).

Conclusions

The isolate from Puli was Race T_1. While this means that the PH_1 resistance gene found in 1497, 1501, and 1517 cannot be used in this area, it also means that the presence of this gene will not affect screenings for other non-race-specific resistance genes. Isolates virulent against gene PH_1 were discovered even before it had been successfully incorporated into commercial tomato cultivars in the USA, thus negating its value there as well. Studies attempting to character-

ize this isolate as a potato race could provide valuable information, but they have been hampered by a lack of differential cultivars.

Table 5. Reaction of differential tomato varieties to one isolate of Phytophthora infestans.

AVRDC Line	USDA PI	West Virginia	Reaction to Race T_0 (from literature)	Reaction to Race T_1 (from literature)	Puli isolate (observed)
L 1497	204976	36	R	S	S
L 1501	204980	106	R	S	S
L 1517	204996	700	R	S	S
L 3975	-	-	-	-	S

An Analysis of the Components of Resistance to Late Blight

Introduction

Resistance to late blight caused by Phytophthora infestans in tomato can be either absolute or partial. Absolute resistance, however, is effective only against certain races. Other types of resistance allow some growth of the pathogen and a limited amount of disease development, but less than do other more susceptible tomato cultivars. More accurate characterization of this resistance would make possible more efficient resistance screening.

Materials and Methods

Detached leaves of cultivars TK-70 and L 1197 were inoculated with P. infestans (50 microliters of spore suspension per leaf, at a concentration of 34,000 sporangia per ml) and were then incubated at 15°C in an illuminated incubator. The lesion size on five leaves of each variety was measured 4, 6, 7, 8, 10, 11, and 12 days after inoculation. The number of spores produced per lesion was calculated from six leaves of each variety at 6, 7, 8, 10, 11, 12, 13, and 14 days after inoculation, and the resulting lines were compared by regression analysis.

Results

The regression lines of spore number and lesion size as a function of time are presented in Figures 1 and 2. An ANOVA showed that the rate of spore production for TK-70 was lower than for L 1197.

The ANOVA for the lesion size data indicates that the lesions increased in size at approximately the same rate (Table 6).

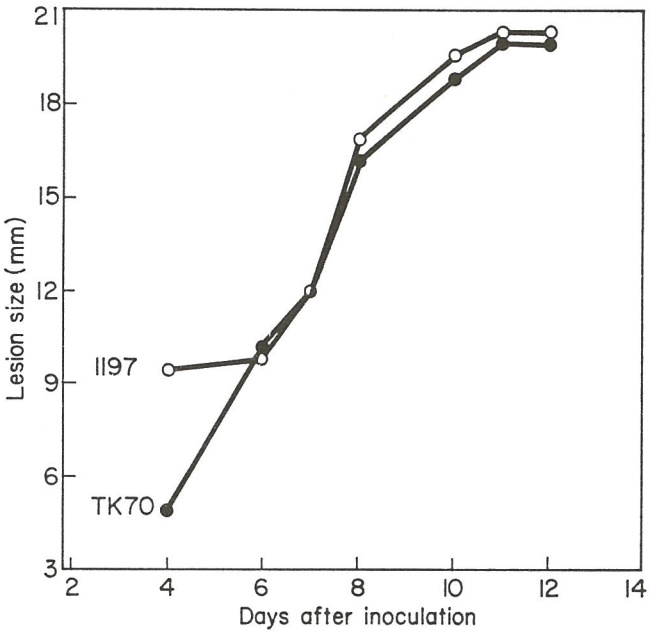


Fig. 1.
Increases in lesion size for two tomato lines infected with Phytophthora infestans.

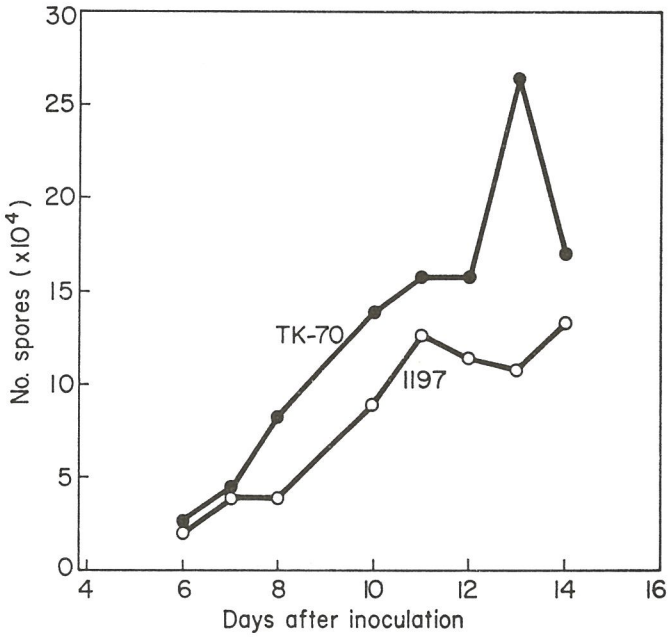


Fig. 2.
Increases in number of spores (x 10^4) for two tomato lines infectd with Phytophthora infestans.

Table 6. Data from regression analysis.

Variety	Lesion size		Spore number	
	Slope	Intercept	Slope	Intercept
TK-70	1.57	2.03	2.5	-12.27
L 1197	2.03	-1.94	1.5	- 7.1
Both lines together	1.80	0.06	2.0	- 9.7
"F" value for contrast comparing TK-70 and L 1197	1.95		12.9	

Conclusions

The resistance reported for L 1197 appears in the form of reduced sporulation; lesion size does not appear to be smaller. Other factors not covered in this experiment, such as reduced penetration, may also contribute to 1197's resistance. Resistance must be confirmed under field conditions, but even if ineffective there, it could still be combined with other types of resistance, and could in the end lead to higher levels of resistance.

A Technique for Screening Large Plant Populations for Resistance to Root-Knot Nematode

Introduction

Successful resistance screening depends on the ability to screen large numbers of plants with maximum opportunity for infection. This experiment was a preliminary attempt to screen large plant populations with a minimum of greenhouse space, inoculum, time, and labor.

Materials and Methods

Flat test:

After being germinated in petri dishes for 4 days in a 30° chamber, tomato seeds were transferred to 34 x 51 x 7 cm plastic trays filled with soil. Two seeds were place in each row. Three lines were used: susceptible line 'L 124', resistant line 'L 97' and segregating line 'CLN 125-0'. At the time of seeding, each hole received 2 ml of an aqueous suspension containing 5,000 eggs of Meloidogyne incognita and was then covered with smoked rice hulls. Trays were placed in a greenhouse maintained at 19° night and 33° day temperatures.

Pot test:

All lines were also seeded in 6 cm diameter plastic pots with 2 plants per pot. At the time of seeding, each pot received 5,000 eggs of M. incognita and was then placed in the same greenhouse as the tomatoes in flats.

All plants were uprooted sixteen days after planting, and symptoms were evaluated along the stems and roots. Seedling height and leaf length were also recorded. Gall ratings were made according to the following scale; 0 = no gall, 1 = 1-3 galls, 2 = 4-10 galls, 3 = 11-30 galls, 4 = 31-100 galls and 5 = more than 100 galls.

Results

Sixteen days after inoculation resistant plants could easily be distinguished from susceptible ones on the basis of galling (Table 7) or

Table 7. Percentage and number of plant stems galled and root gall ratings for flat and pot methods.

Method	Entry	No. of Plants	% g.s.	% g.r.	No. of plant stems galled						No. of plant roots galled					
					0	1	2	3	4	5	0	1	2	3	4	5
Flat	CLN 125-0	113	13.91	22.02[zx]	97	13	1	-	2	-	79	9	13	12	-	-
	L 97	28	3.57	14.29[z]	26	2	-	-	-	-	24	4	-	-	-	-
	L 124	39	66.67	100.00[y]	13	11	10	5	-	-	-	-	22	16	1	-
Pot	CLN 125-0	32	25.00	25.00[zx]	24	5	1	1	-	-	24	3	3	2	-	-
	L 97	16	0.00	6.25[z]	16	-	-	-	-	-	11	5	-	-	-	-
	L 124	14	64.20	100.00[y]	5	2	3	4	-	-	-	-	4	10	1	-

[z] Root showed necrosis symptom.
[y] Galling occurred in all of the root system.
[x] Some seedling showed galling in all of the root system.
g.s. = Seedling stems were infected by Meloidogyne incognita.
g.r. = Root of seedlings were infected by M. incognita.

Table 8. Height and leaf length of plant considered resistant or susceptible.

Method	Entry	Inoculated plants: Plant considered resistant[z] Height	Inoculated plants: Plant considered resistant[z] Leaf length	Inoculated plants: Plant considered susceptible[y] Height	Inoculated plants: Plant considered susceptible[y] Leaf length	Non-inoculated plants Height	Non-inoculated plants Leaf length
Flat	CLN 125-0	4.14	3.52	3.25	2.79	6.87	6.89
	L 97	3.26	3.40	-	-	5.00	5.43
	L 124	-	-	2.36	2.59	6.88	6.88
Pot	CLN 125-0	3.95	3.12	3.04	2.08	5.95	5.88
	L 97	3.43	3.00	-	-	4.80	5.97
	L 124	-	-	2.57	1.53	4.37	5.59

[z] Based on root gall rating at level 0, 1.
[y] Based on root gall rating at level 2, 3, 4, 5.

Table 9. Chi-square values of resistant, susceptible, and segregated lines.

	Entry	No. of plants	Expected segregation	Expected S	Expected R	Observed S	Observed R	Chi-square	Probability
Flat	CLN 125-0	113	1:3	28.5	85.5	25	88	0.42[z]	> 0.5[z]
	L 97	28	0:1	0	28	0	28	...[z]	...[z]
	L 124	39	1:0	39	0	39	0	...	...
Pot	CLN 125-0	32	1:3	8	24	5	27	1.01[z]	0.36[z]
	L 97	16	0:1	0	16	0	16	...[z]	...[z]
	L 124	14	1:0	14	0	14	0	...	...

[z] Chi-square was not calculated; data did not deviate from expected ratio.

height and leaf length (Table 8). The ratio of resistant to susceptible plants in segregating populations conformed to the ratios expected (Table 9).

Conclusions

Both methods were effective in screening tomato seedlings for

resistance to root-knot nematode. The expected segregation ratio was three resistant to one susceptible for CLN 125-0, 1:0 for resistant line 'L 97', and 0:1 for susceptible line 'L 124'. Chi-square values showed that the segregating populations did not depart significantly from the expected ratio, and were based on the classification of root gall index categories 0 and 1 as resistant reactions and categories 2 through 5 as susceptible. Larvae invading the roots of resistant plants developed enough to cause limited gall formation, but not enough to produce eggs or complete their life cycle. Susceptible lines, moreover, showed root gall indices from categories 2 through 5 (Table 7).

In the presence of an inoculum, resistant plants from a segregating line are taller and have larger leaves than do susceptible ones (Table 8). This can help detect resistant plants, but resistance should be confirmed by the root gall index. Inoculation reduced the size of all plants, but resistant plants were affected less than susceptible ones. Even limited gall formation on the roots of resistant plants slightly reduced their ability to absorb nutrients and water.

The flat method is very useful for rapidly and efficiently evaluating seedlings for resistance to root-knot nematode with a minimum of greenhouse space, inoculum, time, and labor. Nematode resistance ratings, however, should be based on the inhibition of nematode reproduction. Measurements of galling alone may not correlate well with actual resistance levels.

Corynespora cassiicola on Tomato in Taiwan

Introduction

In the autumn of 1982 a leaf spotting disease was observed on tomato at AVRDC and in the surrounding area. When routine isolation and identification indicated that the fungus was Corynespora cassiicola (Berk. and Curt.) Wei, a tomato pathogen not yet reported in Taiwan, it was decided to initiate a brief study of the disease.

Materials and Methods

Cultures of C. cassiicola were prepared from naturally infected material from AVRDC, from surrounding commercial production fields in Tainan County, and from a highland tomato production area near Puli. Infected leaves, stems, and fruit were surface-sterilized with a commercial bleach solution for 30 to 60 seconds and plated on PDA. Plates were incubated in an illuminated incubator at 28°C. Cultures were identified with the aid of keys and by comparing them with dried herbarium specimens of C. cassiicola and Helminthosporium carposaprum (McCulloch and Pollack).

Inoculum for pathogenicity tests were prepared from pure 10-12 day-old cultures grown on PDA. The culture surface was scraped with a scalpel, and distilled water was added to form a concentrated spore suspension. The suspension was filtered through two layers of cheesecloth to remove mycelial fragments, and was then adjusted to 20,000 to 30,000 spores per ml.

Cultures identified as C. cassiicola were tested for pathogenicity on tomato plants and fruits. One-month-old potted plants (TK-70) grown in the greenhouse were sprayed with the spore suspension, covered with plastic bags for 46 hours, and returned to the greenhouse. Control plants received only distilled water. Mature green fruits were inoculated by washing them in 50% ethanol, allowing them to dry, and then pushing bits of mycelium into them with a sterile needle. Control plants were damaged by the needle but were not inoculated. Fruits were kept in a moist chamber at 28°C with 12 hours of illumination per day. Subsequent re-isolation and identification of the fungus was performed as above.

Results

Cultures identified as C. cassiicola produced brown-green colonies on PDA, with the mycelia growing into the agar. Most isolates sporulated easily, producing terminal, tretic conidia, sometimes in chains. Conidia size varied within and among isolates. In culture, conidia averaged 85.13 by 8.99 microns (27.24-211.11 by 6.81-13.61), and in tissue, averaged 61.43 by 9.60 microns (23.84-149.82 by 6.81-14.3). Small black necrotic flecks appeared on tomato plants three days after they were inoculated, and larger necrotic spots with a yellow halo appeared four to seven days later. On the fruit there developed creamy brown, flattened, circular lesions similar to those produced by H. carposaprum. If several lesions formed on a leaflet in the field, it would quickly blight and fall off. Other workers have referred to this disease as target leaf spot.

Comparison with isolates and dried specimens of C. cassiicola confirmed the identify of the fungus. A comparison of C. cassiicola with McCulloch and Pollack's original description and with dried specimens of H. carposaprum revealed no clear differences. The type specimen of H. carposaprum (BPI 71481) was examined in the course of this study, but it did not contain intact, mature conidia attached to conidiophores. Other specimens from BPI marked "mass inoculations from original culture" did have attached conidia, and provide evidence in favor of adding H. carposaprum to the list of synonyms given for C. cassiicola (Table 10).

Although it does find its way into some publications, the name H. carposaprum is not commonly encountered. When interpreted in the light of current knowledge of the Corynespora and Helminthosporium, the original description describes the former, not the latter. Although H. carposaprum had been described before either revision of Corynespora and Helminthosporium, it seems to have been ignored by mycologists revising these genera.

Conclusions

This fungus is not new to Taiwan, and has been reported on a number of other hosts on the island, including papaya (as Helminthosporium papayae Sydow), sesame (as Corynespora sesamum (Sacc.) Goto), and cowpea (as Helminthosporium vignicola Kawam.). At AVRDC it has been isolated

from tomato but also from soybean (Glycine max (L.) Merr.) and sweet pepper (Capsicum annum L.). Because the lesions it produces can resemble those of early blight (caused by Alternaria solani Sorauer), target leaf spot may have been present here for some time, and incorrectly diagnosed as early blight.

Table 10. Synonyms for Corynespora cassiicola (Berk. and Curt.) Wei

Corynespora cassiicola (Berk. and Curt.) Wei

≡ Helminthosporium cassiicola Berk. and Curt.

= Cercospora melonis Cooke

= Corynespora mazei Gussow

= Helminthosporium papayae H. Sydow

= Cercospora vignicola Kawamura

= Helminthosporium vignae Olive

= Helminthosporium warpuriae Wakefield

= Helminthosporium sesameum Sacc.

= Helminthosporium carposaprum McColloch and Pollack

≡ Indicates a nomenclatural (obligate) synonym; names are based on the same type specimen.

= Indicates a taxonomic (facultative) synonym; names are based on different type specimens.

The presence of this disease has been reported from a number of other tomato growing areas with tropical or subtropical conditions. In Brunei it was mentioned as one of the main foliar pathogens, and in Florida an epidemic was brought under control only with daily fungicide applications. It has also been reported as a tomato pathogen in Nigeria and India. One series of studies implicated a host-specific toxin in the rapid blighting, and suggested that the toxin might provide an efficient method of screening for resistance. Preliminary studies at AVRDC indicate that our isolates do produce a toxin capable of wilting tomato, but the role it would play in resistance screening has yet to be determined.

The distribution and severity of the infections of tomato by C. cassiicola in the tropics and subtropics are not known at this time, nor is the magnitude of the losses caused by these infections. The similarity of its field symptoms to those of early blight indicates that an effective method of field diagnosis will be needed before its impact can be fully assessed.

Screening for Resistance to Tomato Fusarium Wilt

Introduction

The discovery in 1982 of Fusarium wilt of tomato (caused by Fusarium oxysporum f. sp. lycopersici) made it possible to evaluate techniques for screening for resistance to tomato Fusarium wilt.

Materials and Methods

Seeds of L 305, L 92, TK-70, L 272, L 94, and CL 1561-6-0-5-1-3 were sown on December 31, 1982, and seedlings of each varieties were transplanted to flats on January 4, 1983. Fusarium inoculum was prepared by shaking potato dextrose broth cultures for two weeks and then decanting the unused culture media. Mycelial mats from 25 flasks, each with 25 ml PDB, gave 500 ml of final inoculum. Plants were inoculated by removing them from the flat, dipping the roots in the Fusarium-agar mixture, and then replanting them in the flat. The plants were placed in a heated greenhouse to enhance symptom development, and observed once a week for one month.

Results

The identity of the Fusarium culture was confirmed as race 1. These results also show that TK-70 and CL 1561 carry the gene for resistance to race 1 of Fusarium wilt (Table 11).

Table 11. Reaction of tomato cultivars to Fusarium oxysporum f. sp. lycopersici. Isolate FOL_1

Cultivar	Known reaction to Race 1	Known reaction to Race 2	Observed reaction to FOL_1
L305 (Bonny Best)	S	S	S
L93 (Walter)	R	R	R
L272 (Anahu)	R	S	R
L94 (Floride MH-1)	R	R	R
TK-70	?	?	R
CL 1561-6-0-5-1-3	?	?	R

S = susceptible
R = resistant
1st symptoms appeared 1 week after inoculation
Wilt followed by death 2-4 wks. after inoculation.

Conclusions

Tests indicate that screening for resistance to race 1 of Fusarium wilt resistance is feasible under AVRDC conditions. Screening can be

carried out on young plants. Although they were not selected as resistant lines, cultivars TK-70 and CL 1561 (Tainan No. 2) carry resistance to race 1.

California studies have yielded conflicting data on CL 1561. In one test it was segregating for resistance (Agrigenetics) and in another it was resistant (Peto). It would seem, then, that it is not yet homozygous for resistance to Fusarium wilt.

A Survey of Potato Virus Y (PVY) and Other Viruses on Tomato in Taiwan

Introduction

PVY has frequently been reported in the tropics and subtropics. The purpose of this investigation was to determine the frequency and distribution of PVY on tomato in Taiwan, and to learn which strains are present.

Materials and Methods

The survey included Tainan, Kaohsiung, and Chiayi Counties. Leaf samples were taken from plants showing virus-like symptoms such as mosaic, mottle, yellowing, purple veins, necrosis, leaf deformation, stunt, and bushiness. Each sample was homogenized (1:10) in ELISA (enzyme-linked immunosorbent assay) extraction buffer (pH 7.4) and tested by ELISA against antisera of the following viruses: tomato mosaic virus (ToMV), potato virus Y (PVY), cucumber mosaic virus (CMV), potato virus X (PVX), tobacco etch virus (TEV), pepper mottle virus (PeMV), tomato spotted wilt virus (TSWV), tomato bushy stunt virus (TBSV), tomato ring spot virus (TRSV), and tobacco rattle virus (TRV).

Samples shown by serological tests to be infected with PVY were then subjected to three single LL transfers onto *C. amaranticolor* or detached leaves of *S. tuberosum* A-6, and their host range was determined on 17 test plants of 12 different species.

Results

Results are shown in Table 12. ToMV had been thought to be Taiwan's most common and widespread tomato virus, but this survey showed that both PVY and CMV occur almost as frequently on tomato in Taiwan as does ToMV. The failure to detect PVY and CMV in Chiayi County can be attributed to the small number of samples taken there. Previous surveys have shown that CMV is present in all the major tomato growing areas of Taiwan. More samples must be collected in Chiayi County and other areas of central and northern Taiwan before it can be ascertained whether PVY is also present on tomato island-wide.

TEV was found in only 2 of the 127 samples tested, and may not be an important tomato virus on tomato in Taiwan.

PeMV was detected in 1 of the 127 samples tested; this is the first reported occurrence of the virus on tomato in Taiwan. In a separate

Table 12. Occurrence of PVY and other viruses on tomato in southern Taiwan.

County	Total No. of samples collected	PVY	ToMV	CMV	PVX	TEV	PeMV	TRSV	TSWV	TBSV	TRV	Others[z]
Chiayi	9	0	2	0	0	NT[y]	NT	NT	NT	NT	NT	0
Kaohsiung	39	16	6	5	0	0*	0*	0*	0*	0*	0*	0
Tainan	324	132	140	135	0	1**	2**	0***	0***	0***	0****	5
Total	372	148	148	140	0	1	2	0	0	0	0	5

[z] Viruses belonging to the PVY-group, but not reacting with any of the antisera of PVY-group viruses tested in this study.
[y] NT = not tested.
* Only 5 of the 39 leaf samples were tested for this virus.
** Only 72 of the 324 leaf samples were tested for this virus.
*** Only 57 of the 324 leaf samples were tested for this virus.
**** Only 11 of the 324 leaf samples were tested for this virus.

AVRDC survey, this virus was detected in 4 of the 36 chili pepper samples and in 5 of 47 sweet pepper samples, indicating that it is present on crops other than tomato.

PVX, although reportedly occurring on tomato in Taiwan, was not found in this survey, nor were TSWV, TBSV, TRSV, or TRV.

Five of the viruses isolated (T-697, T 1082, T 1077, and T-704) reacted with none of the PVY group antisera tested (PVY, TEV, PeMV, PVA). Electron microscopic examination showed that these isolates have a length of 690-860 nm and are all of the flexible rod type, indicating that they belong to the Potato Virus Y group. Pinwheels found in thin sections of embedded leaf material give further evidence that the isolates belong to the PVY group. The reactions of the differential hosts used for Potato Virus Y (PVY) identification clearly indicated that these isolates are not PVY itself (Table 13). They were able to infect Datura stramonium, which is immune to PVY, and they did not produce local lesions on S. tuberosum x S. demissum A-6, as PVY would have.

More precise identification will require extensive serological tests using homologous and heterologous antisera, as well as antisera to a number of other viruses belonging to the PVY group. One member of this group, isolate T-697, has already been purified, and antiserum has been produced.

Conclusions

The results of this and other surveys show that PVY occurs frequently on tomato in Taiwan and other Southeast Asian countries, and demonstrate that AVRDC should consider incorporating PVY resistance into its heat tolerant tomato breeding lines. No commercial seed company is known to be currently breeding tomato for resistance to PVY. Since PVY is known to occur as several strains, it should be determined whether these can be differentiated from the Taiwan PVY isolates collected so far. Since PVY symptoms on tomato are fairly inconspicuous, a reliable screening method must be developed.

CMV, which has been reported to cause considerable yield loss in tomato, appears to occur almost as frequently on tomato in Taiwan as do ToMV and PVY. Although the number of CMV strains and the lack of

resistance genes in tomato and its wild relatives will make it difficult, resistance breeding should also be attempted for this virus.

Table 13. Differential host reactions of PVY and a group of five unknown virus isolates belonging to the potato virus Y group.

Host species	Symptoms[z]	
	PVY	Unknown virus isolates
Chenopodium amaranticolor	cL	-
Capsicum annum 'Yolo Y'	-	-
C. frutescens 'Tobasco'	M	-
Cucumis sativus	-	-
Datura metel	Vc,M	M
D. stramonium	-	Vc,M,Def.
Gomphrena globosa	-	-
Nicotiana glutinosa	Vc,M	Vc,M
N. sylvestris	Vc,M,N	M
N. tabacum 'Xanthi'	Vc,M	Vc,M
N. tabacum 'Samsun NN'	Mo	M
'White Burley'	M	M
Petunia hybrida	Vc,M	Vc,M
Physalis floridana	M,N	M
Solanum buberosum 'Kennebec'	nL,N	N,Y
S. tuberosum x S. demissum A-6	nL	-
S. demissum	nL,N	nL

[z] cL = chlorotic local lesions, M = mosaic, Def = leaf deformation, Vc = vein clearing, Mot = mottle, Bl = blistering, N = systemic necrosis, Y = yellowing, nL = necrotic local lesions.

Preliminary Survey of Tomato Viruses in Southeast Asia

Introduction

A survey of selected tomato production areas in the Philippines, Indonesia, and Malaysia was conducted in May of 1983 to determine which viruses are found there. The results of this and future surveys in southeast Asia will help determine which viruses should be considered in AVRDC's resistance breeding program.

Materials and Methods

The areas surveyed in the Philippines were at Los Banos and Tacloban, and those surveyed in Indonesia were in central Java (near Cianjur) and Sumatra (Medan, Padang). In Malaysia tomato leaf samples were only collected from one small tomato growing area near Kelang.

A total of 56 tomato leaf samples showing typical virus symptoms such as mosaic, mottle, yellowing, leaf deformation, leaf curl, stunt or bushiness were collected, dried over calcium chloride, and tested by ELISA (enzyme-linked immunosorbent assay) against antisera to ToMV, CMV, PVY and TLCV.

Both the gamma globulins and the enzyme conjugate of all antisera except PVY were used at a dilution of 1:500. The PVY gamma globulins and enzyme conjugates were used at a dilution of 1:1000.

Results

Although the results shown in Table 14 indicate that ToMV and TLCV are the most frequently detected tomato viruses in the Phillipines and Indonesia, TLCV was not detected in Malaysia.

CMV has so far been found only in the Philippines and Malaysia. When more areas are surveyed and more samples taken, however, CMV may also be detected in Indonesia, and TLCV in Malaysia. PVY, like ToMV, was present in all three countries.

Table 14. The occurrence of four common tomato viruses in the Philippines, Indonesia and Malaysia.

		Philippines		Indonesia		Malaysia
	Total	Los Banos	Tacloban	Java	Sumatra	Kelang
No. of samples collected	56	7	11	9	16	13
No. of samples infected with virus	46	5	9	9	10	13
No. of samples infected with ToMV	21	2	-	8	-	11
CMV	11	2	-	-	-	9
PVY	13	2	1	8	1	1
TLCV	21	2	8	2	9	-

Conclusions

The results of this survey are very similar to those of surveys conducted in Taiwan, where ToMV, CMV, PVY, and leafcurl virus have also been found. Breeding for resistance to ToMV, the most widespread tomato virus, is already underway at AVRDC, and resistance has been incorporated into the Center's heat tolerant breeding lines.

PVY has been found in the Philippines, Indonesia, and Malaysia, and has also been frequently detected on tomato in Taiwan. A number of pure isolates are being maintained, and attempts are being made to differentiate them. An inoculation and screening method is being developed, and a program to incorporate PVY resistance into tomato will be initiated in coooperation with AVRDC's plant breeders.

CMV, which causes considerable yield losses in Taiwan, has also been detected in the Philippines and Malaysia. A number of CMV isolates have been collected from tomato on Taiwan, and attempts are being made to classify them according to Marrou's differential host system. There are no reports in the literature, however, of any gene for CMV

resistance in tomato or any of its wild relatives. As an initial step for identifying resistance genes, wild relatives of L. esculentum will be screened for possible resistance to or tolerance of CMV.

Leafcurl virus has also been detected occasionally on tomato in Taiwan. A pure culture is being maintained at AVRDC on a susceptible tomato line, and preliminary tests are being conducted to establish whether the Taiwan leafcurl virus is the same as tomato yellow leafcurl virus (TYLCV) or tomato yellow dwarf virus (TYDV), both geminous viruses causing leafcurl symptoms on tomato. Materials with reported TYLCV resistance are also being tested through grafting for resistance to the Taiwan leafcurl agent. Routine mass screening and resistance breeding, however, should be conducted in countries such as Thailand or the Phillipines, where the virus appears to be endemic. Screening could then be done under natural infection in the field, rather than with the grafting or whitefly transmission tests that must be used in places like Taiwan, where the leafcurl virus occurs only periodically.

Evaluation of a Hairy-Leafed Tomato Accessions as a Source of CMV Resistance

A. Resistance to M. persicae, the vector of CMV

Introduction

Cucumber mosaic virus (CMV) is a non-persistent aphid transmitted virus. More than 60 species of aphids are able to transmit it, and more than 40 plant families are susceptible to infection. CMV occurs on tomato worldwide, often causing serious crop losses. Previous surveys have shown a high incidence of CMV on tomato in Taiwan. Insecticides, mineral oil, reflective mulches, and intercropping have all proven to be ineffective controls of CMV in the field. Nor has any source so far been found of resistance to or tolerance of CMV in tomato. The search for resistance is further complicated by the fact that CMV occurs as a number of strains.

Resistance to the vector has been considered as an alternate method of indirectly controlling the virus. In the present study aphid behavior was observed on hairy and smooth-leafed tomato lines.

Materials and Methods

The two tomato cultivars used were TK-70 and a hairy tomato, 'L 222'.Virus-free aphids (M. persicae Sulz) were reared on common cabbage (B. oleracea ssp. capitata) in an artificially lighted growth room. The density of hairs on the tomato leaf surfaces was assessed at three growth stages - when the first, fourth and sixth leaves were fully expanded. From each of ten plants a circular leaf piece of 0.44 cm^2 was removed with a corkborer at a point one-third of the way from the tip of the terminal leaf, and the number of hairs was counted under a binocular microscope.

Each of three groups of ten aphids was placed on the upper surface of the expanded first, fourth, and sixth terminal leaflets of a nonhairy tomato. After ten minutes the aphids were transferred individually to a hairy-leafed tomato, with only one aphid per plant.

The probing and walking times of each aphid were observed under a magnifying lens. A probing aphid could be recognized by antennae bent backwards across the entire length of its body.

Results and Conclusions

Results are shown in Table 15. At each growth stage there were significant differences in hair number, aphid probe number, and total probe time between the hairy accession and the non-hairy control. Average probe duration, however, did not vary significantly between the hairy and non-hairy tomatoes.

Leaf position did have a small effect on hair number and on aphid behavior. The only interaction, however, between leaf position and hairiness was in hair number ($F=3.45^{*}$ for 2 and 54 df.). There was no interaction between leaf position, hairiness, and aphid behavior. The main effect of hair versus no-hair (averaged over all three leaf positions) explained most of the observed variations in the six sets of observations on each leaf.

Any differences in CMV infectivity under field conditions will most likely be due to probe numbers and total probe time, and not to the average probe duration.

Table 15. Hair density of hairy and non-hairy tomato and its relation to the feeding behaviour of aphids.

Leaf position	Hair No. (per 44.18 mm^2)	Total Probe time (Min)	Probe No.	Average Probe duration[z] (Min)
Leaf 1				
Hairy	523	1.85	0.97	1.97
Non-hairy	56	4.16	2.04	1.90
Leaf 4				
Hairy	545	1.03	1.61	1.60
Non-hairy	89	2.60	3.74	1.50
Leaf 6				
Hairy	378	0.47	1.03	1.53
Non-hairy	32	1.67	2.53	1.50
Factor	Total value of difference between hairy and non-hairy leaves and significance for each parameter[y]			
Leaf 1	12.91***	3.92***	3.99***	0.41 NS
Leaf 4	12.60***	3.61***	5.82***	0.22 NS
Leaf 6	9.54***	2.53*	4.46***	0.03 NS
df.	59	179	179	17

[z] Values are weighted average for each of the 3 groups of 10 aphids.
[y] NS = $P \geq 0.10$, * = $P < 0.05$, *** = $P < 0.001$.

Only leaves one, four, and six were tested in this study. Since a significant interaction was found between leaf position and hair number, and since there were far fewer hairs counted on the sixth leaf than on the lower leaves, hair density at the various leaf positions should be investigated more thoroughly. This may play a role in the transmission of CMV by aphids under field conditions.

B. Resistance to CMV

Materials and Methods

The hairy accession's resistance to CMV was assessed in 23 plants grown in the field under conditions of natural infection.

Leaf samples showing such typical CMV symptoms as fern leaf, shoestring, mosaic, or undersized leaves were collected at harvest time and tested by ELISA for CMV, ToMV, and PVY.

Results

The hairy-leafed tomato does not carry resistance to CMV. Of the 23 leaf samples collected, 16 were found to be infected with CMV, 22 with ToMV and 6 with PVY. In several samples all three viruses were found together.

Conclusions

It seems obvious that despite the lower total probing time and the lower number of probes observed on the hairy tomato, the average probe duration is still sufficient to assure transmission of CMV by aphids under conditions of natural infection. Since the sixth leaf was found to have significantly fewer hairs than the first leaf, however, it is possible that under natural conditions the hairy tomato could become infected with CMV at a later stage than a non-hairy tomato, and thus have a lower rate of infection. This must be confirmed, though, by field tests comparing CMV infection rates on hairy and non-hairy tomatoes.

Tomato Entomology

Evaluation of Segregating Populations for Fruitworm Resistance

Introduction

Polyphagous insects Heliothis armigera and Spodoptera exigua are both important pests of tomato in Southeast Asia. Both attack foliage when in their early larval instars, and fruit when in their later instars. They cause the most damage by feeding on fruits. In 1980 the fruitworm resistance of two Lycopersicon hirsutum f. glabratum accessions which had shown resistance to other lepidopterous pests at North Carolina State University was confirmed at AVRDC. Since these accessions are not of a cultivated type, and have poor horticultural characteristics, AVRDC's tomato breeder then crossed them with cultivated tomato to breed high yielding tomato cultivars with fruitworm resistance. In 1983 the backcross progeny and their parents were tested to learn more about the inheritance of their resistance, and to select resistant entries with good horticultural characteristics.

Materials and Methods

In October of 1982, 1,070 segregating materials (BC_1F_2) were transplanted which had been selected from an earlier screening in 1981-82. These materials had shown fruitworm resistance, but some of their horticultural characters still resembled those of the L. hirsutum parent.

The seedlings were transplanted 2 m apart on 1.5 m wide beds, and raised according to standard AVRDC cultural practices, except that no insecticide was applied. To augment the ambient insect pest population, laboratory raised fruitworm pupae were released periodically. Each plant was evaluated twice by counting the number of damaged fruits and the number of total fruits.

Entries selected on the basis of lower fruitworm damage were further evaluated by the plant breeder for horticultural traits, and the materials chosen were then backcrossed to the recurrent parent for improvement of their yield and fruit size.

In June, 500 seeds of 10 backcrosses (B_2F_2) were planted individually in clay pots and raised in a greenhouse. When plants were eight weeks old they were evaluated for resistance to S. exigua, which infests tomatoes in the same manner as does H. armigera. One leaf from

each plant was placed in a petri dish lined with moist filter paper. Five first instar larvae of S. exigua were then placed on each leaflet. The mortality rate was recorded periodically over two days, and plants with higher levels of insect mortality were selected for further testing.

Resistant plants selected from the greenhouse experiment were decapitated in late September, and were transplanted to the field in early October. In late December they were evaluated for fruitworm resistance by having their leaves exposed to S. exigua larvae. Larval mortality rates were recorded for each sample, and the percentage of damaged fruits was calculated for each plant. On the basis of these two evaluations, but with greater emphasis placed on the leaf bioassay test, plants were selected for further improvement of their horticultural characters.

Results and Conclusions

In the field test of 1,070 entries, 41 entries belonging to nine backcrosses were free of fruitworm damage. On the basis of their desirable horticultural traits, several entries were selected for further backcrossing with the recurrent parent.

Fifty plants from each backcross were evaluated in a greenhouse by leaf bioassay, and 51 plants were selected which showed relatively high insect mortality rates. Since published reports indicate that fruitworm resistance increases at longer photoperiods, the 51 entries were planted in October and evaluated in December, when the photoperiod at AVRDC is less than 12 hours. Of the 51 entries which had been selected on the basis of their resistance under summer's longer photoperiods and another 160 backcross entries which had not been evaluated in summer, only 3 showed insect mortality rates comparable to that of the resistant parent. All three have certain undesirable horticultural characteristics, and all three are being evaluated by AVRDC's plant breeder. They will also be further evaluated for fruitworm resistance in the seedling stage, and those carrying resistance will be backcrossed to recurrent parents for further improvement of their horticultural characteristics.

Additional Sources of Tomato Fruitworm Resistance

Introduction

Published reports indicate that PI 134417, an L. hirsutum f. glabratum which has elsewhere shown resistance to fruitworm and certain defoliaters, is most resistant to fruitworm at longer photoperiods. Since in Taiwan, as in much of Southeast Asia, tomato is grown in the autumn and winter months, and thus under shorter photoperiods, it is important to find additional germplasm which remains resistant under such short photoperiods.

Initial screening conducted in 1980-81 resulted in the identification of 17 resistant accessions. Two Lycopersicon hirsutum f. glab-

ratum accessions, 76W-P1134417-A and 77W-134417-1, were the least damaged. Since they had also shown resistance in the USA to other insect pests, it was decided to utilize them in AVRDC's resistance breeding program. Because the two L. hirsutum accessions had proven less resistant at shorter photoperiods, other accessions were also rescreened to confirm their resistance.

Materials and Methods

Twenty accessions (including three susceptible checks) were tested in the field in the spring of 1983. Seeds of each accession were sown in 50 x 33 x 7 cm plastic flats. On February 24, when the seedlings were four weeks old, they were transplanted in a single row on 1.5 m beds. Three replicates of each entry were arranged in an RCB design. Standard AVRDC cultural practices were followed, but no insecticides were used. In May each entry was evaluated twice for fruitworm resistance. Percentages of damaged fruit were analyzed by Duncan's Multiple Range Test.

Results

Four of the 20 entries did not bear fruit until May, and were not evaluated for fruitworm resistance. Insect population and fruit damage was higher in the first observation than in the second, and only data from the first observation were used for resistance evaluation. Results are summarized in Table 1.

All 13 accessions which had shown resistance in 1980-81 also proved resistant in 1983. All resistant accessions are wild relatives of cultivated L. esculentum.

Table 1. Resistance of selected tomato accessions to tomato fruitworm.[z-x]

AVRDC accession no.	Identification	Fruit damage %
L139	Lycopersicon pimpinellifolium	3.7d
L177	L. esculentum V. cerasiforme	1.9d
L181	L. esculentum V. cerasiforme	2.0d
L593	L. peruvianum	2.7d
L632	L. pimpinellifolium	0.6d
L633	L. pimpinellifolium	3.4d
L667	L. pimpinellifolium	1.7d
L675	L. pimpinellifolium	3.5d
L677	L. pimpinellifolium	1.3d
L680	L. pimpinellifolium	0.6d
L690	L. peruvianum	3.1d
L691	L. esculentum L. pimpinellifolium	4.3d
L697	L. pimpinellifolium	4.5d
L34	L. esculentum	19.9c
L124	L. esculentum	31.0b
L43	L. esculentum	50.0a

[z] Transplanting date: February 24, 1983.
[y] Observation date: May 10.
[x] Data are means of three replicates. Means followed by the same letter are not significantly different at the 5% level.

Conclusions

Thirteen additional wild tomato acessions have shown moderate levels of resistance to tomato fruitworm. Their resistance will be characterized in 1984 before they are utilized in AVRDC's breeding program.

Evaluation of Chemical and Biological Controls of Tomato Fruitworm

Introduction

Insecticides are widely used on vegetable farms throughout Southeast Asia. Since insect pests often develop resistance to them, especially to the ones used most frequently, new compounds or combinations of compounds must be screened for effectiveness before the target pest becomes resistant to those presently being used. AVRDC has an ongoing project to screen insecticides for the control of various insect pests. Described here are the results of one such test conducted in 1983.

Materials and Methods

The procedures used were identical to those described in AVRDC's publication "Vegetable Pest Control: Insecticide Evaluation Tests". Each test included nine insecticides and one untreated check. The chemicals were selected on the basis of their efficacy in controlling the target pests or related pests in previous tests at AVRDC or elsewhere. An effort was made to include chemicals with a mode of action different from that of currently used insecticides. Each chemical was sprayed weekly on 4.5 m x 3 m plots, and each treatment had four replicates.

Efficacy was evaluated when the insect population was high. The percentage of damaged fruits in a 10 plant sample from each plot was recorded at periodic intervals. At harvest each plot's marketable yield was determined, and all data was analyzed by Duncan's Multiple Range Test.

Results and Conclusions

Insecticide efficacy and marketable yields are shown in Table 2. Deltamethrin and methomyl gave the best control of tomato fruitworm. Except for diflubenzuron, all other insecticides also reduced fruitworm infestation from the levels recorded for the untreated check. *B. thuringiensis* alone did not give satisfactory control. The good control given by a mixture of *B. thuringiensis* and deltamethrin is more attributable to the deltamethrin than to the *B. thuringiensis*. Diflubenzuron did not control tomato fruitworm, and produced no synergistic effects when mixed with triazophos; triazophos alone was as effective as the mixture of triazophos and diflubenzuron. Nor did diflubenzuron have any

synergistic effects when mixed with methomyl.

None of the insecticides had a clearcut effect on fruitworm infestation or on marketable yield. Infestation levels were low and constant, and fruit was often damaged by heavy rains.

Table 2. Effectiveness[z-t] of selected insecticides in controlling tomato fruitworm.

Insecticides	Rate kg ai/ha	Damaged fruits (%)	Marketable yield (t/ha)
Deltamethrin 2.8EC	0.025	0.51d	50.4a
B. thuringensis (Bt)	0.5	3.51b	48.6a
Deltamethrin + Bt	0.025+0.5	0.24d	48.6a
MK936 0.36SL	0.018	2.07c	36.5bc
Diflubenzuron 25WP	0.075	4.65a	44.8ab
Triazophos 40EC	0.25	2.36c	35.6bc
Diflubenzuron + triazophos	0.075+0.25	2.31c	32.2c
Methomyl + diflubenzuron	0.5+0.075	0.65d	45.4ab
Methomyl 90WP	0.5	0.84d	46.6a
Control		4.78a	48.2a

[z] Cultivar: TK 70.
[y] Transplanting date: 11/9/82.
[x] Insecticides applied: 12/14/83, 12/21, 12/28, 1/4/83, 1/11, 1/18, 1/25, 2/1, 2/8, 2/15, 2/22, 3/1, and 3/8.
[w] Observation date: 2/28/83.
[v] Harvest date: 3/12/83.
[u] Data shown are means of four replicates. Means in each vertical column followed by the same letters are not significantly different at the 5% level.
[t] Plot size: 15 sq.m.

Tomato Physiology

The Ability of Various Growth Regulators to Induce Fruit-Set in Parthenocarpic and Non-Parthenocarpic Tomatoes

Introduction

Although naturally parthenocarpic tomatoes have been shown to possess some level of heat tolerance, the application of 4-chlorophenoxyacetic acid (CPA) has resulted in even better fruit set at high temperatures. AVRDC scientists have also shown that high temperatures reduce the endogenous level of auxins and gibberellins in the reproductive organs of two lines of non-parthenocarpic tomatoes. This study was designed to investigate the effects of plant growth regulators on the fruit set and the fruit yield and quality of parthenocarpic and non-parthenocarpic tomatoes at various temperatures.

Materials and Methods

Cultivars CL 1131-0-0-43-8-1, TK 70, Severianin, and (SxP)-0-4 were sown on May 11, 1983, and transplanted to the field on June 13. All plants were pruned and maintained as double stems. The second to the sixth cluster were treated with CPA (100 mg/l), GA_3 (400 mg/l), or 0.02% Tween 20 by dipping the entire cluster into the solution. Plants were treated twice a week, and only the clusters with at least one newly opened flower were treated. Plants were harvested on August 3. An RCB design was used with three 20-plant replicates. A similar experiment using CL 1131-0-0-43-8-1, TK 70, Severianin, Pt 944 H_6-(2)-3-0, and PT 953 V-1-0 was sown on September 30, transplanted to the field on October 17, and harvested on December 28, 1983.

Results

In the summer experiment, neither CL 1131-0-43-8-1 nor TK-70 were able to set any fruit without growth regulators, but Severianin and (SxP)-0-4 were (Table 1). Application of either CPA or GA_3 substantially increased the fruit set of CL 1131-0-0-43-8-1, but CPA was much more effective than GA_3 in increasing fruit size and yield. Only CPA was able to increase the fruit set and yield of TK 70. GA_3 was able to increase the fruit set and yield, but not the fruit size, of both

Severianin and (SxP)-0-4. CPA increased the fruit size of Severianin, and increased the fruit set of both Severianin and (SxP)-0-4. Applications of CPA or GA_3 resulted in seedless fruits for both parthenocarpic and non-parthenocarpic tomatoes. With or without the application of CPA or GA_3, Severianin had a high percentage of abnormal fruits. This was probably due to the presence of a rosette structure on the end of the blossom. Applications of GA_3 tended to reduce blossom pericarp splitting on parthenocarpic tomatoes. Applications of CPA, on the other hand, tended to increase carpel number. Path coefficient analysis revealed that the most important factor determining the yield of small fruited varieties such as CL 1131-0-0-43-8-1 was fruit size, but that fruit set rate and fruit number were more important in determining the yields of such large-fruited entries as Severianin and (SxP)-0-4.

Table 1. Effect of growth regulators on fruit-set, fruit yield, fruit number, fruit size, and seed number; summer, 1983.

Entry	Chemical	Fruit-set (%)	Fruit yield (g/5 clusters)	Fruit no./ 5 clusters	Fruit size (g/fruit)	Seed no. (/fruit)
CL-1131-0-0-43-8-1	CPA	76a[z]	793a	27.2b	29.0e	0
	GA_3	78a	367c	33.5a	11.1f	0
	Check	1g	0d	0.0g	-	-
TK-70	CPA	30de	544b	6.2def	88.4a	0
	GA_3	30de	38d	4.1fg	10.4f	0
	Check	0g	0d	0.0g	-	-
Severianin	CPA	38cd	820a	9.4cde	87.5a	0
	GA_3	50b	747a	14.4c	53.2c	0
	Check	15f	321c	4.4c	72.5b	0
(SxP)-0-4	CPA	23ef	431bc	5.4def	80.7ab	0
	GA_3	41bc	409c	10.0cd	40.7d	0
	Check	4g	84d	0.9fg	89.1a	0

[z] Mean separation within columns by DMRT, 5% level.

In the fall-winter experiment, fruit set and fruit yield were high for all entries even without the application of growth regulators - more than 60% and 1.2 kg per five clusters, respectively. Neither CPA nor GA_3 greatly improved fruit set under these favorable conditions. Fruit yield and fruit size of both PT 944 H_6-(2)-3-0 and PT 953 V-1-0, however, were slightly increased by applications of CPA. Those plants which had not been treated with growth regulators had more seeds - from 24 to 125 per fruit. The fruit of plants treated with CPA had fewer seeds than did the fruit of those treated with GA_3.

Conclusions

Both CPA (auxin-type hormone) and GA_3 are important for fruit set and yield at high temperatures. Parthenocarpic tomatoes may be able to produce levels of endogenous auxin and gibberellin high enough to overcome heat stress, and to maintain some level of fruit set and yield even at high temperatures.

Effect of High Temperatures upon the Membrane Permeability and Enzyme Inactivation of Anthers and Pistils

Introduction

Heat-induced membrane disruption and enzyme inactivation have long been considered important factors contributing to reductions in growth and yield. High temperatures also reduce ovule viability, and pollen production and viability. When plant tissue is injured by high temperatures, membrane permeability is increased and electron transport decreased. This makes it possible to assess the relative heat damage by measuring the amount of electrolyte leakage or conductivity. This study investigated the effects of high temperatures upon the membrane permeability and enzyme inactivation of both anther and pistil by measuring electrolyte leakage and 2,3,5-triphenyltetrazolium chloride (TTC) reduction.

Materials and Methods

Four entries (L 123, L 124, L 4841, and CL 1131-0-0-38-4-0) were transplanted to the field on June 3. Newly opened flowers were collected from the field before 09:00 on August 15, and anthers and pistils were separated and incubated in 50° C deionized water for 1.5, 3, 5, 7, 9, 12, 15, 30, 60, and 120 minutes. Each treatment consisted of five anther cones or ten pistils in 10 ml water. After incubation the liquids were measured for electrolyte leakage with a YSI conductance meter, and reproductive tissues were measured for TTC reductivity as described by Onwueme (1979).

Results

Reductive capability decreased at longer incubation periods, but electrolyte leakage increased (Table 2). Both TTC and conductivity

Table 2. Comparison of electrical conductivity of leachates and TTC reduction of anthers and pistils after various incubation periods at 50°C.

	EC (mu/cm/g dry wt.)				TTC (OD530/g dry wt.)			
	5 min	15 min	30 min	60 min	5 min	15 min	30 min	60 min
Anther								
L 123	2.32	3.22	4.90	7.77	153	129	110	14
L 124	2.19	5.00	6.59	14.89	163	147	114	5
L 4841	3.53	4.77	7.84	10.51	150	154	92	14
CL 1131-0-0-38-4-0	2.00	2.63	3.73	11.72	129	112	84	10
Pistil								
L 123	2.92	5.51	7.33	9.92	60	134	52	26
L 124	3.60	4.69	7.03	11.38	65	151	53	32
L 4841	3.74	5.33	10.62	11.92	66	128	20	16
CL 1131-0-0-38-4-0	3.26	7.45	11.08	14.34	82	120	41	10

tests showed similar rates of heat-induced mortality. When plants were grown under hot summer conditions both anther and pistil of different varieties survived a maximum of about 15 minutes at 50° C. In a previous report, leaf tissue was also reported able to withstand about 15 minutes at such temperatures. The pistils of both L 123 and CL 1131-0-0-38-4-0 had more electrolytes than did the anthers, suggesting that the cell membrane in the pistils of both lines was more easily damaged by high temperatures than was the cell membrane in the anthers. The anthers of L 124 and L 4841 had a higher reductive capability, which suggests that the enzyme they contain might be more heat-stable.

Conclusions

Although previous suggestions that TTC reduction and electrolyte conductivity could be used to test heat tolerance in tomato had been based primarily on work done with leaf tissue, much of the damage caused by high temperatures can be traced to disruptions of the reproductive growth processes. Both anther and pistil seem able to withstand similar lengths of time at high temperatures. Varietal differences in TTC and conductivity tests of both anther and pistil at 50° were not great enough to justify their use as measures of heat tolerance. Contrary to what others had concluded from experiments from leaf tissue, plants did not seem able to acclimate to high temperatures.

Evaluation of Optimum Pollen Storage Conditions

Introduction

Pollen production is easily affected by high temperatures. Less is produced, and that which is produced is usually non-viable. Viable pollen produced under favorable conditions could be stored, though, and used for later pollination of flowers produced under unfavorable conditions. This study attempted to determine the optimum conditions for storing pollen.

Materials and Methods

Pollen from cultivars L 123, L 143, L 1104, and CL 1131-F_5-43-8-1 was collected in March of 1983, and pollen from L 124, L 229, L 387, L 229 x L 1076, L 229 x L 125, L 1076 L 2991, and L 1076 was collected in June. Pollen from the first batch was kept in capsules, placed in flasks with silica gel, and stored at -20° C, 4° C, or 25° C for 0, 3, 8, or 21 weeks. Pollen from the second batch was stored at -20° C for 0, 6, and 12 weeks. Pollen was gradually brought to ambient temperature and humidity before being tested for viability.

Results

A liquid medium consisting of 20% sucrose and 100 ppm H_3BO_3 main-

tained the best pollen germination. Adding ions of Ca^{-2}, Mg^{+2}, or Mn^{+2} did not further improve viability. As previously reported, there were significant varietal differences in pollen germination. Under cool season conditions heat tolerant selection CL 1131-F_5-43-8-1 showed a low level of pollen germination, but that of heat tolerant selection L 1976 was the highest.

Regardless of storage temperature, pollen viability decreased rapidly during the first three weeks (Table 3). After 21 weeks of storage at 25, 4, and -20° C, viability remained at 2%, 13%, and 35% of the control's, and at 0.4%, and 5.7% of the total possible. Initial pollen viability was generally low for L 124, L 229, L 387, and CL 1131-F_5-43-8-1. The initial viability of pollen from the hybrids was generally high. After 12 weeks of storage at -20° C, viability was 6 to 29% of the control's (Table 4), and 2.7 to 14.3% of the total possible.

Table 3. Pollen germination rate[z] (%) after storage at various temperatures.

Storage duration (weeks)	25°C	4°C	-20°C
0	16.4a[y]	16.4a	16.4a
3	2.0b	5.8b	7.3b
8	1.6bc	1.4c	1.0c
21	0.4c	2.4c	5.7b

[z] Mean of 3 replicates for L 124, L 229, L 387 and CL 1131-F_5-43-8-1.
[y] Mean separation within columns by DMRT, 5% level.

Table 4. Pollen germination rate (%) after storage at -20°C.

Entry	Weeks in storage 0	6	12
L 3690xL 387	9.3c[z]	4.1b	2.7b
L 299xL 1076	46.7ab	6.4b	2.9b
L 299xL 125	33.3b	10.8ab	4.6b
L 1076xL 2991	37.8b	19.6a	8.0ab
L 1076	64.7a	11.2ab	14.3a

[z] Mean separation within columns by DMRT, 5% level.

Conclusions

Even when stored at low temperatures and low humidity, pollen quickly loses its viability. Whether that which does remain viable can evoke fruit set at high temperatures has yet to be determined.

The Effect of Respiration Inhibitors and Uncouplers on Plant Height and Fresh Weight

Introduction

Root respiration must be maintained if the plant is to survive under flooded conditions. The root respiration of several flood tolerant species has been shown to be largely cyanide resistant. The classical cyanide-sensitive electron transport system coupled to phosphorylation is not operating, and instead the alternate pathway is operating, which branches from the classical pathway, and can be inhibited by hydroxamic acid (SHAM). This study was designed to investigate the effect of an inhibitor of the cytochrome pathway(KCN), an uncoupler of phosphorylation [dinitrophenol(DNP)], and an inhibitor of the alternate pathway (SHAM) on the growth response of flooding tolerant and flooding sensitive tomatoes.

Materials and Methods

Twenty-five-day-old seedlings of selections L 123, L 124, L 166-1, L 275, L 387, L 3040, and CL 1131-0-0-38-4-0 were transferred to an aerated water culture of ¼ strength Hoagland's solution. After one week the Hoagland's solution was changed to full strength. The 2,4-DNP treatment was maintained at 10 mM, the KCN treatment at 5mM, and the SHAM at 2 mM. One group of plants was not treated with any chemicals. The roots of another group were not treated with chemicals, but they were bubbled with N_2 gas. Plants were treated for five days. Each treatment was replicated five times with three plants per treatment. Shoot fresh weight was measured two weeks after the completion of the treatment.

Results

All chemicals tended to reduce plant growth. Aeration with N_2 gas also reduced plant growth, but not as drastically as the chemicals did (Table 5). The height of plants treated with chemicals or bubbled with N_2 gas averaged about 71% that of the control, and their fresh weight averaged about 44% that of the control. Small varietal differences were found in growth responses after chemical or N_2 treatment.

Conclusions

Varietal differences in growth response to inhibitors or uncouplers of respiration did not correspond well with actual flooding tolerance. Flooding tolerance may depend more upon the ability of the plant to shuttle air from the shoot to the root than upon which differential pathway its electron transport system utilizes.

Table 5. Growth response of tomato whose roots have been treated with respiration inhibitors and a respiration uncoupler.

	Top height (cm/plant)	Fresh weight (g/plant)	Height ratio (% of control)	Weight ratio (% of control)
Main-plot (treatment)				
Control	38.1a[z]	17.1a	-	-
DNP	26.5b	6.1c	70.2ns	36.0b
KCN	25.6b	6.4c	66.7	37.7b
SHAM	27.5b	7.3bc	77.0	42.4b
N_2 bubbling	29.3b	9.6b	71.2	59.9a
Sub-plot (entry)				
L 123	32.0a	10.2ab	64.7cd	34.7c
L 124	24.6b	8.7abc	76.8ab	47.1ab
L 166-1	31.2a	9.6abc	61.7d	49.0a
L 275	24.7b	8.2bc	73.3bc	38.6bc
L 387	32.5a	10.0ab	85.2a	47.7ab
L 3040	35.2a	11.1a	77.7ab	45.5ab
CL 1131-0-0-38-4-0	25.8b	7.4c	59.4d	45.2ab
Interaction MP x SP	ns	ns	ns	ns

[z] Mean separation within columns by DMRT, 5% level.

Chinese Cabbage Breeding

Evaluation of New Germplasm for Heat Tolerance

Introduction

New accessions received in 1983 were evaluated for heat tolerance, and a confirmatory evaluation was made of accessions which had been tentatively identified as heat tolerant in 1982. Promising entries from these tests could serve to broaden the genetic base of AVRDC's breeding program.

Materials and Methods

Six untested accessions were compared with heat tolerant Hybrid No. 62 in a two-replicate trial sown on April 20 and transplanted on May 5. An RCB design was used, and each 6 m^2 plot was worked into 4 m double-row beds with 40 cm between plants and 50 cm between rows.

Five accessions which had tentatively been identified as heat tolerant in 1982 were compared again with standard check Hybrid No. 62. This trial was sown on April 20 and transplanted on May 9. Experimental design and plot specification were similar to those described above, except that three replications were used instead of two.

Results

Only two of the new accessions (B801 and B804) yielded harvestable heads. Of the two, B 801 was more heat tolerant, and had a higher heading rate. Although its harvest rate and yield were comparable to those of Hybrid No. 62 (Table 1), its heads were less compact, and it also appeared to be slightly more susceptible to soft rot. The difference in susceptibility may not be significant, however.

Of the five accessions that were retested, only three (B775, B794, and B795) proved to be heat tolerant. Their marketable yields were similar to those of Hybrid No. 62 (Table 2). Although slightly lower yielding than the other accessions, B775 appeared to be the most heat tolerant; its heading rate and earliness were similar to those of Hybrid No. 62. Its head weight was significantly lower than that of the other entries, but its heads were more compact. Lines B794 and B795 had slightly larger heads than other entries, but their heads were significantly less compact, and both accessions tended to be later maturing.

Table 1. Yield and other horticultural characteristics[z] of new accessions evaluated for heat tolerance at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity[y] (DAT)	Head Weight (g)	Harvest rate (%)	Heading rate (%)	Solidity (g/cc)	Soft rot (%)
B801	21	43	637	100	100	0.57	8
B804	6	-	859	22	80	0.48	12
Hybrid No. 62 (Check)	22	43	673	100	100	0.73	2

[z] Figures are means of two replications; since other entries gave no yield whatsoever, no statistical analysis was carried out.
[y] DAT = days from transplanting to 50% plot harvest. Since it did not attain 50% harvestable heads no figure is given for B804.

Table 2. Yield and horticultural characteristics[z] of accessions reevaluated for heat tolerance at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity[y] (DAT)	Head Weight (g)	Harvest rate (%)	Heading rate (%)	Solidity (g/cc)	Soft rot (%)
B775	21	39 b	671 b	95	100	0.83 a	0.7
B794	25	43 ab	902 a	78	93	0.57 c	1.0
B795	22	45 a	866 a	59	85	0.44 d	9.0
Hybrid No. 62 (check)	25	39 b	814 a	85	100	0.75 b	1.0
CV (%)	16	5	8	9	13	5	58

[z] Means followed by same letter are insignificantly different.

Conclusions

New accessions B775, B794, B795, and B801 were found to be heat tolerant, and had yields similar to those of Hybrid No. 62. To determine whether their germplasm might be useful in other ways, they should be further evaluated for disease resistance and other characteristics.

Combining Ability Trials

Introduction

The search continued for hybrid combinations which would outperform

Hybrid No. 62. Several combinations selected from last year's combining ability trials were retested against Hybrid No. 62 in the summer of 1983.

Materials and Methods

Three groups of hybrids were compared to Hybrid No. 62. The first had seven entries, the second eight, and the third ten. Each was planted in three trials:

Trial no.	Sowing Date	Transplanting Date
I	May 20	June 9
II	June 20	July 11
III	July 20	August 11

All trials followed an RCB design with two replications. Each 6 m^2 plot consisted of a double-row 4 m bed with 40 cm between plants and 50 cm between rows.

Results

Table 3 shows the yield and selected horticultural traits of three combinations selected from Group A, whose entries were from 1982's CAT-II test. Although none outyielded Hybrid No. 62, they were similar in all other respects; selections had been made on the basis of head characteristics and overall appearance. Due to local preferences, similarities to local cultivars were also used as selection criteria. Levels of soft rot incidence were negligible, and #82-60R had the highest rate of damage (2%).

Table 3. Yield and other horticultural characteristics[z] of selected combinations from Group A combining ability trials AVRDC in the summer of 1983.

Entry	Yield[y] (t/ha)	Maturity (DAT)	Growth (kg)	Head Weight[x] (%)	Harvest rate (%)	Heading rate (%)	Head shape Index	Solidity (g/cc)
82-50R	18	36	1.2	652	74	99	1.3	0.58
82-60R	17	36	1.1	549	77	97	1.4	0.59
82-46R	16	36	1.1	570	74	96	1.5	0.56
Hybrid No. 62 (check)	18	36	1.1	555	97	100	1.3	0.57
CV (%)	19	3	9	11	20	8	7	12

[z] All figures are averages of three trials.
[y] Due to the damage done to root systems by flea beetle larvae, yields in Trial III were generally low.
[x] In Trial I heads of #82-50R were significantly larger than those of Hybrid No. 62.

Only one of the seven combinations tested in Group B (derived from the 1982 CAT-III test) was selected for further consideration. Its yield and other horticultural characteristics were similar to those of Hybrid No. 62 (Table 4), but its overall appearance (i.e. smooth, untextured, thick, dark green leaves) was closer to that of preferred local cultivars than was Hybrid No. 62's. Soft rot incidence was negligible; all entries had an average infection rate of less than 1%.

Table 4. Yield and other horticultural characteristics[z] of selected combinations from Group B combining ability trials held at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity (DAT)	Growth (kg)	Head Weight (%)	Harvest rate (%)	Heading rate (%)	Head shape Index	Solidity (g/cc)
82-82	21	37	1.4	666	92	99	1.3	0.54
Hybrid No. 62 (check)	23	36	1.4	712	100	100	1.2	0.59
CV (%)	14	4	6	12	17	4	6	12

[z] All figures are averages of three trials.

Two of eight entries were selected from Group C, which had been derived from 1982 CAT-VI trials. None of them significantly outperformed Hybrid No. 62 (Table 5); they were selected primarily for their resemblance to popular local varieties. Both combinations had smooth, dark green leaves, and uniformity and vigor superior to that of local tropical cultivars. Although differences in head size were insignificant, the selected combinations tended to produce heads slightly smaller than those of Hybrid No. 62. Levels of soft rot incidence in these trials were negligible; all entries had an average infection rate of less than 1%.

Table 5. Yield and other horticultural characteristics[z] of combinations selected from Group C combining ability trials held at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity (DAT)	Growth (kg)	Head Weight[y] (%)	Harvest rate (%)	Heading rate (%)	Head shape Index	Solidity (g/cc)
82-156	17	36	1.2	530	97	100	1.2	0.55
82-157	18	37	1.2	576	94	100	1.2	0.56
Hybrid No. 62 (check)	20	36	1.3	657	98	100	1.2	0.55
CV (%)	13	0.7	7	10	12	0	6	12

[z] All figures are averages of three trials.
[y] Hybrid No. 62 had significantly larger heads only in Trial II.

Conclusions

None of the hybrid combinations tested in 1983 significantly outperformed Hybrid No. 62; the six chosen were selected mainly for their resemblance to local cultivars. Some will be further improved for uniformity, and others will be entered in 1984's advanced yield trials.

Advanced Yield Trials

Introduction

Three hybrid combinations selected from advanced yield trials conducted in the summer of 1982 had consistently outperformed check varieties Hybrid No. 62 and WWCC in all three trials. They also matured as early as or earlier than Hybrid No. 62. To confirm their outstanding performance, they were included in a series of advanced yield trials conducted in the summer of 1983.

Materials and Methods

Eight separate trials were conducted:

Trial No.	Sowing Date	Transplanting Date
I	April	May 9
II	May 5	May 26
III	May 20	June 9
IV	June 3	June 23
V	June 20	July 25
VI	July 5	July 25
VII	July 20	August 25
VIII	August 5	September 1

The three selected hybrid entries and a fourth which had done relatively well in 1982 were compared with standard checks Hybrid No. 62 and WWCC. An RCB design was used with four replications. Each 12 m^2 plot consisted of two double row beds 4.0 m long with 40 cm between plants and 50 cm between rows.

Each trial was analyzed individually for yield and selected horticultural characteristics. Combined analyses were then made to determine the stability of each entry's performance. The Eberhart and Russell model (1966) was used to compare stability (see Eberhart, S.A. and W. A. Russell. 1966. Crop Science 6:36-40).

Results

Table 6 shows the overall mean yields of each entry. Hybrids 80-32 and 80-37 yielded consistently higher than other entries, the only

Table 6. Overall mean yields (t/ha)[z] in eight advanced yield trials held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean	Percent of Hybrid No. 62
	I	II	III	IV	V	VI	VII	VIII		
81-29	26.7a	18.3ab	14.5cd	11.0c	26.9ab	21.4a	15.5b	24.7	19.9	105
80-37	25.4ab	18.7a	18.2a	16.3a	29.7a	22.1a	19.2a	23.8	21.7	115
80-32	23.8ab	14.7de	17.1ab	15.2ab	28.4a	20.4a	18.9a	24.3	20.4	108
81-39	22.8ab	16.8bc	14.0d	9.6cd	23.3b	12.0b	16.6ab	25.2	17.5	92
Hybrid No. 62 (check)	24.1ab	16.4cd	16.0bc	13.9b	25.6ab	19.1a	14.0b	22.2	18.9	100
WWCC (check)	22.2b	13.0c	15.8cd	7.6d	17.7c	13.8b	13.6b	26.3	16.2	86
CV (%)	10	7	8	11	10	16	12	15	-	-

[z] Means followed by the same letter are insignificantly different.

Table 7. Days to maturity[z] of various entries across eight advanced yield tests held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean
	I	II	III	IV	V	VI	VII	VIII	
81-29	38b	34b	32b	42bc	35b	35b	39b	41b	37
80-37	38b	34b	32b	40c	35b	35b	39b	41b	37
80-32	38b	34b	32b	39c	35b	35b	39b	40b	36
81-39	38b	36b	32b	45b	35b	41a	40b	46a	39
Hybrid No. 62 (check)	38b	34b	32b	40c	35b	35b	39b	41b	37
WWCC (check)	41a	46a	35a	51a	45a	42a	46a	48a	44
CV (%)	2	5	0	6	2	4	3	3	-

[z] Expressed as days from transplanting to 50% plot harvest; means followed by same letter are insignificantly different.

exception being 80-32 in Trial II. Selection 80-37 yielded about 15% more than high yielding check Hybrid No. 62, and 80-32 yielded 8% more. Entry 81-29 also performed slightly better than Hybrid No. 62, but the differences were in many cases insignificant.

In each trial hybrids 80-32, 80-37, and 81-29 matured as early as Hybrid No. 62 (Table 7). WWCC was the latest of all entries, and matured an average of five to eight days later than any other.

Hybrid 81-39 and check WWCC both had significantly lower harvest rates than the other entries (Table 8). Variations among the other entries were frequently insignificant, and significant variations occurred mainly in comparisons with Hybrid 80-29, which had slightly lower harvest values than the others. Hybrids 80-32, 80-37, and 62 were far superior to all other entries.

Except in Trials IV and VIII, heading rates varied little, and were comparable to those of heat tolerant check Hybrid No. 62. All entries were consistently superior to check hybrid WWCC (Table 9).

Table 8. Harvest rate (%)[z] of various entries across eight advanced yield tests held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean
	I	II	III	IV	V	VI	VII	VIII	
81-29	100a	80ab	69b	50c	84ab	61a	92a	81bc	80
80-37	98a	92a	99a	97ab	78ab	64a	99a	94ab	92
80-32	92ab	74b	99a	100a	87a	74a	100a	97ab	93
81-39	80b	78b	81b	43c	69b	28b	94a	81bc	70
Hybrid No. 62 (check)	92ab	87ab	100a	93b	87a	69a	94a	99a	92
WWCC (check)	77b	38c	84b	15d	31c	30b	59b	64c	50
CV (%)	14	11	13	16	12	16	12		-

[z] means followed by same letter are insignificantly different.

Table 9. Heading rate (%)[z] of various entries across eight advanced yield tests held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean
	I	II	III	IV	V	VI	VII	VIII	
81-29	100a	100a	100a	99a	100a	100a	98a	94bc	99.5
80-37	100a	100a	100a	100a	100a	100a	100a	96b	99.9
80-32	100a	100a	100a	100a	100a	100a	100a	100a	100.0
81-39	100a	100a	100a	89b	100a	100a	98a	87c	99.0
Hybrid No. 62 (check)	100a	100a	100a	100a	100a	100a	100a	96b	99.9
WWCC (check)	92b	81b	95b	29c	50b	62b	61b	62d	69.0
CV (%)	1	4	4	6	2	4	9	8	-

[z] means followed by same letter are insignificantly different.

Differences in head weight were less pronounced than other differences (Table 10), but check WWCC tended to have heavier heads than most other entries. Hybrids 80-37 and 81-29, however, had heads only slightly smaller. Hybrid No. 62 usually had smaller heads than other entries.

Head compactness (expressed in terms of specific gravity) varied little between test entries and Hybrid No. 62 (Table 11). Except in trials I, III, IV and VII, however, all entries showed firmer heads than did WWCC.

Table 10. Mean head weights (g)[z] of various entries across eight advanced yield tests held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean
	I	II	III	IV	V	VI	VII	VIII	
81-29	806	618a	525ab	453c	893bc	825a	495bc	828b	680
80-37	778	596a	562a	504b	1009a	823a	584a	742bc	700
80-32	763	513b	522ab	457c	915b	720b	572ab	742bc	652
81-39	778	573ab	478b	439c	857bc	700b	521ab	849b	649
Hybrid No. 62 (check)	760	529b	485b	437c	825c	694b	438c	679c	606
WWCC (check)	774	637a	522ab	581a	943ab	749ab	538ab	1014a	720
CV (%)	6	7	7	5	6	7	9	9	-

[z] means followed by same letter are insignificantly different.

Table 11. Head density (g/cc)[z] of various entries across eight advanced yield tests held at AVRDC in the summer of 1983.

Entry	Advanced trial set								Mean
	I	II	III	IV	V	VI	VII	VIII	
81-29	0.67	0.54a	0.58ab	0.46ab	0.61a	0.64ab	0.46ab	0.67a	0.58
80-37	0.70	0.61a	0.60a	0.52a	0.65a	0.69a	0.49a	0.61abc	0.61
80-32	0.69	0.62a	0.58ab	0.46ab	0.59a	0.65ab	0.50a	0.62abc	0.59
81-39	0.66	0.52ab	0.49ab	0.53a	0.56a	0.56b	0.46ab	0.56bc	0.54
Hybrid No. 62 (check)	0.70	0.60a	0.50ab	0.46ab	0.57a	0.66ab	0.42ab	0.64ab	0.57
WWCC (check)	0.62	0.41c	0.48b	0.42a	0.42b	0.43c	0.37b	0.54c	0.46
CV (%)	10	14	13	11	11	10	14	9	-

[z] means followed by same letter are insignificant.

Soft rot, which often causes significant yield losses, did not influence the outcome of these trials. Rates of infection ranged from 0.4% (#80-32) to 2.9% (#81-39). Coefficients of variation varied greatly, but were consistently high, ranging from 24 to 78 %.

Stable entries generally have yields and head weights with means above average, regression coefficients (b) close to unity, and insignificant deviations from regression (S^2d). Entries with stable maturity have means lower than the overall average (implying earliness), and an insignificant S^2d. Those with stable heading and harvest rates have means higher than the overall average, regression coefficients close to zero (implying consistent heading ability across the range of environments), and an insignificant S^2D. For the sake of clarity, these standards are summarized in Table 12.

Table 12. Indications of stability

	Yield	weight	Maturity	Harvest rate	Heading rate
Mean	$> \bar{\bar{x}}$	$> \bar{\bar{x}}$	$< \bar{\bar{x}}$	$> \bar{\bar{x}}$	$> \bar{\bar{x}}$
Regression (b)	1.0	1.0	1.0	0	0
Deviation from regression (S^2d)	ns	ns	ns	ns	ns

Note: $\bar{\bar{x}}$ = overall mean; ns = not significant.

Only 80-32 and 80-37 came close to satisfying all of these prerequisites (Table 13). The only obvious limitation of 80-32 was its relatively high regression coefficient for harvest rate. Hybrid 80-37 had a high regression coefficient for harvest rate, and may have also had a higher regression coefficient for heading rate. Of all entries, check WWCC was shown by virtue of its high regression coefficients for

Table 13. Means and stability parameters[z] for various characters of entries in advanced yield tests held at AVRDC in the summer of 1983.

Entry	Yield (t/ha)			Maturity (DAT)			Harvest Rate(%)			Heading Rate(%)			Head Weight (g)		
	mean	b	S^2d	mean	b	S^2d	mean	b	S^2d	mean	b	S^2d	mean	b	S^2d
81-29	19.9	1.2	2.9	37	1.0	0.8	80	0.8	122	99.5	0.9	7.9	680	1.1	1313
80-37	21.7	0.9	2.8	37	0.9	0.7	92	1.0	35	99.9	0.5	10.3	700	1.0	3119
80-32	20.4	0.9	3.5	36	0.8	1.0	93	0.8	107	100.0	0	0	652	1.0	1537
81-39	17.5	1.1	5.8	39	1.3	3.8	70	1.3	48	99.0	1.6	9.9	649	1.0	1150
Hybrid No. 62 (check)	18.9	0.9	2.0	37	0.9	0.7	92	0.8	31	99.9	0.6	5.0	606	0.9	1360
WWCC (check)	16.2	1.0	9.7*	44	1.2	8.7**	50	1.3	85	69.0	2.4	90.8**	720	1.1	5799*
General Mean	19.1	-	-	38	-	-	80	-	-	94.6	-		668	-	-

[z] b = regression coefficient; S^2d = deviation from regression
* = significant at 5% probability level; ** = significant at 1% probability level.

heading and harvest rates, and its significant S^2d for yield, maturity, heading rate, and head weight, to have the most unstable performance. Of the test entries, 81-39 was the least stable genotype. Although Hybrid No. 62 gave comparatively stable yields, its mean yields were lower than the overall mean.

Conclusions

Hybrids 80-32 and 80-37 yielded consistently better than all other entries, and matured as early as Hybrid No. 62. Their harvest and heading rates were also high, and their head weights were only slightly lower than those of WWCC, the large-headed check. Both performed relatively stably in advanced trials, and in the future both will be distributed to cooperators.

Further Improvement of Hybrids 58 and 59

Introduction

Combinations 58-19 and 81639 had been selected in the summer of 1982 for further tests against original Hybrids 58 and 59, respectively. Although in the summer of 1982 58-19 had given 7 t/ha more yield, matured about one week earlier, and had a higher harvest rate than Hybrid #58, its large coefficient of variation had rendered such results rather inconclusive. Combination 81639, on the other hand, had consistently outperformed Hybrid 59 for yield, maturity, and harvest rate in the early summer trial, but only for maturity and non-wrapper leaf weight in the late summer trial. Thus, in 1983 the new combinations were further tested against their respective original counterparts to determine whether they should be considered as replacements.

Materials and Methods

Three sets of paired trials with the advanced combination and the original hybrid were conducted for both hybrids according to the following schedule:

Trial	Sowing Date	Transplanting Date
I	May 20	June 9
II	June 20	July 11
III	August 1	September 1

Each trial consisted of eight randomly distributed paired plots (equivalent to eight replicates of two entries). Each 6 m^2 plot consisted of a double row 4 m bed, with 40 cm between plants and 50 cm between rows.

Results

Combination #58-19 differed significantly from Hybrid #58 in few respects. The most notable exception was its head shape index; in Trial II 58-19 produced significantly more elongated heads than Hybrid #58. Its low coefficient of variation indicates good sensitivity of comparisons. Soft rot may have been an exception, but overall infection rates still averaged less than 1%. Averages of selected characters over three trials are shown in Table 14.

Table 14. Yield and selected horticultural characteristics[z] of an advanced combination and an original Hybrid 58 planted at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity (DAT)	NWL weight (g)	Harvest rate (%)	Heading rate (%)	Head weight (g)	Solidity (g/cc)	Head shape index[y]
#58	24	36	827	99	100	731	0.56	1.4
#58-19	23	36	810	99	100	704	0.56	1.5
CV (%)	11	0.7	9	6	0	10	8	7

[z] All figures were averaged across 3 trials.
[y] Indicated significant deviation only in Trial II.

In most cases differences between 81639 and Hybrid 59 were also slight. Exceptions were vegetative growth, nonwrapper leaf weight, and head shape index. Combination 81639 tended to produce fewer nonwrapper leaves, and thus thriftier growth. It also had more elongated heads than Hybrid 59, and showed a tendency to be slightly earlier. Soft rot infection was again minimal, and did not influence the outcome of the trial. Averages of selected characters over three trials are shown in Table 15.

Table 15. Yield and selected horticultural characteristics[z] of an advanced combination and an original Hybrid 59 planted at AVRDC in the summer of 1983.

Entry	Yield (t/ha)	Maturity[y] (DAT)	Growth[x] (kg)	Head weight (g)	NWL weight (g)	Harvest rate (%)	Heading rate (%)	Head shape[w] index	Solidity (g/cc)
#59	22	39	1.7	764	935	85	99.7	1.3	0.5
#81639	22	37	1.5	714	749	92	100.0	1.4	0.6
CV (%)	22	6	7	12	9	31	4	4	17

[z] All figures were averaged across 3 trials.
[y] #81639 was significantly earlier only in Trial III.
[x] #81639 had significantly lower values in all trials.
[w] #81639 had significantly more elongated heads in Trials II and III.

Conclusions

It would not be advantageous to replace the original Hybrid #58 with a more advanced combination such as 58-19. Further selection on the paternal side of its pedigree, which showed some variation in the S_4 inbred generation, was not effective in improving its overall performance.

Although no improvement was obtained over Hybrid #59 in yield or any other characters, combination 81639 had less vegetative growth and fewer nonwrapper leaves, with no sacrifice in yield. It also matured slightly earlier, and had slightly longer heads. Thus, 81639 could be a useful replacement for Hybrid 59.

An Evaluation of Hybrid No. 62's Reciprocal Cross

Introduction

The male inbred parent of Hybrid No. 62 usually exhibits a weak self-incompatibility (SI) system, making it unwarranted to blend seeds from both parents when producing hybrid seed. Previous efforts to select a derivative of the male line with sufficiently strong and stable SI had been unsuccessful, but when mass increasing the male line through bee pollination in 1983, it was noticed that a number of plants had extraordinarily low seed set. Strongly self-incompatible plants were selected to perpetuate the line and to test the incompatibility system in a hybrid seed production scheme with the strongly self-incompatible female line. In this experiment, hybrid seeds from the regular or direct cross were compared with those from the reciprocal cross (i.e. those harvested from what was usually the male line) for sibbing rate and important horticultural characteristics.

Materials and Methods

Paired plots of the direct cross (designated as #62) and the reciprocal cross (designated as #62R), were randomly allocated in the

experimental area. Seeds were sown on April 20, 1983, and seedlings transplanted May 9. Each 3.6 m^2 plot consisted of a single 4.8 m row with 40 cm between plants. Paired treatments occupied a double-row bed with 50 cm between rows.

Results

Table 16 compares the sibbing rates and various horticultural characteristics of #62 and #62R. Clearly, #62R significantly outyielded #62, and produced larger, more compact heads. The increased head weight was apparently not due to an increased number of non-wrapper leaves. No statistical comparison was made of sibbing rate, but the level was lower in #62R (only 2 sibs out of 480 plants, or 0.4%) than in #62 (5 sibs out of 480 plants, or 1%). No other measured traits varied between the two types of cross. Soft rot damage was negligible.

Table 16. Comparison of horticultural characteristics[z] and sibbing levels between direct and reciprocal crosses of ASVEG #1 (Hybrid #62); AVRDC, summer 1983.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Harvest rate (%)	Heading rate (%)	Solidity (g/cc)	Head shape index	Sibbing rate (%)
#62R	22a	38	654a	446	100	100	0.6a	1.3	0.4
#62	20b	38	624b	445	100	100	0.5b	1.3	1.0
CV (%)	10	1	11	8	0	0	6	6	-

[z] Means followed by the same letter are insignificantly different.

Conclusions

It appears that Hybrid No. 62 may be outperformed by 62R, its reciprocal cross. Although differences in appearance were slight, 62R had slightly higher yields, probably as a result of its larger, more compact heads. Average head weight varied by only 30 grams, however, and so it may still be possible to simply blend seeds from direct and reciprocal crosses. This will be further investigated in 1984.

Cytosterility Backcross Program

Introduction

In 1983 work continued on transferring cytoplasmic male sterility (CMS) into an open-pollinated heat tolerant cultivar and into self-compatible heat tolerant inbred lines with good combining ability. Attention was focused on the new families derived from substitution crosses between CMS Brassica juncea and radish-derived CMS materials which had originally been preselected for vigor, normal leaf color, and functional nectaries.

Materials and Methods

CMS families from B. juncea:

After preliminary selection at the seedling stage for normal green leaf color and morphological resemblance to the Chinese cabbage parent, eighteen plants selected from four BC_1 families descended from crosses with inbred line B18 were vernalized at AVRDC and transplanted to the Puli Branch Station of Taichung DAIS (District Agricultural Improvement Station). Twenty four plants of a single family of B-18 were included for comparison and as a pollen source. Plants were sown on May 25, and all vernalized selections were transplanted to Puli on July 29. Because of poor seed set in 1982, there were generally few seedlings per family. Before carrying out futher backcrosses to B-18, flowers of CMS plants, generally five per plant, were examined for functional nectaries and other important characteristics.

Simultaneously, 39 plants from 7 BC_2 families descended from crosses between B-18 and one of two lines descended from local open-pollinated cultivar B 129 were also planted along with the parents. Recurrent parent lines of 24 plants each were included for comparison and as a pollen source. Again, plants were selected for normal traits and then vernalized at AVRDC before being moved to Puli. Plants were also selected for functional nectaries before being further backcrossed to B129.

CMS families from radish:

Twenty-four BC_2 families from crosses between B129 (represented by two self-compatible lines) and radish-derived CMS materials with a B. pekinensis background which had been preselected for vigor, green color, and functional nectaries were replanted in the fall of 1983 for further selection and backcrosses. Preliminary selection for relative green leaf color and Chinese cabbage-like characteristics was made at the seedling stage, and selected plants were vernalized.

The same procedure was followed with 11 BC_2 families from crosses with self-compatible inbred line 7252-1 as recurrent parent.

Forty seedlings from each of these recurrent parents crosses were included for comparison and as a pollen source for further backcrosses.

Results

As reported in AVRDC's 1982 Progress Report, CMS from B. juncea appears to be a better choice than the radish-derived CMS which had been used earlier in AVRDC breeding programs. CMS backcross derivatives from the former appear to have more nectaries, even though most of them are still smaller than those of normal lines (Table 17 and 18). Moreover, even though many plants were chlorotic it was possible to select normal-looking green CMS plants. Except for the second family in Table 18, CMS families still had flowers much smaller than those of the recurrent parent. Most flowers examined on the selected CMS plants had visible nectar secretions.

Table 17. Characteristics of the best original parents and derivative BC_1 families resulting from crosses between inbred B-18 and B. juncea CMS; AVRDC, 1983.

Family/pedigree[z]	CMS F_1 parents						BC_1 Progenies		
	leaf color[y]	petal size[x]	stamen[w]	nectar gland outer	nectar gland inner	nectar secretion (%)	chlorosis (%)	no. selection	Leaf Color[y]
(B. juncea CMS/CT1-32)-2/-2/RP	DG	.2N	V	2	2	100	72	3	SY-LG
(B. juncea CMS/CT1-32)-7/-2/RP	DG	.3N	P	2	2	100	67	3	DG
(B. juncea CMS/CT1-32)-10/-3/RP	DG	.4N	V	2	2	100	33	4	LG-DG
(B. juncea CMS/CT1-56)-5/-1/RP	DG	.5N	V	2	2	100	83	8	LG-DG
B-18 (RP or recurrent parent)	DG	N	N	2	2	100	-	-	

[z] Numbers after slash (/) are plant numbers of BC derivatives selected as parents for further BC.
[y] DG = dark green; SY = slightly yellow; LG = light green
[x] Figures are approximate fractions of petal size of B-18 (value of 1.0)
[w] V = vestigial anther; P = petaloid anther.

Table 18. Characteristics of BC_2 families derived from crosses of lines from B129 with B. juncea CMS; AVRDC, 1983.

Family/pedigree	Chlorosis (%)	No. selection	Leaf color	Best selection			
				Petal size	Nectar gland outer	Nectar gland inner	Nectar secretion (%)
(B. juncea CMS/CT1-32)-1/-2/RP	82	4	LD-DG	.2N	2/1	2/1	100
(B. juncea CMS/CT1-32)-1/-3/RP	100	4	LD-DG	.9N	2/1	2	100
(B. juncea CMS/CT1-32)-2/-5/RP	60	4	SY-DG	.2N	2/1	2	80
(B. juncea CMS/CT1-32)-7/-4/RP	40	4	SY-DG	.4N	2	2	100
(B. juncea CMS/CT1-56)-5/-2/RP	88	5	SY-DG	-	-	-	-
(B. juncea CMS/CT1-56)-5/-3/RP	90	3	SY-DG	.4N	2/1	2/1	60
(B. juncea CMS/CT1-56)-5/-4/RP	77	7	SY-DG	-	-	-	-
CT1-32 (RP)	0	-	DG	N	2	2	100
CT1-56 (RP)	0	-	DG	N	2	2	100

Plants selected from various backcross families resulting from crosses with the improved radish-derived CMS were inferior to those resulting from crosses with CMS B. juncea. The greatest differences were seen in the number of nectar glands (especially the inner, normally functional glands), degree of greenness of selected plants, and, to some extent, nectar secretion among CMS flowers. Flowers of many radish-derived CMS lines, however, were of normal size or larger (Tables 19 and 20).

The number of nectar glands present in radish-derived CMS varied from 0 to 2 for both inner and outer nectaries. (Plants usually have two normally developed inner glands and two vestigial outer glands). Nectar glands were still smaller than normal. All outstanding selections showed vestigial anthers. Most lines with petaloidal anthers were rated as poor sources of acceptable selections. The best selections originated from families derived from crosses with original CMS sources which had moderate nectar gland scores (NGS = 4-5 or 5).

Conclusions

Derivatives of CMS B. juncea continued to exhibit small flowers. Pods were smaller and had fewer seeds than those of the recurrent Chinese cabbage parent. Although chlorosis has reoccurred in some families, it has usually been possible to select normal green derivatives. A more stringent selection for fertility should enhance the eventual usefulness of CMS lines derived B. juncea.

Greater selection pressure must also be imposed upon radish-derived CMS families for functional nectar glands and progressively more normal foliage color. Analysis of the existing variations shows that improvement may be easier to attain in the B. juncea CMS than in these materials.

(continued on next page)

Table 19. Characteristics of the best original parents and derivative BC_2 families resulting from crosses of lines of B129 with new radish-derived CMS; AVRDC, 1983.

Family/pedigree	BC_1 parents									BC_2 progenies		
					Nectar gland							
					outer			inner				
	NGS[z]	Leaf color[y]	Petal size[x]	Stamen	0	1	2	0	1 2[u]	Nectar secretion (%)	Overall rating[w]	Chlorosis (%)	Selection no.(%)	Degree of yellowing[v]
(RC5-5/CT1-27)-1/-2/RP	4-5	SY	<N	V	-	+	+	+	- +	100	G	97	5(3)	1-3
(RC5-5/CT1-27)-1/-4/RP	4-5	DG	<N	V	-	+	+	+	- +	100	VG	98	2(1)	1
(RC5-5/CT1-27)-1/-5/RP	4-5	LG	N	V	-	+	+	+	- +	100	VG	89	2(10)	1
(RC5-5/CT1-27)-1/-7/RP	4-5	LG	N	V	-	+	+	-	- +	100	G	96	5(4)	1-2
(RC5-5/CT1-32)-2/-1/RP	4-5	DG	N	V	+	+	+	+	+ +	80	VG	98	2(2)	3
(RC5-5/CT1-32)-2/-2/RP	4-5	LG	N	V	-	-	+	+	+ +	60	G	99	1(1)	2
(RC5-5/CT1-32)-2/-3/RP	4-5	LG	>N	V	-	-	+	-	+ +	100	G	100	0(0)	-
(RC5-13/CT1-27)-1/-3/RP	5	DG	N	V	+	+	-	+	+ -	80	G	91	3(9)	2-4
CT1-27 (RP)	9	DG	N	N		+			+	100	-	0	-	0
CT1-32 (RP)	9	DG	N	N		+			+	100	-	0	-	0

[z] NGS = nectar gland score of original CMS source; 0 = absent to 9 = normal number and size
[y] DG = dark green; SY = slightly yellow; LG = light green
[x] N = normal petal size (like RP)
[w] Overall rating for freedom from disease, functional nectary and leaf color; VG = very good and G = good
[v] Scale of 0 = no yellowing to 5 = severe yellowing
[u] + = presence, - = absence

Table 20. Characteristics of the best original parents and derivative BC_2 families resulting from crosses between self-incompatible line 7252-1 with new radish-derived CMS; AVRDC, 1983.

Family/pedigree	BC_1 parents								BC_2 progenies		
	NGS[z]	Leaf color[y]	Petal size[x]	Stamen	Nectar gland outer 0 1 2	Nectar gland inner 0 1 2[u]	Nectar secretion (%)	Overall rating[w]	Chlorosis (%)	Selection no.(%)	Degree of yellowing[v]
(RC5-13/7252-1)-2/-2/RP	5	SY	N	V	- + +	- - +	100	G	100	0(0)	-
(RC5-13/7252-1)-2/-3/RP	5	LG	N	V	+ + +	+ + -	40	G	100	0(0)	-
(RC5-13/7252-1)-2/-5/RP	5	LG	N	V	- + +	- + +	80	G	88	3(12)	2
(RC5-13/7252-1)-2/-6/RP	5	LG	N	V	- - +	+ + +	80	G	100	0(0)	-
(RC5-13/7252-1)-2/-7/RP	5	DG	N	V	- - +	+ + +	40	G	33	1(33)	1
(RC5-13/7252-1)-2/-8/RP	5	LG	N	V	- + +	- + +	80	G	94	3(6)	3
(RC5-13/7252-1)-2/-9/RP	5	DG	N	V	+ + +	+ + +	60	G	92	1(8)	4
(RC5-13/7252-1)-2/-10/RP	5	LG	N	V	- + +	- + +	80	G	92	3(8)	2-3
7252-1 (RP)	9	DG	N	N	+	+	100	-	0	-	0

[z] NGS = nectar gland score of original CMS source; 0 = absent to 9 = normal number and size
[y] DG = dark green; SY = slightly yellow; LG = light green
[x] N = normal petal size (like RP)
[w] Overall rating for freedom from disease, functional nectary and leaf color; VG = very good and G = good
[v] Scale of 0 = no yellowing to 5 = severe yellowing
[u] + = presence, - = absence

Breeding for Disease Resistance

Introduction

Work continued on transferring through backcrossing the high levels of downy mildew and soft rot resistance possessed by Hakuran (B639) to a local open-pollinated cultivar and a number of heat tolerant inbred lines.

Additional screening, selection, and backcrossing was also carried out to incorporate downy mildew resistance from a Brassica pekinensis accession from Korea (B742) into a number of heat tolerant inbred lines.

The recently initiated backcross program to transfer to a number of heat tolerant inbred lines and local cultivars the resistance to strains C_2 and C_4 and immunity to strains C_1 and C_3 of TuMV shown by B708 or PI 418957 was also pursued further. Since AVRDC pathologists learned in 1982 that PI 418957 is susceptible to a new strain (C_5), new crosses have been made with B730, which showed resistance to C_5 as well as to the four strains previously identified. Although some lines which had originated from B141 (C_1 resistant) were still being tested in 1983, this program is now being de-emphasized.

Materials and Methods

A set of materials from the Hakuran backcross program was planted for further selection in 1983. This planting involved 18 families from 1982's BC_2F_1 selections. Ten were BC_3F_1 and eight were BC_2F_2. The total plant population was 1,527 plants from BC_3F_1 families and 525 plants from BC_2F_2 families. Included were 20 plants each of soft rot susceptible check B141 and soft rot and downy mildew resistant check Hakuran (B639). To serve as a downy mildew susceptible check and as an inoculum source, a row of Bing Luh (B14) was planted for every two rows of BC families, and another was planted around the perimeter of the experimental plot. Seeds were sown on September 2, and seedlings were transplanted to a downy mildew nursery on September 26. Soft rot inoculation was performed on November 4.

Seven BC_1F_1 families from crosses between B742, a downy mildew resistant donor, and seven heat tolerant inbred lines were planted at AVRDC on May 25, and seedlings were vernalized and transplanted to the Puli Branch Station of the Taichung DAIS on July 29 for further selection and backcrossing. The BC_1F_1 families numbered 40 to 48 plants each. Twenty plants of each of the inbred parents were included. Advanced generations produced from this planting are currently being evaluated in a downy mildew nursery.

Three-way crosses of B742, heat tolerant inbreds, and TuMV resistant PI 418957 were grown at AVRDC for mass-sibbing to develop populations segregating for downy mildew, TuMV, and heat resistance. These materials were sown on August 1, and vernalized seedlings were transplanted on October 12. Each family consisted of 20 plants. Seeds produced from this planting have not yet been evaluated.

Five F_1 families of crosses between TuMV resistant PI 418957 and

five local heat tolerant cultivars were sown on August 10, and vernalized seedlings were transplanted on October 11. Each family consisted of 10 plants. TuMV resistant, heat tolerant plants will be selected in 1984 from F_2 populations derived from each cross.

Two F_1 families from crosses between PI 418957 and inbreds B-18 and N-4 were also grown in Puli to obtain a BC_1F_1 with B-18 and N-4 as recurrent parents. Seeds were sown on May 25, and on July 29 five vernalized seedlings from each family were transplanted to Puli for subsequent pollination. The advanced generation of this planting will be evaluated in 1984.

Four BC_3F_1 families and 13 BC_2F_2 families derived from backcrosses of inbred line B18 and TuMV-C_1 resistant line B141 were further screened by AVRDC plant pathologists in the fall of 1983. Seeds were sown on September 16 and seedlings were transplanted on October 6. The parents were included, as was TuMV susceptible check B-40. Each family of 96 plants was artificially inoculated with TuMV-C_1 three days before transplanting.

An additional 65 test crosses between a number of the above lines and several stable AVRDC inbreds were also screened for TuMV-C_1. Seeds were sown on October 24 and seedlings were transplanted on November 14. Seedlings and field-grown plants were artificially inoculated with TuMV-C1 on November 4 and November 24, respectively. Plots consisted of 10 meter double-row beds with 40 cm between plants and 50 cm between rows. An RCB design was used with two replications. In addition to the test entries, Hybrid No. 62 (standard check), B141 (TuMV-C_1 resistant check), and B40 (TuMV susceptible check) were included as controls.

Results

Levels of soft rot incidence among BC_3F_1 and BC_2F_2 families from crosses between recurrent parent B129 and donor parent Hakuran was unusually low, and further selection emphasized heading characteristics and resistance to downy mildew. Table 21 compares the range of heading rates among groups. With the exception of one family in each of the two generations, the range of heading was already high, with the best families matching the 100% heading rate of the checks. Only those plants which were free of downy mildew infection or only slightly

Table 21. Heading rate (%) and selection intensity among BC_3F_1 and BC_2F_2 families of Hakuran backcrosses; AVRDC, 1983.

Entry/Generation	No. family	Total plants	Range of % heading[y]	Selection[z]		
				CC Type	Intermediate	%
BC_3F_1	10	1527	80-100	24	8	2.0
BC_2F_2	8	525	85-100	8	0	1.5
B141 (SR susceptible check)	1	36	100			
B639 (SR/DM resistant check)	1	25	100			
B14 (DM susceptible check)	1	2092	100			

[z] Only downy mildew (DM) plants selected; CC = Chinese cabbage; intermediate = still carried some obvious Hakuran characters.

[y] One BC_3F_1 family had only 58% heading, and one BC_2F_2 had only 25% heading. Neither was included in the above table.

infected were selected. In some cases plants which still exhibited some of the characteristics of Hakuran were kept for their high level of resistance to downy mildew.

All BC_3F_1 and BC_2F_2 families from backcrosses of inbred line B18 with B141 were rated resistant to TuMV-C_1 in field screening (Table 22). Eighteen resistant plants which showed earliness, good head characteristics, and minimal tipburn problems were selected from BC_3F_1 families for use in developing new inbred lines. Similarly, 25 plants were taken from BC_2F_2 families. Although these selections are not resistant to all five TuMV strains, they may nonetheless prove useful, especially when one considers that breeders are only beginning to develop multiple strain resistance.

Table 22. Turnip mosaic virus (strain C_1) resistance and selection rate in BC_3F_1 and BC_2F_2 families; AVRDC, 1983.

Generation/entry	No. family	Total plants	Infection rate (%)			Selection	
			Overall	Best family	Rating[z]	No.	%
BC_3F_1	4	380	5	3	R	18	5
BC_2F_2	13	1235	3	1	R	25	3
B40 (susceptible check)	1	20	80	-	S	-	-

[z] R = resistant (<20% infection); S = susceptible (>75% infection)

Fifty-seven percent of the preliminary combinations of some of above BC_3F_1 and BC_2F_2 families and a number of stable, heat tolerant inbred lines proved immune or resistant to TuMV-C_1 (Table 23). These combinations appear to be more resistant than Hybrid No. 62 to strain C-1. A horticultural evaluation of these materials has already been conducted, but the data have yet to be analyzed. Resistant combinations which show further advantages over Hybrid No. 62 will be tested in 1984.

Table 23. Reaction to TuMV-C_1 of combinations of stable, heat tolerant inbred lines with TuMV-C_1 resistant BC_3F_1 and BC_2F_2 families; AVRDC, 1983.

Reaction/entry	No. of Combination	Range of Infection (%)	Percent of total
Immune	3	0	5
Resistant	34	2-20	52
Moderately resistant	20	21-38	31
Moderately susceptible	8	42-68	12
Susceptible	0	-	0
B141 (resistant check)	-	5(R)	-
B40 (susceptible check)	-	100(S)	-
Hybrid No. 62 (standard check)	-	48(MS)	-
Total	65	-	100

Conclusions

Selections with a high level of resistance to downy mildew could be derived from the Hakuran backcross program. Some of them are already very similar to Chinese cabbage in terms of heading ability and overall morphology. Advanced generations from these selections will be evaluated in 1984 for such characteristics as heat tolerance and resistance to soft rot and downy mildew.

Several lines resistant to TuMV-C1 have been derived from the backcross program. When combined with stable inbreds, certain combinations have even proven immune. Advanced generations of the parent lines of combinations which are immune or highly resistant will be multiplied for eventual use in the development of hybrids which are heat tolerant and highly resistant or immune to strain C_1. These combinations may be useful as temporary replacements for TuMV-susceptible tropical hybrids while hybrids with multiple strain resistance are still being developed.

International Cooperation

In 1983 AVRDC distributed a total of 2,098 seed packets to 179 cooperators in 68 countries. Breeding lines made up a total of 1,820 packets, and accessions a total of 266 packets. The remainder were cytoplasmic male sterile lines and inbred stocks of Hybrid No. 62 which had been distributed to the Taiwan Seed Improvement and Propagation Service, and AVRDC's Thailand and Philippine Outreach Programs. Usually 2 to 3 g were sent for each entry, but in a number of cases quantities ranged from 100 grams to 2 kg per entry.

Brunei

Mr. Ramon F. Santiago of the Sinaut Agricultural Training Centre conducted two single replicate trials of 17 AVRDC entries at approximately 5° N latitude and 21 m above sea level. The first was grown from January 18 to March 29, 1983. The second was carried out during the wet season (July through to September). Table 24 shows the yield and other horticultural characteristics of the most promising entries from each trial. Open-pollinated lines 77M(3)-33 and 77M(3)-26 outyielded local check B189 C_1 when harvested about 60 days after planting. All entries were severely damaged by soft rot during the hot, wet season trial.

Table 24. Yield and selected horticultural characteristics[z] of promising entries in single-replicate trials held at Sinaut, Tutong, Brunei; 1983.

Entry	Yield (t/ha)	Head weight (g)	Maturity (DAT)	Harvest rate (%)	Soft rot (%)
77M(3)-33	18	508	61	61	21
77M(3)-26	18	458	60	83	41
B189 C_1 (check)	7	300	60	42	57

[z] All figures are averages of two single-replicate trials; B40 (heat sensitive check) did not give any yield.

Cook Island

Mr. K. Turepu of the Tokoitoku Research Station tested 11 AVRDC entries in a three-replicate trial sown on July 14, 1982 and transplanted August 11. The trial site was located at 21°155' south. Mr. Turepu considers two entries, 77M(2/3)-43 and 77M(2)-26, as potentially good lines for release to local growers (Table 25). They yielded 12 t/ha in 55 to 62 days, and without soft rot damage. Although yield levels were acceptable, they were still rather low, primarily because of low heading rates and low head weights under the conditions of the test. Problems with seed supply are still delaying the release of both entries.

Table 25. Performance[z] of the best AVRDC entries at Cook Island; 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Growth (g)	Head Weight (g)	Harvest rate (%)	Heading rate (%)	Solidity (g/cc)	Soft rot (%)
77M(2/3)-43	12	55b	858	427	89	92	0.46	0
77M(3)-26	12	62a	938	399	94	94	0.56	0

[z] Means followed by the same letter are insignificantly different.

Costa Rica

Mr. S. H. Lai, formerly AVRDC's Development Officer, planted a trial of ten entries (three from AVRDC, six from various Taiwan seed companies, and one local loose-headed cultivar) at Alajuela, which is located at 850 m above sea level. Seeds were sown on October 24, 1983, and seedlings were transplanted on November 18.

Hybrid No. 59 gave the highest yield (39 t/ha) 39 days after transplanting. Most entries performed well, ranging in yield from 23 to 39 t/ha when harvested at 36 to 41 days after transplanting. Soft rot, downy mildew, and virus diseases were not a problem during the test.

Guadeloupe

AVRDC sent 76 entries to INRA (Institut National de la Recherche Agronomique) for resistance screening against leaf diseases such as anthracnose (*Colletotrichum higginsianum*) and *Alternaria brassicicola*. Thirty-three of them were selected for a field trial sown on September 9, 1983, and transplanted on September 29. Mean temperature during the test was 26.2°C, and temperatures ranged from 19.8 to 29.9°C. A total of 285 mm of rain fell during the growth period, and there were only five rainless days.

Dr. C. M. Messiaen considered the performance of the F_1 hybrids and open-pollinated cultivars bred by AVRDC to be especially good, not only because of their heat tolerance, but also because of their resistance to leaf diseases (Table 26). The best entries yielded about 30 t/ha, but the local check suffered from severe leaf spots, soft heads, and soft rot damage, and was not even worth harvesting.

Table 26. Performance of the best AVRDC entries in Guadeloupe; 1983.

Entry	Yield (t/ha)	Head weight (g)	Head formation[z] (%)	Leaf spots[y] score
Hybrid #58	31	1060	89	1
77M(2/3)-43	32	1009	94	2
Hybrid #62	30	972	92	1
Local (check)	x	x	x	4

[z] Described specifically as well differentiated heads.
[y] Rated on a scale of 0 to 4; 0 = completely healthy, 4 = severely damaged.
[x] No harvests due to severe leaf spots (Alternaria + anthracnose), absence of firm heads, and soft rot damage.

INRA hopes seeds of these entries will be available from commercial seed growers for distribution to their farmers, and is also interested in extending its trials to Haiti and other areas.

Indonesia

A three-replicate trial of six AVRDC lines and one local check was conducted by Dr. John Fitzgerald, University of Sriwijaya, Palembang, Sumatra, at about 3°C south latitude and 5 m above sea level. Seeds were sown on August 30, 1982, and seedlings were transplanted on September 23. Table 27 compares the performance of the best entry, 76M(2)-20, with that of the local cultivar. Even though heading rate and harvest rate were good, the low average head weights of some entries made for fairly low yields. Heat tolerant entries had heads of lower density, and may have been harvested before their heads were completely filled out.

Table 27. Performance[z] of the best AVRDC entry against the local check at Palembang, Sumatra, Indonesia; 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Growth (g)	Head Weight (g)	Harvest rate (%)	Heading rate (%)	Solidity (g/cc)	Soft rot (%)
76M(2)-20	8a	52	467	234	100	100	0.21	19
Local (check)	5b	53	408	166	99	100	0.09	11

[z] Means followed by the same letter are insignificantly different.

Jamaica

Ms. Jennifer Brand, Crops Research Division, Ministry of Agriculture, tried two AVRDC hybrids (Hybrid #58 and #62) at the Top Mountain Research Station, which is 1,057 m above sea level and has a cool and moist climate. No specific data was provided, but the performance of

both hybrids was reportedly outstanding. The following are her descriptions of these varieties:

Hybrid #58 - Very firm, solid head; excellent quality. Was harvested 42 days after transplanting, but could have been harvested at 35 days. Average head weight was 900 grams.

Hybrid #62 - Generally similar to #58, but with larger heads; average head weight was 1400 grams, and the largest head weighed 2,300 grams.

More seeds have been requested for further trials at the same station, and also at the Lawrencefield Research Station, which is located at sea level and has a hot and dry climate.

Japan

On-farm trials of four AVRDC open-pollinated varieties were carried out in 1983 in cooperation with the Nagasaki Prefectural Comprehensive Agriculture and Forestry Experimental Station, the Isahaya Agricultural Extension Station (Nagasaki Prefecture), and the National Federation of Agricultural Cooperative Association (Nagasaki Prefecture). The trials were held at Isahaya City, which is located at 32°N. Plot sizes were 200 m^2 at Kaizu-cho, 1000 m^2 at Nagata-cho, and 2,000 m^2 at Tahira-cho.

As a result of these trials 77M(3)-26 and 77M(3)-35 were selected for naming and formal release in 1984. Their descriptions follow:

77M(3)-35: Dark green, large foliage; erect growth habit; 65 days from sowing to harvest; cylindrical head; uniform heading; comparatively tolerant of diseases and easy to cultivate.

77M(3)-35: Dark green, vigorous; erect plant type; large cylindrical head; tolerant of diseases; slightly later maturity.

Although both were generally reported superior in appearance and quality, their heads were considered small (only 1 kg average weight) by Japanese standards. Almost all summer Chinese cabbage are used for pickling however, and cylindrical heads are more easily processed than round ones. Thus, 77M(3)-26 and 77M(3)-35 do have certain advantages in the local market.

Liberia

Mr. Philip Kamanda, Vegetable Specialist of the Central Agricultural Research Institute of Liberia's Ministry of Agriculture, evaluated eight entries in a three-replicate trial at Suakoko, which is located at 163 m above sea level and 6°58' south. The trial was sown on June 1, 1983, and was transplanted on July 1.

Hybrid #58 had the highest yield (22 t/ha) 61 days after transplanting, a 100% harvest rate, and a mean head weight of 407 g. All AVRDC entries performed relatively well, ranging in yield between 17 and

22 t/ha. They were also rated highly in organoleptic tests, and seemed well suited to Liberian tastes. More seeds of the same set have been requested for further tests.

Papua New Guinea

Mr. R. Croyden of LAES, Keravat, East New Britain Province tested 20 AVRDC entries against 2 Japanese hybrids (Tropical Delight, a semi-heading hybrid, and Saladeer, a heat tolerant tropical type hybrid) in a three-replicate trial located at 4° south latitude. Table 28 compares the best AVRDC entries with the two Japanese hybrids. The AVRDC entries were far superior in almost every respect, but Tropical Delight may have been less susceptible to soft rot. Although the level of soft rot incidence was not significantly higher in the AVRDC entries, the co-operator felt that the resistance of Tropical Delight was more reliable.

Table 28. Performance[z] of the best AVRDC entries against Japanese hybrid checks at Keravat, PNG; 1982.

Entry	Yield (t/ha)	Maturity[y] (DAT)	Head Weight (g)	Harvest rate (%)	Heading rate (%)	Soft rot (%)
Hybrid #62	27a	47	943a	67	100	33c-e
77M(3)-33	24a	47	692b-e	85	99	28c-e
77M(3)-26	23a	47	730a-e	75	99	24c-e
Tropical Delight (check)	13f	47	564de	55	93	14e
Saladeer (check)	2g	47	538e	13	92	90a

[z] Means followed by the same letter are insignificantly different.
[y] Single, once-over harvest practice followed.

Philippines

Dr. E. T. Rasco of the Institute of Plant Breeding, at the University of the Philippines at Los Banos, reported the approval for release in 1982 of two open-pollinated varieties from AVRDC: 77M(3)-27, given the local name "Esperanza", and 77M(3)-35, with the local name "Corazon". Both lines were multiplied in 1983 for distribution to growers.

Mrs. E. P. Bongato of AVRDC-POP (Philippine Outreach Program) reported that after exhaustive peformance trials, heat tolerant Hybrid #62, locally named "Reyna Elena", was approved for release in 1983. Rainy season production of AVRDC breeding lines has proven feasible in the POP trials. Experimental production of Hybrid #62 seed is currently being undertaken by the POP.

Chinese Cabbage Pathology

Chinese Cabbage Downy Mildew Observational Planting

Introduction

Accurate disease assessment can provide important clues as to the type of resistance that is present, and accurate assessment of quantitative resistance is an important part of resistance breeding. This study was designed to show which types of resistance to downy mildew which are present in Chinese cabbage, and to find suitable methods of assessing that resistance.

Methods and Materials

In the fall of 1982 thirty-two lines of Chinese cabbage previously reported to be resistant and six plots of Pin-luh, known to be susceptible, were planted in double row beds (20 plants/bed) without replication. Standard AVRDC cultural practices were followed. Seed was sown on September 23, plants were transplanted on October 14, and final data was collected on November 29. Affected leaf area estimates were recorded on three dates for two leaves per plant as was the final incidence of disease in each plot. Final disease incidence data was analyzed using a Chi-square test for homogeneity.

Results

None of the lines were completely resistant to Chinese cabbage downy mildew; disease incidence varied from 50 to 100% (Table 1). Chi square values indicate, however, that with the small number of plants tested variations in disease incidence could be easily explained as random variation. Examining only two leaves per plant brought inconsistent results (Table 1). No increase in disease incidence could be discerned from these data.

Conclusions

Neither method of quantifying downy mildew incidence in Chinese cabbage is satisfactory; instead the entire plant must be evaluated.

Table 1. Observational planting for Chinese cabbage downy mildew.

Line	Final incidence[z] # inf.	Total #	11/5/82	11/15/82	11/22/82
L14 (Pin-luh)	20	20	12.25	14.5	19.75
L147	11	15	1.09	0.63	3.5
L200	12	20	0.5	0.12	0.875
L201	12	18	0.81	1.3	3.1
L202	13	19	0.13	0	0.125
L204	16	18	1.05	0.7	0.3
L205	17	18	0.9	1.0	0.9
L309	19	20	0.9	4.8	3.6
L313	18	20	1.25	2.5	2.4
L14 (Pin-luh)	20	20	30.75	12.6	30.6
L315	19	19	10.0	2.9	3.2
L317	19	19	4.5	8.1	0.6
L349	15	15	3.9	2.5	5.8
L371	15	15	3.9	2.5	5.8
L417	17	17	31.4	24.3	8.6
L597	20	20	38.6	36.75	29.23
L598	20	20	25.5	45.75	25.2
L304	20	20	48.37	1.37	7.88
L14 (Pin-luh)	20	20	41.62	12.87	18.3
L14 (Pin-luh)	19	19	15.4	3.4	16.45
L312	19	20	0.25	8.0	0.26
L308	20	20	2.0	11.5	14.53
L492	15	17	0	3.0	7.25
L470	20	20	2.0	5.75	9.75
L503	20	20	2.1	3.3	5.8
L539	19	19	2.75	6.05	2.78
L581	20	20	4.5	32.5	42.3
L14 (Pin-luh)	19	19	38.7	6.45	18.7
L582	20	20	3.25	16.75	18.7
L583	19	20	0.5	3.25	6.0
L584	19	19	18.2	18.7	21.1
L585	15	17	0.88	3.24	3.75
L586	19	19	0	1.32	25.3
L587	19	19	0	0.53	11.05
L588	20	20	0.25	0.5	2.25
L589	10	20	0	1.0	1.25
L14 (Pin-luh)	20	20	23.25	1.63	8.25

[z]Chi-square value for homogeneity = 11.86 with 38 d.f. (n.s.).

Since all lines were infected to some degree, either the field inoculum is heterogeneous, the Chinese cabbage lines are heterogeneous, or no absolute race specific resistance is present.

Components of Downy Mildew Resistance

Introduction

This experiment was designed to learn more about the components of resistance to downy mildew so that more effective methods of resistance screening could be developed.

Methods and Materials

Chinese cabbage varieties 77M(3)-35, 77M(3)-27, and Pin-1uh were sown on April 20 and transplanted on May 10, 1983. Each variety was planted in a solid block of three beds, and was protected from interplot interference by a solid border of maize. Plants were inoculated on May 17 with sporangia of Peronospora parasitica which had been gathered from a downy mildew nursery. On May 26 the number of lesions and the average lesion size were calculated for each plant. On May 31 and June 7, 14, and 22, the number of infected leaves and the percentage of leaf area infected was calculated for each plant in each plot. On May 26, using the three plots of each variety as replicates, an analysis of variance was made for lesion number and average lesion size. Regression analysis was used for the remaining data, with either number of infected leaves or the percentage of leaf area affected as the dependent variable and time as the independent variable.

Results

Populations 77M(3)-27 and 77M(3)-35 both proved more resistant than Pin-1uh (Table 2 and Figures 1 and 2). This resistance was initially expressed in the form of smaller and fewer lesions. In the regression analysis it was expressed as a slower rate of development and a lower overall mean, using either the percentage of area infected or the number of infected leaves as the dependent variable over time.

Table 2. Means and contrasts from downy mildew resistance study, Spring 1983.

Variety	Nine days after Inoculation		Regression Analysis			
			% Area affected		# Infected leaves	
	No. of lesions	Lesion size	Intercept	Slope	Intercept	Slope
77M(3)-35	2.26	0.369	3.76	0.076	0.23	0.05
77M(3)-27	0.87	0.245	1.55	0.151	0.07	0.06
Avg. both resistant lines			2.15	0.11	0.15	0.057
Pin-1uh	19.11	1.753	2.15	0.549	1.27	0.1
F values for contrasts (Both resistant lines compared with the susceptible check)	505 (1,8 df)	1018 (1,8 df)	275 (2,31 df)		298 (2,32 df)	
77M(3)-35 compared with 77M(3)-27	2.37 (1,8 df)	5.56 (1,8 df)	2.35 (2,30 df)		2.72 (2,30 df)	

Conclusions

Using the number of lesions as the dependent variable showed a significant difference between the two resistant varieties and the susceptible check, but no difference between the two resistant varieties. Using lesion size, however, showed not only a significant difference between the average of the two resistant populations and the

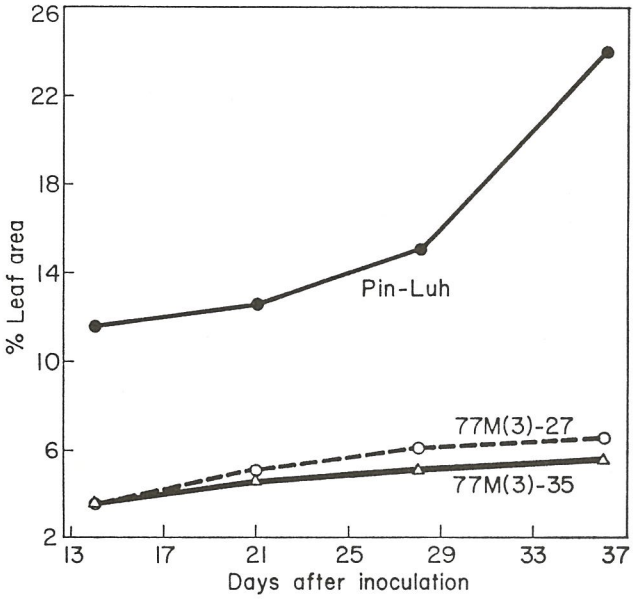


Fig. 1.
Increase over time in the percentage of leaf area infected with Peronospora parasitica.

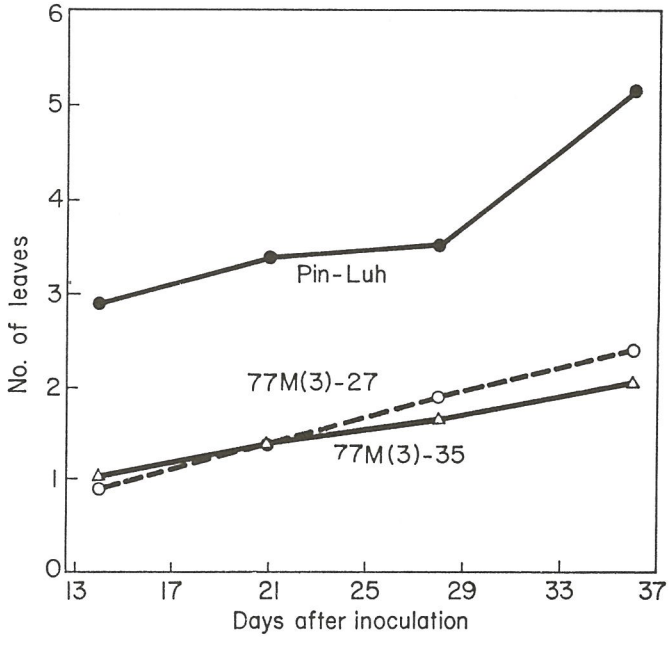


Fig. 2.
Increase over time in the number of leaves infected with Peronospora parasitica.

susceptible check, but also a difference between the two resistant populations, with 77M(3)-27 producing smaller lesions.

When using either the percentage of area infected or the number of infected leaves as the dependent variable, the regression lines of the resistant populations were significantly different from those of the susceptible check, but not from one another. In addition, the line for Pin-luh shows an upward slope not evident in the lines for either of the two resistant populations.

The resistance of these two populations is evident throughout the growing period in the form of fewer infected leaves and less infected

leaf area. Two components of this resistance are a reduced infection efficiency of incoming sporangia and a reduced lesion size. The ability to differentiate between types of resistance is useful when combining diverse resistance types to produce increased levels of resistance.

Testing F_1 Hybrids for Downy Mildew Resistance

Introduction

Work on downy mildew has concentrated on developing methods of screening for resistance and quantifying disease levels so they can be analyzed. The components of resistance and the way in which resistance is expressed are also being examined. One experiment conducted in cooperation with AVRDC plant breeders compared the resistance of seven F_1 hybrids and their parents.

Methods and Materials

Seed was sown on October 27, 1982, and seedlings were transplanted on November 15. The varieties studied are listed in Table 3. The incidence of downy mildew was determined in each plot by examining both the upper leaves and the entire plant. This incidence data was taken on four dates (December 16 and 23, 1982, and January 4 and 12, 1983). The number of infected leaves on the last day was also determined. Incidence data was subjected to an analysis of variance, and suitable contrasts were made between treatment means.

Results

The use of either the incidence of downy mildew on the upper leaves throughout the season or the final number of infected leaves yielded data which showed the differences between the resistant and susceptible lines (Table 3). Measuring disease by the use of absolute incidence of downy mildew was not satisfactory, however, and none of the F values obtained were significant. Apparently none of the material tested carries absolute resistance to downy mildew; even resistant check B 742 was infected in 76.7% of all plants as early as December 16.

Conclusions

The F_1 hybrids were intermediate in resistance between their susceptible and resistant parents. Comparison of the F_1 hybrids with the susceptible inbreds showed significant differences on three assessment dates when using incidence on upper leaves as a measure of disease severity. Whether this resistance is vertical or horizontal cannot be answered, since the inoculum was not controlled. Apparently none of the germplasm tested carries absolute resistance; even resistant check B 742

was infected. Only by using more controlled inoculum can the nature of downy mildew resistance be determined.

Table 3. F_1's and their parents tested for downy mildew resistance.

Line	Dec 16 82 Incidence		Dec 23 82 Incidence		Jan 4 83 Incidence		Jan 12 83 Incidence		Mean # of infected leaves
	upper	all	upper	all	upper	all	upper	all	
B742 x T-1-7-1	0.04	0.85	1.10	0.96	0.50	1.00	0.59	1.00	4.40
B742 x PL 1	0.04	0.81	0.17	0.88	0.60	1.00	0.60	1.00	4.05
B742 x C-2-7-5-21	0.17	0.90	0.23	0.92	0.52	0.96	0.64	1.00	4.20
B742 x C-6-9-2-21	0.13	0.90	0.15	1.00	0.40	1.00	0.46	1.00	4.39
B742 x R-1-8-8-21	0.00	0.69	0.08	0.81	0.56	0.98	0.63	1.00	2.13
B742 x E-7	0.08	0.92	0.17	0.96	0.23	0.98	0.32	1.00	2.46
B742 x E-9	0.02	0.69	0.06	0.88	0.13	0.90	0.27	0.96	3.07
T-1-7-1	0.29	0.98	0.45	0.98	0.56	1.00	0.62	1.00	4.95
PL 1	0.27	1.00	0.28	1.00	0.39	1.00	0.80	1.00	5.14
C-2-7-5-21	0.10	0.75	0.10	0.93	0.12	0.98	0.41	1.00	3.32
C-6-9-21	0.38	0.98	0.38	0.98	0.61	0.98	0.65	1.00	3.65
R-1-8-8-21	0.15	1.00	0.15	1.00	0.74	1.00	0.78	1.00	5.25
E-7	0.28	0.81	0.32	0.98	0.38	1.00	0.44	1.00	3.44
E-9	0.48	0.93	0.52	0.96	0.59	0.98	0.81	1.00	4.35
B742	0.00	0.77	0.00	0.77	0.18	1.00	0.19	1.00	2.65
B14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.48
F-value for variety	8.26	1.72	6.36	0.88	2.49	1.36	2.10	1.00	3.79
MSE	0.02	0.01	0.02	0.01	0.04	0.00	0.00	0.00	0.43
Variety SS	1.92	0.36	1.80	0.15	1.66	0.02	1.42	0.00	24.69
95% LSD	0.27	0.25	0.29	0.23	0.45	0.07	0.14	0.03	1.40
All Susc. parents vs. all F1 hybrids									
S.E. for this contrast	0.05	0.04	0.95	0.04	0.08	0.01	0.03	0.01	1.25
'T' value	4.44	2.22	3.40	1.48	0.81	1.39	5.71	1.07	1.95
Partition of SS									
R & S check vs others	0.37	0.00	0.26	0.01	0.06	0.00	0.00	0.00	0.00
F value (1.15 df)	24.18	0.04	13.99	1.11	1.44	1.11	0.35	0.14	0.00
Res. vs. sus check	1.00	0.05	1.00	0.05	0.68	0.00	0.66	0.00	8.01
F value (1,15 df)	64.52	3.88	52.91	4.76	15.33	0.00	146.52	0.00	18.45
Among the rest (13 df)	0.55	0.31	0.54	0.08	0.91	0.02	0.75	0.00	16.68
F value (13,15 df)	2.71	1.68	2.19	0.56	1.58	1.49	12.90	1.13	2.96

Further study of each entry's disease incidence mean revealed that several inbreds were less susceptible than were the progeny that resulted when they were crossed with B 742.

Resistance in Chinese cabbage is complex, and has yet to be clearly understood. By partitioning the sum of squares, it can be seen that much of the variation is due to the differences between the resistant and susceptible check, and that differences among the group of F_1's and susceptible inbreds remain small.

Evaluation of Techniques Used to Screen for Resistance to Soft Rot in Chinese Cabbage

Introduction

This experiment was designed to re-affirm the effectiveness of AVRDC's current inoculation method, which involves injecting a suspension of soft rot bacteria into the petioles of two of the plant's leaves. Since infection normally occurs on the stem near the soil line, and seldom through the leaves, it was hypothesized that this might not be an effective way to measure resistance.

Methods and Materials

A 2 x 5 factorial design was replicated six times in a completely randomized design. Seeds were sown on April 15 and seedlings were transplanted to the field on the May 4. Individual plots consisted of 20 plants in a 5m double row-bed. Standard AVRDC cultural practices were followed. Plots were inoculated on June 16 with one of eight different treatments (Table 4). One factor in the inoculation consisted of breaking or not breaking one leaf per plant, and the other consisted of one of four inoculation procedures with a bacterial suspension at 0.3 OD - either no inoculum, standard AVRDC injection inoculation (two injections per plant on different leaves, with a total dose of 1 ml per plant, or spraying with inoculum to runoff, either with special drop nozzles or an overhead spray. This resulted in a total of eight treatments (Table 4). The incidence of soft rot was recorded 4, 6, 8, and 12 days after inoculation. This data was analyzed with an ANOVA, and appropriate contrasts were made of treatment means.

Results

Bacterial soft rot developed differently in each treatment (Table 4). Values of the contrasts between treatment means and their "t" values are presented in Table 5. The weights given to each of the treatment means to obtain its specific contrast value are presented in Table 4.

Conclusions

Breaking the leaves did not appear to affect the amount of soft rot. The effects of inoculation began to appear on the fourth day. Inoculation method had a significant effect upon results; more plants had soft rot in the injection treatments. Nozzle type did not appear to affect the number of plants infected with soft rot, though, and differences observed between the two treatments were insignificant.

No interactions were immediately apparent, but by the eighth and twelfth day the interaction between breaking the leaves and inoculation

Table 4. Treatments and contrasts for bacterial soft rot experiment.

Factor	Treatment							
	1	2	3	4	5	6	7	8
Leaves								
Leaves broken	no	yes	no	yes	no	yes	no	yes
Leaves unbroken	yes	no	yes	no	yes	no	yes	no
Inoculation								
No inoculation	yes	yes	no	no	no	no	no	no
Injection inoculation	no	no	yes	yes	no	no	no	no
Overhead spray	no	no	no	no	yes	yes	no	no
Drop Nozzle spray	no	no	no	no	no	no	yes	yes
Multiplier for:								
Main effects contrasts								
Breaking leaf	1	-1	1	-1	1	-1	1	-1
Inoculation	-3	-3	1	1	1	1	1	1
Inject vs spray	0	0	-2	-2	1	1	1	1
Nozzle type	0	0	0	0	-1	-1	1	1
Interaction contrasts								
Break x inoculate	-3	3	1	-1	1	-1	1	-1
Break x inoc. type	0	0	-2	2	1	-1	1	-1
Break x nozzle	0	0	0	0	-1	1	1	-1
Treatment mean on								
Day 4	0	0.00833	0.324	0.241	0.0439	0.0171	0.0435	0.0254
Day 6	0.00877	0.0171	0.755	0.802	0.105	0.0171	0.13	0.045
Day 8	0.00877	0.0264	0.837	0.887	0.15	0.0425	0.199	0.045
Day 12	0.018	0.0699	0.857	0.905	0.176	0.104	0.284	0.0626

Table 5. Contrasts of treatment means and their "t" values (value divided by its standard error) from the bacterial soft rot experiment.

	4 days		6 days		8 days		12 days	
	value	"t"	value	"t"	value	"t"	value	"t"
Main Effects Contrasts								
Breaking leaf	0.119	1	0.117	0.9	0.194	1.6	0.194	1.4
Inoculation	0.67	3.2	1.78	8.5	2.06	10.1	2.12	9.2
Inject vs spray	1	-6.8	-2.81	19.1	-3.01	-20.9	-2.9	-17.8
Nozzle type	0.008	0.1	5.23	0.6	0.051	0.6	0.067	0.7
Interaction contrasts								
Break x inoculate	0.153	0.7	0.151	0.7	0.264	I.3	0.402	1.7
Break x Inoc. type	0.121	-8.2	0.267	1.8	0.36	2.5	0.39	2.4
Break x Nozzle	-0.008	-1.0	-0.003	-0.1	0.046	0.5	0.149	1.5

method was statistically significant. More soft rot resulted when the leaves were broken and spray inoculated than when plants were simply spray inoculated, but breaking the leaves had little effect in the injection inoculation treatments.

Under the conditions of this experiment, injection was the most effective means of inoculation. Inoculum was applied to the leaves, however, which may not be the actual site of bacterial penetration. None of the other inoculation methods, with or without breaking the leaves, was effective, and none can be recommended without further testing.

The Effect of Root Knot Nematode on Chinese Cabbage

Introduction

While some Chinese cabbage may be susceptible to root knot nematode, the magnitude of the damage it can cause is unknown. In the spring of 1982 a study was conducted with artificially infested plots to determine the magnitude of any loss that might be caused by Meloidogyne incognita.

Materials and Methods

Eight 20-plant double row beds of Chinese cabbage were planted according to standard AVRDC cultural practices. Each pair of plots was treated as a block in laying out the treatments and in subsequent statistical analyses. Treatments consisted of nematode infection (an aqueous suspension of 1,800 eggs of Meloidogyne incognita applied to each plant at transplanting time) and no nematode infection (no eggs, and 15 kg/ha of 10% Nemacur applied in a 15 cm deep furrow in the middle of the beds immediately before transplanting). Seeds were sown on April 15, seedlings were transplanted on May 5 and inoculated on May 6, and mature plants were harvested on June 28. Each plant was weighed, and mean plant weights in each plot were used as the dependent variable in the ANOVA.

Results

Plants from nematode-free plots were larger than those in the nematode-infested plots. Those from the nematode-free plots weighed an average of 698 g, but those from the nematode-treated plots averaged only 507 g. This difference, 191 g, had a t value of 4.9.

Conclusions

The study confirmed reports already in the literature; Chinese cabbage can be damaged by root knot nematode. Average losses were approximately 27% of the weight of the disease free check. Whether the Nemacur treatment may have controlled other pathogens than just root knot nematode cannot be answered with the data from this experiment. Nemacur is only effective against nematodes, however, and any differences observed must be attributed to reduced numbers of either root knot or other nematodes.

Host Reactions to Five Taiwan Strains of Turnip Mosaic Virus (TuMV)

Introduction

TuMV has a wide host range, and infects not only Crucifers, but

also plants of other families. Until now, however, no host range studies have been conducted with all five strains of TuMV. The following study investigated the host ranges of all five strains.

Materials and Methods

At least four test plants of each species or cultivar belonging to the families Amaranthaceae, Balsaminaceae, Chenopodiaeae, Compositae, Cruciferae, Cucurbitaceae, Ficoidaceae, Lamiaceae, Leguminosae, and Solanaceae were mechanically inoculated with one isolate of each strain. After inoculation all plants were maintained in an artificially lighted controlled environment growth room (12 hour photoperiod, day temperature 26°C, night temperature 20°C). To confirm the presence or absence of the virus in inoculated and non-inoculated leaves, back inoculations to Chenopodium amaranticolor were made four weeks after inoculation.

Results and Discussion

Of the 88 plant species tested in the host range study, 57 were susceptible to one or more strains of TuMV (Table 6).

Table 6. Host range of five strains of turnip mosaic virus (TuMV) found in Taiwan.

Hosts	Reaction[z]				
	TuMV-C1 (T-61)[y]	TuMV-C2 (T-37)	TuMV-C3 (T-40)	TuMV-C4 (T-91)	TuMV-C5 (T-42)
Cruciferae					
Brassica campestris ssp. *pekinensis*					
Hiratsuka No. 1	-/-	1/M,N,LD	1/VC,M,D,LD	1/VC,M,D	1/VC,M,N
Shimoyama Chitose	-/-	1/M	1/M	1/VC,M	1/VC,M
Kasumi	-/-	1/M	1/VC,M	1/VC,M,N	CL/VC,M,N
Shin-Ju	-/-	CL/CC,M	VC/M,N	VC/VC,M,N	CL/CL,M,N
Nozaki cross No. 1	1/M	1/M,LD	1/M,LD	1/M,LD	1/M,LD
No. 2	1/-	CL/M	CL/CL,M	1/M	1/M
No. 3	-/-	CL/M	CL/CL,M	1/M	1/M
Ping Luh	-/-	CL/M	1/M	CL/CL/M	1/M
AVRDC acc. 204	-/-	CL/M,N or -/-	1/M	CL/M	1/M,N
AVRDC acc. 205	-/-	CL/CL,M	CL/M	1/M	1/M
AVRDC PI 419069	1/-	1/-	1/-	1/-	1/- or 1/1
Line 8247	-/-	-/-	-/-	1/M	CL/CL,M
Tropicana	-/-	-/-	-/-	CRS/M or 1/1	1/M or -/-
AVRDC acc. 730	-/-	-/-	-/-	-/-	1/M or -/-
B. campestris ssp. *chinensis*					
Small Pai-tsai	NL/M,N	1/M	1/M	1/M	1/M
Green Petiole Pai-tsai	CL/M	CL/M	1/VC,M	CL/M	1/VC,M
B. campestris ssp. *rapa*					
Presto	1/M	1/M	1/M	1/M	1/M
B. juncea					
AVRDC acc. B96	1/M,N	CL/M	CL/M	CL/M	CL/M
B. napus	N/M,LD	-/M	-/M	-/VC,M	-/VC,M
B. nigra					
Yellow flower	CS/M	-/M	-/M	-/CL,M	-/CL,M
White flower	CS/-	CS/M	CS/-	CS/-	CS/-
Cruciferae					
B. oleracea ssp. *capitata*					
Musca	CL/-	-/-	-/-	-/-	CL/M
Phoenix	-/-	-/-	-/-	-/-	CL/M
Bislet	-/-	-/-	-/-	CL/M	CL/M
Hidena	-/-	-/-	-/-	CL/M	CL/M

(Continued on next page)

Table 6. (Continued from last page) Host range of five strains of turnip mosaic virus (TuMV) found in Taiwan.

Hosts	Reaction[z]				
	TuMV-C1 (T-61)[y]	TuMV-C2 (T-37)	TuMV-C3 (T-40)	TuMV-C4 (T-91)	TuMV-C5 (T-42)
Tohshun As	-/-	-/-	CL/M	CL/M	CL/M
CM -/-	-/-	-/-	CL/M	CL/M	
B. oleracea ssp. *botrytis*					
45 days extra early	-/-	-/-	-/-	CL/CRS	-/-
Fengshan extra early	-/-	-/-	-/-	1/M	-/-
Farmers early	-/-	-/-	CRS/-	-/-	CL/-
Raphanus sativus sp. *niger*					
Meilong early	1/M	1/M	1/M	1/M	1/M
Chenopodiaceae					
Chenopodium amaranticolor	CNL/-	CL/-	CL/-	CL/-	CL/-
C. quinoa	CNL/CL,M	CNL/CL,M	CNL/CL,M	CNL/CL,M	CNL/CL,M
Spinacia oleracea					
ORO 1265	CL/M	1/M	1/M	1/CL,M	1/M
Vicking	1/CL,M	CL/M	CL/M	CL/CL,M	1/M
Bloomsdale Long Standing	CL/M	1/M	1/M	1/M	1/M
Amaranthaceae					
Camphrena gomphrena	NL/-	NL/-	NL/-	NL/-	NL/-
Compositae					
Cichorium endivia					
Broad leaf batavian	CL/CL,M	-/-	-/-	CL/CL,M	CL/CL,M
Green Curled	1/-	-/-	-/-	-/-	-/-
Compositae					
Zinnia elegans					
torch CL/CL,M	CL/CL,M	1/M	CL/CL,M	CL/CL,M	
Helianthus annuus	CS/M	-/-	-/-	-/-	-/-
Ficoidaceae					
Tetragonia expansa	CRS/-	CRS/-	CRS/-	CRS/-	CRS/-
Solanaceae					
Nicotiana clevelandii	NL/M,N	NL/M,N	NL/M,N	NL/M,N	NL/M,N
N. glutinosa	CS/-	CS/-	CS/-	CS/CS	CS/CS
N. rustica	-/-	CL/-	CL/-	CL/-	CL/-
N. tabacum					
Samsun, Xanthi	CNL/-	CNL/-	CNL/-	CNL/-	CNL/-
White Burley	CNL/-	CL/-	CNL/-	CL/-	CL/-
Petunia hybrida	1/M	1/M,LD	1/M,LD	1/M,LD	1/M,LD
Physalis floridana	CS/1	CL/CL,M,LD	CL/CL,M,LD	CL/CL,M,LD	CL/CL,M,LD
Balsaminacae					
Impatiens balsamina					
Royal mixed colors	1/1	1/M	-/-	CL/M	CL/M

[z] Format for symptom symbols: Reaction on inoculated leaves/reaction on non-inoculated leaves. NL = necrotic lesions, CL = chlorotic lesions, CS = chlorotic spots, LD = leaf-deformation, M = systemic mosaic, VC = vein-clearing, N = necrosis, CRS = chlorotic ringspot, 1 = latent infection, - = symptomless (no virus, recovered by back-inoculation to *C. amaranticolor*).

[y] Strains T46, T37, T40, T91, T42, representing strains 1, 2, 3, 4, and 5 respectively.

Plants immune to all 5 strains of the virus were:

Cruciferae: *Brassica oleracea* ssp. *capitata* "Cia-chio" and "Hitoma", *B. oleracea* ssp. *italica* "Unidentified local variety", and *B. caulorapa* ssp. "Grand Duke"

Chenopodiaceae: *Beta vulgaris* "Eckendorfer Gelbe"

Compositae: *Lactuca sativa* "Celtuce"

Solanaceae: *Capsicum annuum* "Tobasco", *Datura stramonium*, *Lycoper-*

sicon esculentum "Perou", Solanum melongena "Pintung Long", and Nicotiana sylvestris

Lamiaceae: Ocimum basilicum

Cucurbitaceae: Cucumis sativus "National Pickling" and Cucumis melo "Charentais"

Amaranthaceae: Amaranthus mangostanus

Leguminosae: Glycine max "Bragg", Medicago sativa "Maxidor", Phaseolus vulgaris "Pinto" and "Saxa", Pisum sativum "Dark Skin Perfection", Vicia faba, Vigna radiata "V2010", and Vigna unguiculata "Blackeye".

Most TuMV strains produced severe symptoms on Chinese cabbage, pai-tsai, rape, mustard, and radish. The following types of reactions were observed on these hosts: chlorotic or necrotic local lesions, severe mosaic, necrosis, and leaf deformation. Strain 1 infected only 5 of 18 Chinese cabbage cultivars, and induced either latent infection or mild mosaic.

Brassica species with n=9 chromosomes, such as common cabbage, cauliflower, broccoli, and kohlrabi, were frequently found to be immune to all five TuMV strains or at least to strains C1 and C2. Some cultivars were susceptible to strains C3, C4, and C5, which produced chlorotic local lesions on the inoculated leaves and mild mosaic symptoms on the non-inoculated leaves. Chlorotic ringspots were observed only twice on two cultivars of cauliflower. No necrotic ringspots were observed.

The results of this study and of previous screenings of AVRDC Chinese cabbage accessions and breeding lines for resistance to strains C4 and C5 indicate that resistance or immunity to these two strains is not commonly found in Chinese cabbage. So far only one Chinese cabbage line (AVRDC accession B 730), has been identified which carries immunity to all five strains. This line did, however, include a small percentage of individual plants susceptible to TuMV-C5, suggesting that it was not genetically pure.

Several non-cruciferous hosts could be identified as as possible TuMV differential cultivars: Helianthus annuus, Nicotinia rustica, Physalis floridana, and Impatiens balsamina "Royal Mixed Colors".

Conclusions

Accession B730's resistance to all five TuMV strains will be studied further to determine the mode of inheritance of the genetic factor(s) involved, and to assess their potential use as a source of resistance for AVRDC's Chinese cabbage breeding program.

Since genes for resistance to TuMV strains C1, C2, and C3 have already been located in several Chinese cabbage lines, it is important to continue the search for genes carrying resistance to TuMV-C4 and C5.

Screening of Chinese Cabbage Accessions for Resistance to TuMV

Introduction

Genes carrying resistance to TuMV-C1, C2, and C3 had already been located in several Chinese cabbage lines. Since resistance to TuMV-C5 and C-4 has been detected only in accession B730, however, it was decided to rescreen new germplasm for these two strains.

Materials and Methods

Twenty-five plants (or fewer when seed was unavailable in sufficient quantities) of each new accession (B750-B801) were artificially inoculated at the seedling stage (4-6 leaves) with sap from B. juncea plants infected with TuMV-C5. Accessions B783-B801 were also screened for resistance to TuMV-C1. Inoculum was prepared by grinding one part of TuMV-infected plant tissue in five parts 0.01M phosphate buffer, pH 7.0. The inoculated plants were kept in a growth room (26° day, 16-20°C night, 9000 lux) and observed for symptom development. Symptoms were recorded 21 days after inoculation. Several new accessions (B802-B812, B763, B792, B794, B795) were also inoculated with strain C1 under field conditions.

Disease ratings were based on disease incidence: R = 0-20% of plants infected, MR = 21-40% plants infected, MS = 41-75% plants infected, and S = more than 75% of the plants infected.

Results

All but three of the new accessions were rated susceptible to TuMV-C5. The remaining three were rated moderately susceptible. Of the 18 new accessions screened in the greenhouse for resistance to TuMV-C-1, immunity was found in ten (B748-790, B792, B793, B796, and B798) and resistance in two (B792, B797).

Of the ten new accessions (B802-812) which had been inoculated with C-1 in the field and left to be naturally infected with ambient TuMV strains, only B806 was rated immune.

To determine whether it also carries resistance to other strains of TuMV occurring in AVRDC fields, this accession will be tested by artificial inoculation under controlled greenhouse conditions.

Conclusions

Although resistance to TuMV-C5 is rare in Chinese cabbage, immunity to C1 is quite common. Resistance or immunity to C5 appears to be inherited independently of resistance or immunity to C1.

Statistical Analysis Programs

Although not strictly speaking a part of its research mandate, AVRDC's plant pathology unit developed a statistical analysis program which greatly facilitates its data analysis. Programs written for small pocket computers (Sharp PC 1500 or Radio Shack PC 2) allow maximum portability, and facilitate data analysis under adverse conditions. These particular machines were selected because of their small size, low cost, and the added feature of a built-in printer.

Programs are presently available for multiple regression analysis, analysis of variance, and probit analysis. The multiple regression analysis program is an adaptation of one developed by statistics personnel at AVRDC, and has been optimized for the small computer. It allows the input of either raw data or a sums-of squares and cross-products matrix, and permits the "intercept" component to be either a supplied variable or one generated internally by the program. The analysis of variance program handles both completely randomized and randomized complete block designs, and also allows the user to calculate contrasts of treatment means, standard deviation, "t" values, the probabilities of t values, and an LSD at a significance level of either one or five percent. The probit analysis program accepts as input dose levels, number of subjects and number responding. The logarithm of dose level may be optinally calculated, and probits are calculated internally making tables unnecessary. The probit line is fitted iteratively, and results include observed proportion, predicted probit, and slope and chi-square values. Although written specifically for the bacterial wilt data, this program would be useful for anyone using probit analysis.

Listings of these programs are available to interested persons, and they may also be obtained on cassette tape.

Chinese Cabbage Entomology

Use of Sprinkler Irrigation for Diamondback Moth Control

Introduction

Diamondback moth is a serious pest of crucifers only during the dry season, which at AVRDC usually lasts from October through April. Although summer temperatures are ideal for the insect's survival and multiplication, its infestation levels from May through September are minimal. In the summer of 1980, however, when Taiwan experienced a severe drought, much higher levels of diamondback moth infestation were observed. This made it seem as though frequent rains might be detrimental to the diamondback moth, and a preliminary experiment was therefore conducted to study the effects of three different irrigation methods on diamondback moth infestation.

Materials and Methods

A 0.2 ha field was rototilled and worked into 1.5 m wide beds. Three irrigation treatments were tested: furrow irrigation, sprinkler irrigation from one central point, and sprinkler irrigation from 1.5 m above the cabbage plants. Each treatment was replicated four times.

To supplement the ambient population of diamondback moth, two rows of cabbage were planted around the edge of the field and a large number of diamondback moth larvae and adults were released. Six weeks later, seedlings of common cabbage (cv. KK cross) were transplanted in two rows on each bed in 10 x 9 m plots. Water was applied to the furrow-irrigated plots when necessary, as judged by the dryness of the soil. Sprinkler-irrigated treatments were irrigated for five minutes at dusk every other day. All other standard cultural practices were followed, except that no insecticide was applied.

Experimental plots were twice evaluated for insect infestation when diamondback moth populations were especially high. The number of insect larvae and pupae was recorded for a 20 plant sample from each plot. Yield was determined at harvest by weighing the head without the outer leaves. Insect infestation and yield data were analyzed by Duncan's Multiple Range Test.

Results and Conclusions

Sprinkler irrigation significantly reduced insect infestation, and significantly increased the crop yield (Table 1). Reduced levels of insect infestation, however, may not have been the only reason for

increased yields. Frequent sprinkler irrigation keeps the soil continually moist, but furrow irrigation applied when judged necessary, the method used by most farmers, probably induces occasional water stress.

In addition to reducing insect infestation, this system also uses water more efficiently. The initial high investment required would in the long run be more than made up for by reduced water and insecticide costs.

Table 1. Effect of various irrigation methods on diamondback moth infestation and Chinese cabbage yield[z-x].

Irrigation methods	No. of DBM larvae+pupae /20 plants		Marketable Yield (t/ha)
	1/6	1/19	
Furrow irrigation	13.2a	84.9a	67.5b
Sprinkler, from central source	9.6b	51.6c	73.6ab
Sprinkler, from over head source	7.9b	60.7b	77.8a

[z] Cultivar: KK cross.
[y] Transplanting date: October 27, 1983.
[x] Harvest date: January 19, 1984.
[w] Data are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level. Plot size: 9 x 10 m.

Evaluation of Chemical and Biological Controls of Diamondback Moth, Cabbage Webworm, and Aphid

Introduction

Insecticides are widely used on vegetable crops throughout Southeast Asia. Since insect pests develop resistance to them, especially to the ones which are used frequently, new compounds or combinations of compounds must be screened for effectiveness before the target pest becomes resistant to those already in use. AVRDC has an ongoing project to screen insecticides for the control of various insect pests. Described here are the results of three such tests conducted during 1983.

Materials and Methods

The procedures were identical to those described in AVRDC's publication "Vegetable Pest Control: Insecticide Evaluation Tests". Each test included nine insecticides and one untreated check. Insecticides were chosen which had effectively controlled the target pests or related pests in previous tests conducted at AVRDC or elsewhere. An effort was made to include chemicals with modes of action different to those of insecticides currently in use. Each chemical or combination of chem-

icals was sprayed once a week on 4.5 x 3 m plots. Each treatment was replicated four times.

Efficacy was evaluated when the insect population was high. The number of insects found in a 10 plant sample from each plot was recorded at periodic intervals, and marketable yields were recorded at harvest. All data was analyzed by Duncan's Multiple Range Test.

Results

First test:

This test was conducted in the cool dry season, when diamondback moth and aphids are major pests. MK-936, an avermectin compound, and profenfos, an organophosphorus compound, gave best control of diamondback moth (Table 2). Deltamethrin and Bacillus thuringiensis SIII also provided good control.

Deltamethrin + heptanophos, triazophos, MK 936, profenfos, and deltamethrin gave superior control of aphids.

Aphid infestation had the greatest influence on Chinese cabbage yields; treatments in which aphids were effectively controlled had the highest yields.

Second test:

Since diamondback moth prefers it to Chinese cabbage, and since it is more tolerant of aphid damage, common cabbage was used in this test. During the second test the diamondback moth population was very high (Table 3).

A mixture of deltamethrin and B. thuringiensis SIII gave numerically better control of diamondback moth than did other chemicals, especially when the insect population was high. Bactospeine, phenthoate + fenvalerate, fenvalerate, permethrin, and deltamethrin were also effective.

Deltamethrin, permethrin, fenvalerate, and phenthoate + permethrin, provided good control of aphids.

All insecticide treatments gave better yields than did the untreated control.

Third test:

This test was done in the summer, when cabbage webworm was the major pest of Chinese cabbage. Insecticides MK936, profenfos, phenthoate, and parathion gave superior control of cabbage webworm (Table 4). Yields were significantly greater for these treatments than for the untreated check or for plots treated with any of the other insecticides.

Conclusions

Profenfos, deltamethrin, and MK936 gave superior control of diamondback moth, and profenfos, MK936, phenthoate, and parathion gave superior control of cabbage webworm.

Table 2. Evaluation of insecticides for the control of diamondback moth and aphids on Chinese cabbage.[z-t]

Insecticides	Rate (kg ai/ha)	No. of diamondback moth larvae+pupae /10 plants on			No. of plants/10 with estimated No. of aphids/plant				Yield (t/ha)
		2/2	2/23	3/4	0-10	11-100	101-1000	1000*	
Deltamethrin 2.8EC +heptanophos 40EC	0.0125+ 0.2	1.75abc	0.75de	5.75bcd	9.25a	0.50ab	0.25b	0.00c	75.6a
Dimilin 25WP + triazophos 40EC	0.075+ 0.25	1.75abc	1.25bcde	9.75abc	8.25a	1.50ab	0.25b	0.00c	78.8a
B. thuringensis SIII	0.5	0.75bc	1.00cde	3.00cd	1.75bc	2.00a	2.00a	4.25ab	61.6ab
Danitol 10EC	0.05	1.00bc	3.00a	6.00bcd	3.50b	1.25ab	2.25a	3.00b	65.4ab
MK-936 0.36SL	0.02	0.00c	0.00e	1.25cd	8.75a	0.75ab	0.25b	0.25c	70.0a
Dimilin 25WP	0.075	3.75a	2.50abc	13.50ab	1.75bc	2.00a	2.00a	4.25ab	62.3ab
Triazophos 40EC	0.25	1.00bc	1.75abcd	9.00abc	8.50a	1.25ab	0.25b	0.00c	73.7a
Proferfos 50EC	0.50	0.50bc	0.25de	0.25d	9.50a	0.25b	0.25b	0.00c	71.2a
Deltamethrin 2.8EC	0.025	0.75bc	1.00cde	6.75bcd	8.50a	1.00ab	0.25b	0.25c	73.5a
Control		2.75ab	2.75ab	16.25a	1.25c	1.00ab	2.00a	5.75a	52.3b

[z] Cultivar: New King.
[y] Transplanting date: 1/5/83.
[x] Insecticides applied: 1/13, 1/20, 1/27, 2/3, 2/10, 2/17, and 2/4.
[w] Observation date for aphids: 3/4.
[v] Harvest date:3/4.
[u] Data shown are means of four replicates. Means in each vertical columns followed by the same letter
[t] are not significantly different at the 5% level.
Plot size: 15 sq.m.

Table 3. Evaluation of insecticides for the control of diamondback moth and aphids on Chinese cabbage.[z-t]

Insecticides	Rate (kg ai/ha)	No. of diamondback moth larvae+pupae /10 plants on				No. of plants/10 with estimated No. of aphids/plant			Yield (t/ha)
		2/2	2/17	2/23	3/4	0-10	11-100	101-1000	
Bactospeine	0.5	15.5a	13.25abcd	39.25bcd	39.50c	2.00b	4.50ab	3.50ab	62.7a
B. thuringiensis SIII	0.5	14.0ab	13.75abcd	43.50bc	49.25bc	2.00b	4.75ab	3.25abc	61.9a
Deltamethrin 2.8EC + +B.t SIII	0.025+ 0.5	7.75bc	5.50cde	16.75e	19.25c	7.75a	2.25ab	0.00d	62.6a
Phenthoate 50EC + fenvalerate 20 EC	0.5 + 0.05	5.00c	4.25e	13.75e	31.00c	8.25a	1.25b	0.50bcd	61.4a
Phenthoate 50EC + permethrin 10EC	0.5+ 0.05	5.25c	14.00abc	24.50cde	53.00bc	8.50a	1.25b	0.25cd	58.9a
Phenthoate 50EC	0.5	17.00a	21.00a	70.00a	97.25a	2.50b	5.00a	2.50abcd	60.3a
Fenvalerate 20EC	0.05	5.50c	7.50cde	26.75cde	32.50c	7.75a	2.25ab	0.00d	63.3a
Permethrin 10EC	0.05	10.00abc	12.00abcd	27.00cde	35.25c	8.50a	1.25b	0.25cd	61.5a
Deltamethrin 2.8EC	0.025	8.00bc	5.00de	20.75de	40.00c	8.25a	1.75ab	0.00d	60.8a
Control		16.75a	18.50ab	55.50ab	75.75ab	1.25b	2.75ab	6.00a	52.8b

[z] Cultivar: K. Y. Cross.
[y] Transplanting date: 1/14/83.
[x] Insecticides applied: 1/28, 2/4, 2/11, 2/18, 2/25, 3/4, 3/11 and 3/18.
[w] Observation date for aphids: 2/25.
[v] Harvest date:4/4.
[u] Data shown are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level.
[t] Plot size: 15 sq.m.

Table 4. Evaluation of insecticides for the control of cabbage webworm on Chinese cabbage.[z-t]

Insecticides	Rate (kg ai/ha)	No. of larvae per 48 plants			Percent damaged plants per plot			Yield (t/ha)
		7/18	7/26	8/2	7/18	7/26	8/2	
Cypermethrin 2.5EC	0.05	6.33bc	4.33bcd	21.33bc	13.89bcd	16.67c	43.05c	19.02abc
Larvin 75WP	0.5	11.33b	9.33abc	17.67bc	13.22bcd	13.20cd	44.44c	17.31abc
Bendiocarb 40WP	0.5	6.33bc	8.00bcd	31.33ab	15.97bc	19.44bc	64.58ab	14.54bcd
MK936 0.36SL	0.02	0.00c	1.33cd	2.33c	1.39e	5.5de	7.64d	19.13abc
Profenfes 50EC	0.5	0.00c	0.00d	2.67c	0.00e	0.00e	8.33d	24.06a
Phenthoate 50EC	0.5	0.67c	0.00d	4.67c	6.25cde	5.55de	20.14d	19.50ab
Bactospeine 100EC	0.5	13.00b	16.67a	50.33a	17.36bc	27.78b	68.06a	11.55cd
Danitol 10EC	0.05	9.33b	4.67bcd	26.33b	20.83b	17.36c	52.78bc	13.29bcd
Parathion 47EC	0.5	0.33c	0.00d	0.67c	3.47de	2.08e	6.25d	18.74abc
Control		31.67a	11.00ab	33.33ab	47.92a	48.61a	74.31a	7.42d

[z] Cultivar: Hybrid No. 62.
[y] Transplanting date: 7/5/83
[x] Insecticide applied: 7/8, 7/12, 7/15, 7/19, 7/22, 7/29, and 8/5.
[w] Sampling dates: 7/18, 7/26, 8/2.
[v] Data shown are means of four replicates. Means in each vertical columns followed by the same letter are not significantly different at the 5% level.
[u] harvest date: 8/12.
[t] Plot size: 14.85 sq.m.

Sweet Potato Breeding

Germplasm Collection

In 1983 a total of 366 sweet potato clones and 2,048 seeds were collected from Taiwan, Indonesia, Japan, Puerto Rico, the Phillipines, and Tonga (Table 1). From these, 354 accessions were established after observation and multiplication. These materials are now being evaluated for yield and horticultural characteristics, and are being characterized according to standard IBPGR descriptors. By December of 1983 AVRDC's sweet potato germplasm collection included 1,200 acessions.

In 1983 AVRDC was designated by the International Board for Plant Genetic Resources (IBPGR) as the international repository for sweet potato germplasm in Asia and the Pacific.

Table 1. AVRDC sweet potato introductions in 1983.

Source	Material	Number introduced	Number established
Taiwan, ROC	clone	330	322
Indonesia	clone	13	13
Puerto Rico	clone	9	9
Japan	clone	6	6
Tonga	clone	4	0
Philippines	clone	3	3
USA	clone	1	1
	seed	2048	-
Total	clone	366	354
	seed	2048	-

Hybridization and Outcrossing Populations

Crossing efforts in 1982-83 focused on improving the organoleptic qualities and nutritional characteristics of staple and dessert types, on improving the dry matter and starch yields of feed and industrial types, and on incorporating into both of these types, resistance to sweet potato weevil and witches' broom. In addition, outcrossing

populations for low sugar, high protein, and bush-type lines were continued in 1983. A total of 214,837 seeds were collected from hand, open pair, and polycrossing nurseries (Table 2).

Table 2. Sweet potato hybridizations in 1983.

Crossing type	Purpose	No. of combinations	No. of seeds obtained
Handcross	To improve dessert lines	22	8,194
	To improve staple lines	14	4,195
	To improve feed lines	8	1,172
	To improve industrial lines	12	2,139
Open pair	To incorporate witches' broom resistance	2	19,712
	To improve weevil resistance	2	1,198
Polycross	To develop low-sugar lines	-	10,820
	To develop high-protein lines	-	7,435
	To develop bush-type lines	-	11,407
	To maintain Jones' population	-	70,393
	Other	-	78,172
Total		60	214,837

Seedling Screening and Observational Trials

Introduction

In 1983 as many as 214,837 true sweet potato seeds were collected from various sources, and the lack of reliable and rapid screening techniques for measuring their yield potential and stability was a major problem. To reduce the number of clones in the yield trials, rigorous selections were made for both dry matter and protein content at the seedling stage and at the first vegetatively propagated stage.

Materials and Methods

Seedling screening:

A total of 48,050 seeds collected from various populations in 1982 and 1983 were sown on April 26 and June 10, and were screened from September 1 through October 20. Selections were primarily made for qualitative traits such as plant type, flesh and skin color, and the appearance and shape of the storage root. Two other seedling screening techniques were used to identify superior genotypes in the field - rapid dry matter determination using specific gravity (see AVRDC's 1982 Progress Report) and rapid protein determination using an indicator

paper test (see the Nutrition Chemistry section of this report). So that enough planting materials could be produced for the observational trial, immediately after screening the cuttings from the selected clones were transplanted to the field for multiplication.

Observational trial:

A total of 2,731 clones screened from seedlings in 1982 were planted from October 5 through October 28, 1982 for observation of yield and horticultural characteristics. Five cuttings from each clone's multiplication plot were transplanted to the field in rows 1 m apart, with 0.4 m between plants. Control cultivars Tainan 15 and AIS 35-2 were planted every 40 clones. Selections were made on the basis of yield, dry matter content, and the appearance and uniformity of the roots. For further selection selected clones were grouped into orange-fleshed and yellow or white-fleshed clones.

Results

Seedling screening:

A total of 2,731 clones were selected from 48,050 seedlings derived from true seeds. The mean selection rate of all populations was 5.7% (Table 3), lower than in any previous year at AVRDC. The specific gravity method of assaying dry matter content at the seedling stage has greatly reduced the number of clones which must be advanced to yield trials. Selection rates in various populations ranged from less than 2% to 7%. In general, hand crossed populations had the highest selection rate, followed by polycrossed and Co^{60} treated populations. The open-paired population for combining weevil and stemborer resistance had the lowest selection rate (Table 3).

Table 3. Selection rate of seedling screenings in various populations in the summer of 1983.

Population	No. of seeds sown	Specific gravity	Selection	
			number	rate(%)
Hand cross	16,295	1.02	758	4.7
Isolated open-pair	4,198	1.02	59	1.4
Isolated polycross	10,550	1.02-1.04	582	5.5
Co^{60} treatment	4,000	1.02	205	5.1
Non-isolated polycross	15,607	1.02-1.04	1,080	6.9
Introduced[z]	1,000	1.02	47	4.7
Total	51,650	-	2,731	5.3

[z] Introduced by Dr. J. Bouwkamp, University of Maryland, USA.

The specific gravity used to screen seedlings for dry matter varied from 1.02 to 1.04, and was high enough to maintain a selection rate of 5 to 10% in most populations. Previous studies indicate that clones of such densities should have a dry matter content of at least 25%.

Observational trials:

A total of 142 orange-fleshed and 197 white or yellow-fleshed clones were selected from the observational trials. Total root yields ranged from 10.7 to 100 t/ha in the first population (Fig. 1), and from 15.2 to 94.0 t/ha in the second population (Fig. 2). The mean dry matter yield in the dry season at AVRDC was 10.3 t/ha for the orange-fleshed population (Fig. 3) and 11.95 t/ha for the white- or yellow-fleshed population (Fig. 4). Using the specific gravity method to screen rigorously for dry matter content at the seedling stage, then, did not reduce the total dry matter yield of the population; enough genetic variation exists in AVRDC's present populations so that high-yielding clones can be selected which also have a high dry matter content. By comparing the distribution of dry matter yields in each year's populations it can be seen that the dry matter content of AVRDC populations has been substantially increased over the past two years.

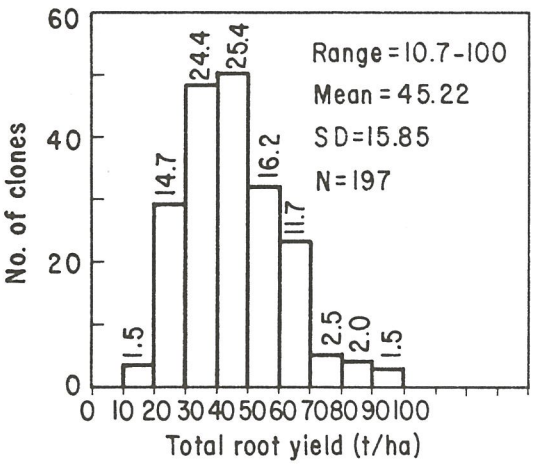


Fig. 1. Distribution of total root yields of selected orange-fleshed clones in observational trials, fall 1982.

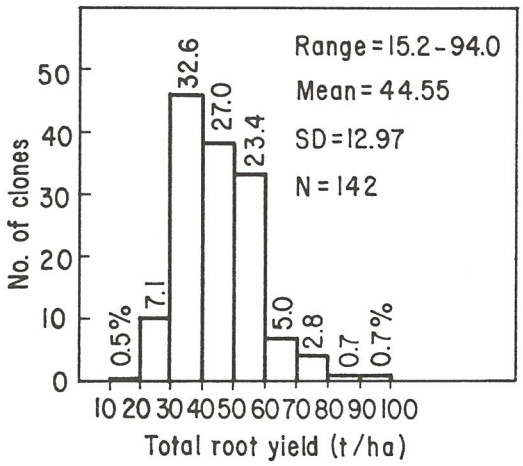


Fig. 2. Distribution of total root yields of selected yellow-fleshed clones in observational trials, fall 1982.

Conclusions

Rapid field screening using specific gravity as an indicator allows AVRDC breeders to rigorously and accurately screen a large seedling population for high dry matter content. Even more importantly, this selection method has proven effective in raising the dry matter yield of AVRDC's entire breeding population. Thus, AVRDC's populations can be screened for high yielding clones which also have a high dry matter content, and further selections can then be made for yield stability and agronomic characteristics.

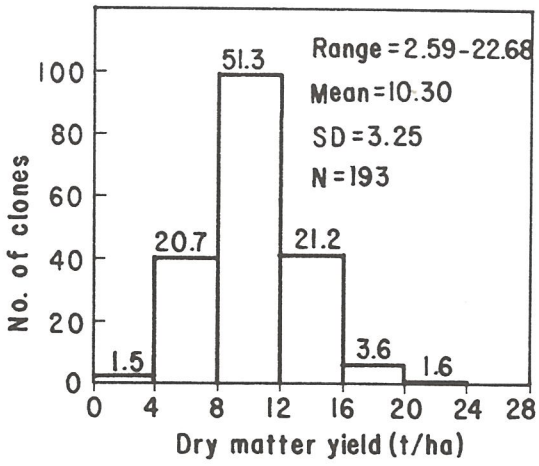


Fig. 3. Distribution of dry matter yields of selected orange-fleshed clones in observational trials, fall 1982.

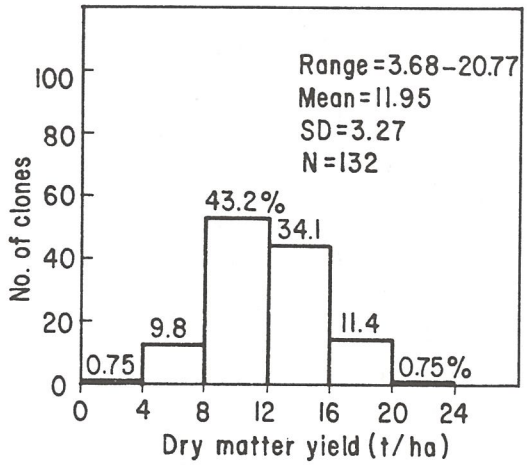


Fig. 4. Distribution of dry matter yields of selected yellow-fleshed clones in observational trials, fall 1982.

Wet Season Yield Trials

Introduction

Selection for adaptation to hot, wet environments is one of the principle objectives of AVRDC's breeding program. In Taiwan the wet season lasts from April to October. Precipitation during this period usually totals about 1,500 mm, and temperatures range from 25 to 30° C. Similarly adverse environments are responsible for low yields in many of the sweet potato growing areas of Southeast Asia and the Pacific.

Materials and Methods

After being divided into 16 groups according to their utilization types and previous performance, 172 entries were evaluated in replicated trials planted on July 11 and harvested between December 12 and 20. Each 10 m^2 plot had 40 plants. Local cultivar Tainung 65 and AVRDC selection AIS 35-2 were used as standard checks in all groups. Selections were based on yield, root appearance and uniformity, dry matter content, nutritional content (β-carotene, sugar, and starch contents), and organoleptic qualities.

Results

Marketable root yields in the preliminary trials ranged from 0.2 to 34.2 t/ha, with a mean of 10.4 t/ha (Fig. 5). The mean dry matter

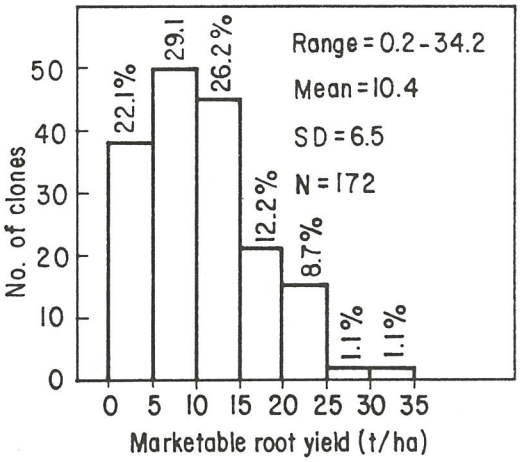


Fig. 5.
Distribution of the marketable root yields of selected clones in preliminary yield trials, 1983 wet season.

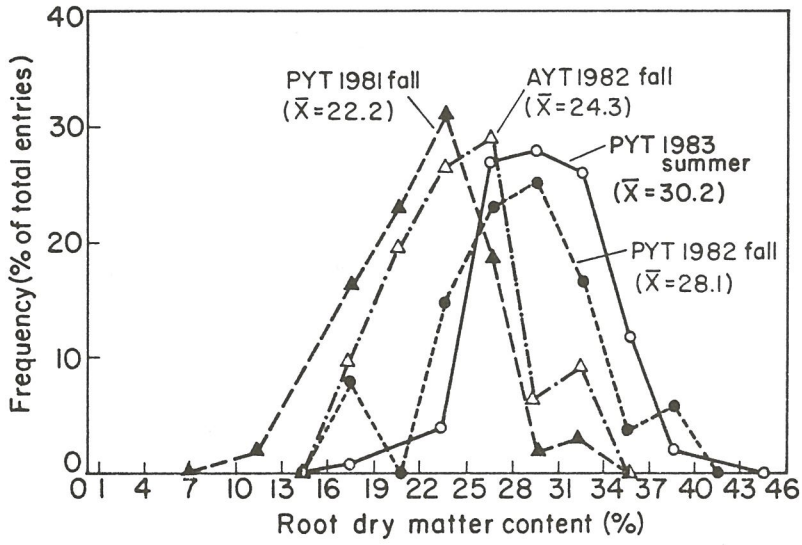


Fig. 6. Distribution of the dry matter contents of various sweet potato populations.

content of this population was 30.2%, 2% higher than that of the population tested in the dry season of the previous year (Fig. 6).

Mean dry matter yields were 3.5 t/ha (Fig. 7). Fourteen selections had significantly higher dry matter yields than did control cultivar AIS 35-2, and 23 entries (13.4%) had dry matter yields of over 6 t/ha (Fig. 7), a figure considered quite high for the hot, wet season.

Thirty seven entries (21.5%) with superior yield and horticultural characteristics were selected for further evaluation (Table 4). They will be grouped according to utilization type in the next evaluational trials. In addition, eight selections with specific characteristics (e.g. CN 1423-90, with a 38% dry matter content) were chosen as parental materials.

Selection CN 1308-1's excellent eating qualities and attractive root shape made it the best dessert cultivar of the trial. Selections CN 1421-243 and CN 1423-557, which both have dry matter contents of over

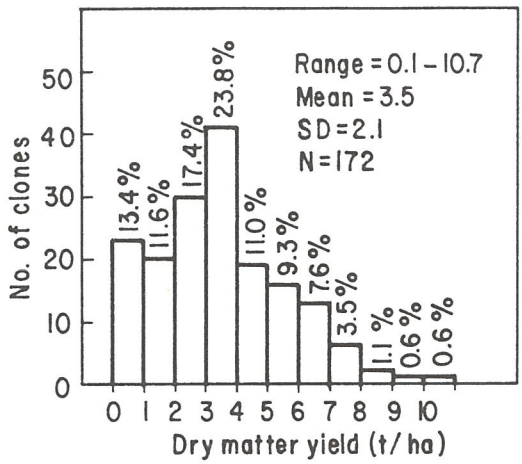


Fig. 7.
Distribution of dry matter yields of selected clones in preliminary yield trials, 1983 wet season.

Table 4. Characteristics of breeding lines selected from preliminary yield trials[z] held in the summer of 1983.

Entry	Appearance	Uniformity	Flesh color	Marketable root yield[y]	Dry matter[y]	Biological yield	Eating quality	Utilization type
Group A								
CN1308-1	G	G	Y	20.2*	29.1*	53.8	E	Dessert/Staple
CN1345-8	F	F	Y_1	21.8*	32.5*	68.7	F-G	Feed/Ind
CN1421-68	G	G	O_3Y_2	17.5	34.6*	36.0	G	Dessert
CN1424-36	G	F	O_3Y_4	24.9	30.1*	56.2	F	Feed
CN1419-57	F	F	Y_3	20.7	32.6	60.6	P-F	Ind
CN1423-557	G	G	Y_3	21.6	35.1	62.6	G	Staple/Ind.
CN1419-193	F	F	Y_2	15.1	35.8*	28.2	F-G	Ind.
CN1419-224	F	F	Y_2	20.0	36.8*	43.7	F-G	Ind.
CN1421-243	G	G	Y_4O_1	18.3*	35.7*	95.2	F-G	Staple/Feed
Group B								
CN1424-9	G	G	O_3Y_4	15.8	26.5	64.2	F-G	Dessert
CN1346-8	F	F	Y_4	12.3	32.1*	45.5	-	-
CN1419-139	F	G	O_4	16.9	35.8*	39.6	F-G	Dessert
CN1308-6	G	G	O_6	22.7	29.7*	41.4	F	Dessert
CN1304-11	E	G	O_4Y_3	21.2*	29.7*	41.4	F	Dessert
CN1424-4	P	P	Y_6	20.9*	29.3	39.5	-	Feed
CN1407-8	F	P	Y_2	15.4	31.3*	51.6	-	-
CN1423-114	G	F	Y_4	16.2	31.7*	44.1	G	Staple
CN1423-41	F	F	Y_4	16.5	32.4*	41.5	F	Feed
CN1346-9	P-F	F	Y_1	13.8	43.4*	45.3	G	Staple/Ind.
CN1405-114	F	P	Y_2	18.6	33.6*	36.5	G	Ind.
CN1424 NH-4	F	G	Y_5O_1	30.0*	29.4	49.4	F-G	Staple
CN1421-153	G	G	O_3Y_2	21.6*	27.3	63.7	P-F	Feed
CN1421-56	F	G	O_2Y_5	15.8*	33.2*	54.9	-	-
AIS 35-2 (check)[x]	G	G		14.3	29.1	50.9	F-G	Dessert

[x] Common control cultivar used in all groups
[y] * = significantly higher than the control cultivar at p = 0.05 in the same trial.
- = significantly lower than the control cultivar.
[z] Selected from 172 entries. Planted on July 11, 1983, harvested on December 12-20, 1983. Replicated 2-3 times.

35%, are promising lines for use as a staple food or for starch extraction. With a total biological yield (roots plus vines) of 95.2 t/ha, CN 1421-243 would make an excellent animal feed.

Conclusions

On the basis of these trials, 37 elite lines were selected for further screening for agronomic characteristics and for adaptability to hot, wet environments. Most of them yielded more than 20 t/ha in hot, wet conditions, and all of them had a higher dry matter content and dry matter yield than those selected in previous years. in these trials significant progress was also made toward the development of cultivars especially suited for human consumption, for animal feed, or for industrial use.

Measurement of Yield Stability in Multi-Location Yield Trials

Introduction

Measuring the yield stability of an improved cultivar over a wide range of environments is one of the most difficult tasks the sweet potato breeder must face. Such efforts are greatly restricted by international quarantine requirements, and even though AVRDC has recently developed disease-free meristem cultures for international testing of elite germplasm, these cultures grow slowly and have a low survival rate.

Thus, in order to better understand the nature of the yield stability and performance of AVRDC's breeding materials under varied environments, a multi-locational yield trial was conducted in ten locations within Taiwan during the hot, wet and the cool, dry seasons of 1983. The specific objectives of this project were 1) to evaluate the adaptability of promising selections to varied environments, 2) to indentify the disadvantages of these selections when grown in the farmer's field in varied environments and with varied cultural practices, and 3) to better understand the nature of sweet potato's yield stability and how it can be accurately measured.

Materials and Methods

In 1983 five advanced selections from the AYT and ten preliminary selections from the PYT were evaluated with four control cultivars in ten locations during the wet season, which lasts from April through November. In 1983 and 1984 similar materials were planted in the cool, dry season, but only the results of the wet season trials are reported here. The materials, locations, and experimental design are described in Tables 5 and 6.

Plots were spaced 1 m apart and arranged in an RCB design. Each received 40 kg/ha N, 60 kg/ha P_2O_5, and 160 kg/ha K_2O. Soil and chemical composition analyses and organoleptic tests were conducted according to standard AVRDC procedures.

Stability analysis was a modified regression analysis as described by Finlay and Wilkinson (1963), Eberhart and Russel (1966), and Langer and Bailey (1979).

Table 5. Elite sweet potato selections and check varieties tested in multi-location, summer yields trial in 1983.

Acc. no. or cross no.	Pedigree/entry name
AYT	
CN 1028-15	PI 344129/B6708(OP)//57(OP)-4
CN 1108-13	PI 344129//HDK 6/B7078///Tainung 63
CN 1058-10	B6708(OP)//Tainung 27//HDK///PI344129//OK8-28/Rose centennial (OP)
CN 942-47	B6712 (OP)
CN 1038-16	PI 344129//Red Tuber Tail/OK 63-3-118///AIS 057-4
AIS 0122-2*	Southern Queen/OK 6-3-106
I 57**	Tainung 57 (TN 57)
AIS 35-2*	HDK 6/B6708
I 430*	Tainung 65 (TN 65)
PYT	
CN 1232-9	Centennial/OK 6-3-106//Kyushu No. 12 (OP)
CN 941-32	PI 286621 (OP)
CN 1280-3	Centennial/OK 6-3-106//Kukei No. 53
CN 1229-16	Centennial/OK 6-3-106//Kukei No. 63
CN 1219-1	Kukei No. 63/Poly Tainung 57 (2)
CN 1216-10	Kukei No. 63//Centennial/OK 6-3-106
CN 1229-2	Centennial/OK 6-3-106//Kukei No. 53
CN 1229-14	Centennial/OK 6-3-106//Kukei No. 63
CN 1221-1	Nun Lin No. 17 (OP)/Kukei No. 63
CN 1280-4	Centennial/OK 6-3-106//Kukei No. 53

* Check cultivars developed at AVRDC.
** Check cultivars developed at Chia Yi Agr. Exp. Station.

Table 6. Description of the multi-locational, summer yield trial, 1983.

Locations	No. of entries	No. of replications	Plot size (m^2)	Planting date	Harvesting date
Suilin	20	2	10	4/14/83	9/14/83
Taipou	10	2	20	4/18/83	9/18/83
Yuanchang	10	2	20	4/18/83	9/18/83
Penghu DAIS	20	2	10	5/3/83	10/3/83
Taoyuan DAIS	20	2	10	5/17/83	10/18/83
Chinshan	10	2	10	5/18/83	9/23/83
Taichung DAIS	20	2	10	5/20/83	10/19/83
Taitung DAIS	20	2	10	5/24/83	10/27/83
Hualien DAIS	10	2	10	5/25/83	10/25/83
AVRDC	20	4	20	1/14/83	11/11/83

Results

Yield and yield components:

Root yield and dry matter, protein, and starch contents are shown in Table 7. Yields ranged from 29.2 to 46.6 t/ha. At 46.6 t/ha, CN 1028-15 had the highest mean yield over ten locations, and outyielded AIS 0122-2, AVRDC's highest yielding check cultivar. The lowest yielding selection observed was CN 1038-16, which at 29.2 t/ha still yielded 73.8% more than TN 65, the lowest yielding check. Selection CN 1028-15 also produced the highest mean dry matter yields of 11.4 t/ha.

PYT selections CN 1232-9 and CN 941-32 yielded more than 20 t/ha of fresh roots, roughly 6% less than AIS-0122-2, the highest yielding check cultivar, and 60.7% more than TN 65. Selections with at least 30% dry matter yielded a relatively low 7.1 to 19.9 t/ha, with a mean of 16.2 t/ha.

Most AYT materials had sugar contents ranging from 16.2 to 26.9%, and β-carotene contents ranging from 0.7 to 8.2%. Selection CN 1028-15, which yielded 46.6 t/ha and had relatively high dry matter and protein contents, was rated "good" in organoleptic tests, and local cultivar TN 57 was rated "excellent". Half of the PYT materials were rated "good", with moderate sweetness and acceptable texture.

Table 7. Root yields and dry matter, protein, and starch contents of elite sweet potato selections from multi-location, summer yield trials; 1983.

	Root yield (t/ha)[z]		Dry Matter[z]		Protein[y]		Starch[x]	
	Total yield (t/ha)	Market yield (t/ha)	% of dry weight	DM yield (t/ha)	% of dry weight	Protein yield (t/ha)	% of dry weight	Starch yield (t/ha)
AYT								
CN1028-15	46.6a	40.1a	24.5c	11.417a	4.7a	0.54	47.4c	5.41
CN1108-13	33.7b	28.7b	25.1c	8.458bc	3.7bc	0.31	58.6b	4.96
CN1058-10	30.8bc	26.1bc	23.1d	7.115cd	4.5ab	0.32	49.3d	3.51
CN942-47	31.5bc	27.1bc	25.0c	7.875bc	3.7cd	0.29	53.1c	4.18
CN1038-16	29.2bc	24.5bcd	28.8a	8.410b	3.1d	0.26	63.2a	5.31
AIS0122-2(CK)	28.6bc	23.8cd	20.0e	5.72 ef	5.0a	0.29	45.6d	2.61
TN 57 (CK)	28.4bc	23.7cd	26.7b	7.583cd	3.4d	0.26	58.4b	4.43
AIS 35-2 (CK)	25.3c	20.3d	25.1c	6.350de	4.0bc	0.25	55.0bc	3.49
TN 65 (CK)	16.8d	14.3e	29.5a	4.956f	3.2d	0.16	62.9a	3.12
PTY								
CN1232-9	27.0	24.8	28.4	7.668	4.1	0.31	66.0	5.06
CN941-32	24.0	23.7	26.6	6.384	4.0	0.26	57.2	3.65
CN1280-3	29.5	16.6	28.1	5.479	4.4	0.24	63.8	3.49
CN1229-16	19.1	17.0	34.1	6.513	4.2	0.27	65.5	4.27
CN1219-1	19.9	17.5	30.3	6.029	4.1	0.25	65.8	3.97
CN1216-10	18.1	16.8	30.2	5.466	4.6	0.25	62.8	3.43
CN1229-2	18.4	15.4	33.1	6.10	4.2	0.26	63.1	3.85
CN1229-14	14.4	13.2	33.9	4.881	4.4	0.21	62.6	3.06
CN1221-1	16.4	14.5	37.1	6.084	4.6	0.28	66.2	4.03
CN1280-4	7.1	5.5	30.2	2.144	4.4	0.10	61.1	1.31

[x] AYT mean of ten locations; PYT mean of six locations.
[y] AYT mean of nine locations; PYT mean of six locations.
[z] AYT mean of eight locations; PYT mean of five location.

Yield and growing environments:

Mean temperature and cumulative precipitation during the growing period are shown in Table 8. The maximum and minimum temperatures recorded during the entire growing period were 33 and 23.2° C. Total rainfall during the five-month experimental period ranged from 532 mm to 1152 mm. Soil type varied from sandy loam to clay loam. The percentage of organic matter ranged from 0.22 to 2.97%, and the pH from 4.67 to 7.62. This range of environments was well-suited to measuring adaptability and yield stability in the hot, wet season.

Table 8. Rainfall (mm) and temperature (°C) of different experimental locations in MLYT; summer, 1983.

Locations	Rainfall 150 days total (mm)	Temperature (°C)		
		Maximum	Minimum	Mean
Suilin	900.9	31.0	23.2	27.1
Taipou	1152.0	31.9	23.3	27.6
Yuanchang	901.0	31.0	23.2	27.1
Kinshan	904.7	29.5	23.4	26.5
Penghu	-	-	-	-
Taoyuan	848.2	32.4	24.4	28.4
Taichung	513.9	33.5	24.3	28.9
Taitung	558.3	32.0	24.9	28.5
Hualien	718.0	30.5	23.9	27.2
AVRDC	1021.8	31.8	24.8	28.3

Table 9 shows the marketable root yields of all selections grown at each location. The selections with the highest mean marketable yields were CN 1028-15 and CN 1239-9, which yielded 68.5% and 42% more than AIS 0122-2, the highest yielding control cultivar. The mean yield of Tainung 65, the lowest yielding control cultivar, was significantly lower than that of most AVRDC selections. Recently released by the Chiayi Agricultural Experimental Station for dry season production, Tainung 65 is apparently not well adapted to hot, wet environments.

Optimum sweet potato yields can be obtained with 520-660 mm of precipitation over a four month period (AVRDC, 1976), but yields in Taichung and Tainan Counties, which both fell within that precipitation range, were surpassed by yields in Taipou and Yuanchang counties, which received over 900 mm of precipitation, and had slightly higher temperatures. Although the yield potential of many selections was greatly affected by these differences, some selections gave good yields over a wide range of environments. Overall mean yields ranged from 13.1 to 55.3 t/ha. Dry matter content appeared to be affected by the amount of precipitation in each location. The higher the accumulated precipitation, the lower was the dry matter content and the dry matter yield. Protein content ranged from 2.5 to 6.1% of dry weight, and sugar content from 15.2 to 52.3% of dry weight.

Table 9. Marketable root weight (t/ha) of selections in multi-location wet, season trials, 1983.[z]

Entry	Suilin	Taipou	Yuanchang	Penghu	Taoyuan	Taipei	Taichung	Taitung	Hualien[z]	AVRDC	Mean
AYT											
CN1028-15	21.0a	48.0a	59.0a	31.0a	44.4a	49.4a	34.3a	50.1a	48.6a	15.0b	40.1a
CN1108-13	16.0b	31.1abc	39.0b	19.2cde	42.2a	24.3bc	24.4cdef	31.0bcd	43.5a	16.0ab	28.7b
CN1058-10	16.4b	29.0bcd	40.0b	20.0cd	29.0abcd	32.4b	26.4bcde	27.0cd	28.7d	12.2bc	26.1bc
CN942-47	14.4bc	41.0ab	29.0bc	15.3def	35.0abc	26.0bc	22.0defg	35.0bc	34.6bc	19.0a	27.1bc
CN1038-16	15.0bc	36.1abc	31.0bc	17.0cdef	17.4def	25.0bc	21.2defg	42.0ab	30.3cd	10.0cde	24.5bcd
AIS0122-2	12.0bc	33.3abc	38.0bc	14.2def	30.0abcd	24.0bc	12.1hij	26.5cd	37.8b	10.0cde	23.8cd
TN57	8.0def	30.3bc	35.2bc	14.1def	31.0abcd	28.0b	21.0defg	19.1de	35.6bc	15.0b	23.7cd
AIS35-2	9.0def	23.0cde	35.3bc	15.0def	26.0bcdef	24.0bc	16.2ghi	21.0de	21.9e	11.0cde	20.3c
TN65	2.0h	13.0de	27.0bc	10.2f	14.2ef	12.0c	11.0ij	23.0cde	27.1de	4.0fg	14.3e
PYT											
CN1232-9	11.0de			27.4ab	39.2ab		29.2abc	31.0bcd		11.0cd	24.80
CN941-32	9.0def			23.0bc	24.0bcdef		27.1bcd	44.0ab		15.0b	23.68
CN1280-3	9.3def			13.2bc	29.1qbcde		22.1defg	19.0de		7.0ef	16.62
CN1229-16	10.0def			15.0def	24.4bcdef		21.2defg	22.1cde		9.0cde	16.95
CN1219-1	3.0h			16.0cdef	29.1abcde		20.0efg	26.0cd		11.0cd	17.52
CN1216-10	7.3efg			16.0cdef	20.0cdef		21.4defg	28.1cd		8.2cde	16.83
CN1229-2	8.0ef			17.0cdef	18.2def		19.0fgh	22.0cde		8.2cde	15.4
CN1229-14	10.3de			13.0ef	17.0def		18.4fgh	17.3def		3.0g	13.16
CN1221-1	6.4fg			11.0f	18.3def		21.0defg	20.0de		10.0cde	14.45
CN1280-4	0.8h			1.4g	12.3f		6.0j	10.0ef		2.2g	5.45
C.V. (%)	17.0	25.0	16.0	18.3	26.0	24.4	14.0	22.2		24.3	

[z] Total root weight.

Measurement of yield stability:

A regression of the nine AYT cultivars' yield stabilities is shown in Table 10.

By definition, a stable-yielding cultivar should have the smallest possible regression coefficient (b) and deviation from regression (S^2d), but the largest possible coefficient of determination (r^2), meaning that it would perform equally well under all environments. Ideally, however, a cultivar should respond to additional inputs when it is grown in better environments. The perfect cultivar, then, would be one in which $b \doteqdot 1$, $S^2d \doteqdot 0$, and $r^2 \doteqdot 1$. It would also have a high mean yield in all environments.

Table 10. Mean yield, regression response index (b), coefficient of determination (r^2), mean square due to deviations from regression (S^2d) for 9 sweet potato cultivars grown in 8 environments in summer 1983.

Variety/selection	Mean yield (t/ha)	B	r^2	S^2d
V1 CN 1028-15	42.2	1.47	0.95	9.0
V2 CN 1108-13	28.4	0.98	0.76	23.4
V3 CN 1058-10	27.5	0.80	0.82	11.2
V4 CN 942-47	27.2	0.98	0.70	31.7
V5 CN 1038-16	25.6	0.85	0.49	56.0
V6 AIS 0122-2	23.8	1.16	0.90	11.2
V7 Tainung 57	23.3	1.03	0.81	18.5
V8 AIS 35-2	21.2	0.91	0.88	9.6
V9 Tainung 65	14.1	0.82	0.75	18.0
Mean	25.9	1.00	0.78	18.8

Regression coefficients ranged from 0.81 to 1.47 (Table 10). Although CN 1028-15, the highest yielding selection, had the highest regression coefficient, it also had the largest coefficient of determination (r^2= 0.95) Thus, even though unstable, it responded more positively to favorable environmental conditions (Fig. 8). Tainung 65, the low yielding control cultivar, had small b (0.82) and r^2 (0.75) values. It gave stable yields in different environments, but did not respond as well as CN 1028-15 to more favorable conditions.

When an entry's correlation coefficient was plotted against its average yield, most entries were shown to give average yields of average stability (Fig. 9). Except for CN 1028-15 and Tainung 65, most of the tested cultivars showed acceptable levels of adaptability. The deviation of all varieties from linear regression also varied from one location to another, but relatively small deviations were found in both the lowest and highest yielding locations (Table 11). It is difficult to explain why most varieties had a more linear response to environmental conditions when tested under especially favorable or unfavorable conditions, but the existence of such a phenomenon does suggest that it might be possible to select or even artificially create an optimum environment for measuring yield stability.

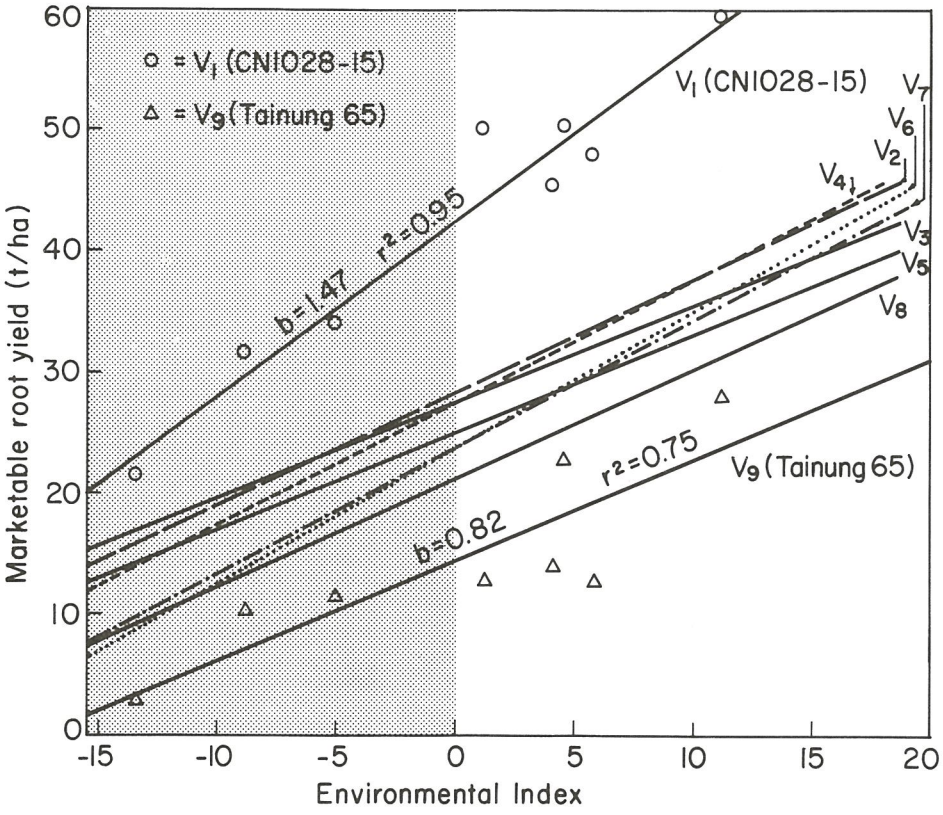


Fig. 8. The response of nine sweet potato cultivars to different growing environments in Taiwan, summer 1983.

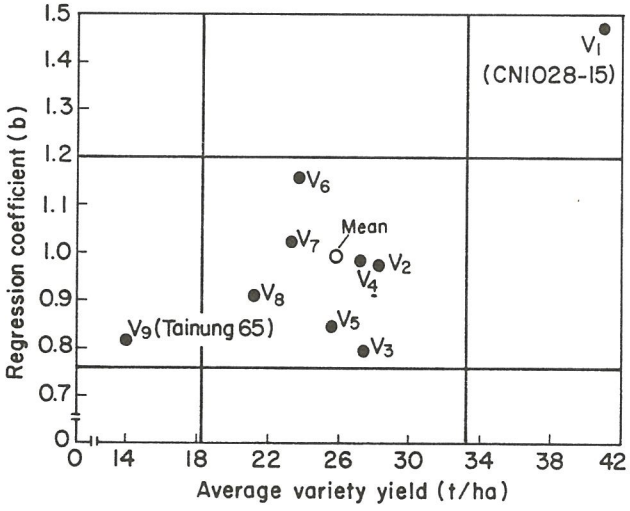


Fig. 9.
Relationship of the average variety yield and stability of nine sweet potato cultivars grown in eight locations in Taiwan, summer 1983.

Conclusions

On the basis of trials at ten locations during Taiwan's wet season, ten elite selections exhibiting excellent adaptability to hot, wet

Table 11. Average responses of sweet potato selections grown at eight locations in Taiwan, summer 1983.

Location	Average Yield (t/ha)[z]	Environmental index	Deviation[y]
Yuanchang	37.1a	11.2	145
Taipou	31.6b	5.7	178
Taitung	30.5bc	4.6	324
Taoyuan	29.9bc	4.0	293
Kinshan	27.2c	1.3	106
Taichung	20.9d	-5.0	53
Penghu	17.3d	-8.6	30
Suilin	12.6e	-13.3	21
Mean	25.9	-	-

[z] Mean marketable root yield of 9 varieties, separated by Ducan's Multiple Range test at the 5% level.
[y] Sum of the square of the deviation from linear regression of all varieties.

environments were identified for release to national programs. Selections CN 1108-13, CN 1058-10, CN 941-32, and CN 1280-3 are suitable for human consumption, and CN 1028-15, CN 1229-16, CN 1219-1, and CN 1221-1 are suitable for animal feed or starch extraction. Most selections had mean yields over ten locations of at least 20 t/ha. One, CN 1028-15, had a mean yield of more than 40 t/ha (11.4 t/ha of dry matter). Although such results suggest a bright future for the development of cultivars suited to a wide range of tropical environments, more emphasis should be placed upon understanding the physiological basis for these cultivars' high yields and excellent adaptability.

An analysis of yield stability parameters showed that most of the promising cultivars gave average yields of average stability. Deviations from a linear response to environmental conditions were found to be smallest in unfavorable environments, which would seem to indicate that a cultivar's yield stability could be assessed more accurately in such environments. More detailed studies are needed, however, to identify the best environments for measuring yield stability at the early selection stages.

Selection of Sweet Potato Cultivars Suitable for Cultivation as Vegetable Greens

Introduction

Sweet potato greens, which include leaves, stems, and petioles, are consumed in many parts of Asia and Oceania, and are particularly rich in vitamins A and B_2. They also contain substantial amounts of protein - almost 20% dry weight. Sweet potato leaves, are in fact, one of the cheapest sources of major nutrients in Asia. They are also far more

tolerant of tropical pests than are most other leafy vegetables, and for a short period of time can actually survive total immersion in water. Indeed, in Taiwan sweet potato tips are one of the few green vegetables that can be found in the markets immediately after a typhoon.

Despite these advantages, the lack of high yielding, tender cultivars makes sweet potato greens relatively unpopular in the tropics. Only the distal 10 cm is tender enough to be consumed as a vegetable, and most conventional prostrated cultivars yield less than 10 t/ha of edible tips. This study was aimed at selecting more tender cultivars, and bush or semi-bush plant types which were more branchinged than the prostrate types, and thus potentially higher yielding in terminal tips.

Materials and Methods

Four cross combinations were made between Dilaw, the tenderness source, and selected clones from the previous crosses. Sixty-five clones established from 260 seeds were evaluated in observational trials grown from October 28, 1982 through January 31, 1983. Light yellow-green selection CN 1367-2 was selected for its exceptional tenderness, excellent organoleptic qualities, and attractive leaf color. It was then evaluated for yield against Dilaw in a replicated trial grown from April 15 through August 12, 1983. A completely randomized design was used with two replications. Plot size was 11.25 m^2.

Hills were planted 40 cm apart, with two rows on each 1.5 m bed, and 30 plants per plot. Plots received three applications of 90 kg/ha N, 60 kg/ha P_2O_5, and 80 kg/ha K_2O, plus four furrow irrigations at monthly intervals. No fungicides nor pesticides were applied during the entire growing period. 10 cm terminal tips were harvested six times, at ten-day intervals beginning 40 days after planting. Samples from the second harvest were used for nutritional analysis according to AOAC-approved methods (1970). Boiled tips from the third harvest were evaluated organoleptically by a ten-person panel whose members were from the Phillipines, Taiwan, Papua New Guinea, and the USA.

Results

Of the 65 clones selected from the second set of crosses, CN 1367-2 had the tenderest leaves and the most attractive leaf color. Selection CN 1364-29 was also yellow-green and very tender, but its tip yield was only 1.8 t/ha, compared with CN 1367-2's 13.4 t/ha (Table 12). No bush or semi-bush cultivars as tender as CN 1367-2 were obtained from this set of clones.

Due to its smaller and thinner leaves, CN 1367 yielded significantly less in the replicated trial than did Dilaw, but it did have many more harvestable tips (Table 13). It was also rated 'excellent' in tenderness and 'good' in flavor (Table 13). It is the tenderest cultivar ever identified at AVRDC, and has a dry matter content of 12.71%, compared to Dilaw's 13.06%. It contained only 12.71% oxalic acid, a chemical harmful because of its corrosive effects and its tendency to cause the formation of crystalline substances in the kidney and liver. Similar concentrations of protein, β-carotene, and vitamins

B_2 and C were found in both cultivars, but significantly less iron and calcium were found in CN 1367-2 (Table 14). Although the total fiber

Table 12. Yield, leaf color, plant type, and tenderness ratings of the selected clones in 1982's OYT.[z]

Entry	Tip yield Wt(kg/ha)	Tip yield No(1000/ha)	Plant type	Leaf color	Tenderness rating
CN1364-24	10,440	1,900	Semi-prostrate	Green	1
CN1364-25	9,033	3,058	Prostrate	Yellowish green	1
CN1364-27	13,156	1,806	Semi-erect	Green (with purple tip)	1
CN1364-29	1,800	408	Erect	Yellowish green	2
CN1364-4	10,650	2,861	Semi-erect	Green	1
CN1364-6	12,533	3,244	Semi-prostrate	Green	1
CN1365-2	11,153	3,233	Erect	Green	1
CN1367-2[y]	13,394	3,133	Prostrate	Yellow	1
CN1370-13	9,853	1,580	Prostrate	Green	1
CN1370-7	11,183	2,700	Bush	Green	1
CN1424-3	8,000	420	Bush	Green (old leaf with purple)	1
Dilaw(I426)	9,291	939	Semi-prostrate	Yellow	2.5

[z] Transplanted on October 28 and harvested from December 6 to January 31, 1983.
[y] Selected clone for further trials.

Table 13. Yield and horticultural characteristics of two sweet potato cultivars suitable for consumption as vegetable greens.[z]

AVRDC selection or accession no.	Tip yield[y] Wt.(t/ha)	Tip yield[y] No.(1000/ha)	Characteristics Leaf color	Plant type	Tenderness/flavor
CN 1367-2	13.1b	2893a	yellow green	prostrated	excellent/good
I426 (Dilaw)	18.0a	1954b	yellow green	prostrated	good/fair

[z] Transplanted in April 15, 1983 and harvested from June 1 to August 12, 1983. Replicated twice.
[y] Mean separation in coloums by Ducan's multiple range test, 5% level.

Table 14. Nutritional attributes of the tips of two sweet potato cultivars.[z]

AVRDC selection or accession no.	Dry matter (%)	Protein (%)	Fiber (%)	Ash (%)	Oxalic acid (%)	ß-carotene	Vit B_2	Fe	Ca	Vit.C
						(mg/100 gm F.W.)				
CN 1367-2	12.71	2.53	1.89	1.46	0.50	0.65	0.21	3.8	95.7	28.0
I 426 (Dilaw)	13.06	2.63	1.79	1.72	0.62	0.80	0.20	6.6	146.4	31.3

[z] Samples of 10 cm tips were collected on July 14, July 18 and August 12, 1983. Data are means of the three analyses.

content in the tips (leaves, stem, and petiole) was similar in both cultivars, the significantly lower fiber content in the stems and petioles of CN 1367-2 may explain why it was rated as more tender (Table 15).

Table 15. Fiber content of various tip portions of two sweet potato cultivars.[z]

Selection/cultivar	Fiber	
	% F.W.	% D.W.
CN 1367-2		
leaves	3.09	12.32
stem	2.03	6.98
petiole	1.08	5.86
Dilaw		
leaves	3.04	13.35
stem	3.09	9.82
petiole	0.88	7.45

[z] Transplanted on October 28, 1982, samples of 10 cm terminal tips were collected and analyzed in January 1983.

Conclusions

Sweet potato cultivars with higher tip yields could be bred by selecting bush or semi-bush types, whose larger number of branches per plant would make for significantly higher tip yield and tip number. Due to the greater stem portion and shorter internodes in the edible tips, however, these types are much less tender than prostrated cultivars. Although efforts to combine tenderness and bushy plant type have so far been unsuccessful, proper management practices, such as irrigation and the application of additional nitrogen, could probably enhance tip growth. Contrary to earlier findings, yellow-green cultivars were tender and palatable. Selection CN 1367-2 has especially good eating qualities. Its nutritional and agronomic advantages, improved organoleptic qualities, and attractive leaf color all make it an excellent choice for home gardeners, particularly in the tropics.

Sweet Potato Production and Utilization Patterns in Asia and the Pacific

Introduction

A sweet potato production and utilization survey was conducted from June through October 1982 through the joint effort of AVRDC's Social Anthropology, Breeding, Economics, and Outreach Programs. The survey's

objectives were 1) to collect the most recent national and regional statistical data on sweet potato production and utilization, 2) to collect data on current patterns and future trends in sweet potato utilization, 3) to collect detailed information on the current status of sweet potato research and farmer's production patterns, and 4) to identify the major problems and constraints of sweet potato production and utilization.

The survey was completed in March 1983. Preliminary results were reported in AVRDC's 1982 Progress Report, and were presented in July 1983 in Puerto Rico at the Workshop on Breeding New Sweet Potatoes for the Tropics. What follows is a brief description of the survey.

Materials and Methods

Between June and October 1982 questionaires were sent to 170 cooperators in 40 countries and territories in Asia and the Pacific. The Mayaguez Institute of Tropical Agriculture in Puerto Rico conducted a similar survey of Central and South America. Four major groups were targeted for the survey - 1) participants in the First International Symposium on Sweet Potato, 2) past AVRDC cooperators, 3) former AVRDC trainees who had worked with sweet potato, and 4) persons on AVRDC's mailing or correspondence lists who had expressed an interest in sweet potato.

By March 1983, 45 completed questionaires had been received from Asia and the Pacific, 3 from Central and South America, and 4 from the United States. Except for Nepal, Pakistan, Burma, Vietnam, and the Maldive Islands, responses were received from most countries and territories in Asia and the Pacific. (Questionaires have recently been sent to Mainland China, and those responses will be included in the final report.) Over 50% of the respondents were either agronomists or breeders.

Because respondents from the same country may have answered questions differently, their answers were treated as individual opinions, and were used to calculate frequencies inside the same group. Only production statistics and climatological figures were generalized for the same country on the basis of available references.

Results

Production trends:

Indonesia, the Phillipines, and India proved to have the largest amounts of land under production (excluding Mainland China, which produces roughly 80% of the world's sweet potato). Among the countries surveyed, Bangladesh, India, the Phillipines, Papua New Guinea (PNG), and most of the Pacific islands had increased the amount of land devoted to sweet potato cultivation during the past ten years (Table 16). The major reasons cited for these increases were the development of new land and the use of sweet potato as a substitute for traditional food crops of a lower social status (i.e. taro and banana). Because of the prevalence of a "taro disease", in PNG sweet potato had also been planted in

Table 16. Production area, average yield, and per capita consumption of sweet potato in Asia and the Pacific.

Country/territory	SP area (1000 ha)	SP area / Agr area (%)	Average yield (t/ha)	Kg/person/year
Japan	70 (-)	2.1	20.0	12.1
Korea	70 (-)	6.2	19.8	37.2
Taiwan	74 (-)	8.1	16.6	70.1
Bangladesh	73 (+)	5.0	10.9	9.2
India	225 (+)	0.6	6.9	2.3
Indonesia	309 (-)	5.8	7.6	15.8
Malaysia	4	1.2	9.7	2.7
Philippines	228 (+)	20.5	4.6	21.0
Sri Lanka	21	3.9	6.2	8.9
Thailand	36 (-)	1.4	9.7	7.6
Papua New Guinea	96 (+)	64.7	4.6	145.2
Pacific Islands	13*(+)	23.8**	11.4	532.3**
World total	13,638	-	8.4	-
Asia total	12.330	-	8.5	-
China	10,860	-	8.5	-

Source: FAO, Production Year Book, 1980 and the AVRDC Survey, 1982.
* = Fiji, New Caledonia, Tonga and Solomon Is.
** = Tonga and Solomon Is.
\+ = increased in the past 10 years.
\- = decrease in the past 10 years.

areas formerly cropped with taro. In Indonesia and Malaysia, however, sweet potato had been replaced by more "prestigious" crops such as corn, legumes, and vegetables.

Roughly 65% of all cultivated land in PNG is planted to sweet potato. In Tonga and the Solomon Islands, sweet potato was ranked as the most important staple crop; their per capita consumption of 532.3 kg per year is the highest in the world (Table 16).

Average yields in the area are generally low, however. Yields averaged only 4.6 t/ha in Papua New Guinea, and 11.4 t/ha in the Pacific Islands. Yields in Japan, on the other hand, averaged 20 t/ha, closely followed by Korea's 19.6 t/ha and Taiwan's 16.6 t/ha (Table 17).

Utilization trends:

Except in Japan, Korea, and Taiwan, sweet potato roots were reportedly used primarily for human consumption. Only small portions of the sweet potatoes produced are used for animal feeds in these countries, and negligible amounts are used for industrial purposes (Table 17). Only 38% of all roots produced were used for human consumption in Japan, and in Taiwan, where most roots are made into dried sweet potato chips used for hog feed, only 11% were used for human consumption. In Japan and Korea 35 to 36% of all sweet potato production is marked for industrial purposes, mainly for starch extraction and fermentation. In Oceania, sweet potato is used primarily as a staple food, with only 9 to 15% being used for animal feed (Table 17).

Table 17. Utilization patterns of sweet potato roots and greens in Asia and the Pacific.[z]

Country/territory	Roots				Greens
	Food (%)	Feed (%)	Indus. (%)	(Starch) (%)	
Japan	38	18	35	(29)	few (petiole)
Korea	56	5	36	(9)	yes (petiole)
Taiwan	11	73	16	(16)	few (leaves)
Bangladesh	100				yes (tips)
India	90	10			few (tips)
Indonesia	90	10			yes (leaves & tips)
Malaysia	70	30			few (tips)
Philippines	80	10	10	(10)	yes (tips)
Sri Lanka	100				no
Thailand	80	15	5	(5)	yes (tips)
Papua New Guinea	85	15			few
Pacific Islands[y]	91	9			some (tips & leaves)

[z] AVRDC survey on sweet potato production and utilization, 1982.
[y] Niue, Palau, Cook Is., Fiji, Tahiti, Vanuatu, Tonga, Guam and Ponape.

Sweet potato greens are consumed as a vegetable in all of the areas surveyed but Sri Lanka and a few of the Pacific Islands. Consumption patterns did differ, however. The Japanese and Koreans, for example, consume only petioles, and people in Taiwan mainly use just the tender leaves. The terminal 10 to 15 cm of the tips are consumed in most of the other areas surveyed (Table 17). In Taiwan, sweet potato greens are often the only vegetable available in the markets after a typhoon. Low yields and the lack of tender cultivars were listed as major production constraints.

Growing environment:

Mean maximum and minimum temperatures in Asia and the Pacific during the major sweet potato growing seasons were listed as 29.6 and 18.5° C. Most of the areas surveyed have minimum temperatures above sweet potato's chilling threshold of 10° C. Frost damage and growth retardation due to low temperatures were reported only in the highlands of Papua New Guinea and in early spring in Japan and Korea. In Japan, clear plastic mulches are used to raise soil temperatures. Most production areas of Asia and the Pacific have both high day and night temperatures. Differences between day and night temperatures are usually small, particularly in Oceania, and this condition was often cited as being favorable to excessive vine growth and detrimental to storage root development.

Rainfall was reported to vary greatly according to location and planting season. Mean monthly rainfall during the sweet potato growing season ranged from 35 to 235 mm. Most sweet potatoes are grown without irrigation, and drought was ranked as the most serious environmental stress. In many areas, though, flooding or excessive moisture was also cited as an important constraint (see next section).

Sweet potatoes are reportedly most often grown in sandy and clay loam soils, but are also produced in volcanic soils in Japan, and in coral sands on some of the Pacific islands.

Desired varietal characteristics:

Varietal improvement was ranked as the number one priority in all countries and territories surveyed, and about 86% of all respondents felt the lack of improved cultivars to be a major constraint in their particular region. The characteristics felt to be most in need of improvement were organoleptic qualities and nutritional content (ranked first for both staple- and snack-type sweet potatoes), insect resistance, high yields (for staple-type cultivars), and appearance, uniformity, and early maturity for the snack types (Table 18).

Table 18. Characteristics of staple- and snack-type sweet potatoes felt to be most in need of improvement.

Characteristics	Frequency[z]	
	Staple	Snack
Eating qualities[y]	17 (1)	17 (1)
Nutritional composition[x]	16 (2)	11 (2)
Insect resistance	13 (3)	6 (5)
High yield	12 (4)	6 (5)
Early maturity	11 (5)	8 (4)
Appearance and uniformity	10 (6)	10 (3)
Disease resistance	7 (7)	3 (6)
High dry matter	5 (8)	3 (6)
High starch	4 (9)	2 (7)
Keeping quality	3 (10)	3 (6)
Plant type	3 (11)	0
Adaptability	1 (12)	1 (8)
Others[w]	3	1

[z] numbers in parenthesis are ranks of importance.
[y] flavor, taste, texture and sweetness.
[x] Refers mainly to higher protein and β-carotene content.
Source: AVRDC survey, 1982.

Interestingly enough, eating quality and nutritional content were considered more important than high yields. Apparently, sweet potato is considered more of a vegetable and a supplementary commodity than a major food crop. Texture (dry or moist), flavor, sweetness, and fiber were frequently mentioned. Of these, dry texture was the most important; 60 to 87% of all respondents preferred dry or moderately dry textures. Moist textures were only preferred in the developed countries. Protein and vitamin A (β-carotene) content were the major nutritional concerns.

Skin and flesh color:

Red was the preferred skin color for staple sweet potatoes, followed by white and purple. Over 50% of the respondents noted a preference for white or yellow flesh color, compared with about 30% who voiced a preference for orange-fleshed varieties. Deep orange was the least favored flesh color; only 8% of those surveyed in Asia and the Pacific preferred this type. Light orange seemed more acceptable in these areas, and was preferred by 18% of all respondents.

Eating texture and sweetness:

In Asia and the Pacific, 77% of all respondents found dry or moderately dry textures most desirable for the staple-type sweet potato; moist textures were preferred only in the United States. Excluding those in South and Central America, 76% of all respondents felt that sweet or moderately sweet roots were preferable to the non-sweet type.

Sweet potato greens:

Tender terminal tips are the most frequently consumed portion of sweet potato used for vegetable greens. The length of the terminal tip felt to be edible ranged from 10 to 15 cm, which indicates a lack of tender cultivars. In areas where leaves and petioles are used, cultivars with large leaves and petioles are preferred. Green or purplish-green were reported to be the preferred stem and leaf colors. Even though they are usually more tender than the green types, yellow or yellow-green cultivars were not considered acceptable.

Leaf shape proved to be a major concern; although roughly a third of all respondents had no preference, one-third preferred deep lobing leaves and one-third preferred non-lobing leaves. The most common way of cooking sweet potato greens was boiling (47%), which was stated by many respondents to cause browning.

Diseases and insect pests:

In Asia and the Pacific, diseases and insect pests were ranked as the most important production constraints of sweet potato, followed by storage, processing, and marketing problems, and the lack of improved cultivars. Sweet potato scab (*Elsinoe batatas*) was listed as the most prevalent pathogen; except for Taiwan, it is important in almost every country throughout Asia and the Pacific (Table 19). Actual yield losses are unknown, and resistant cultivars have yet to be developed. Fusarium wilt (*Fusarium oxyperum*) and witches' broom were ranked next to scab in Asia and the Pacific. Witches' broom, the so-called "little leaf disease," has been found in India, Indonesia, the Phillipines, Tonga, Vanuatu, Papua New Guinea, and Taiwan's Penghu Islands.

Sweet potato weevil (*Cylas formicarius*) was listed as the most destructive insect pest, and was rated far more important than any other insects in the survey. It is a major pest in almost every country but Japan, Korea, and New Zealand. The stem borer (*Omphisa anastomosalis*), rated as the second most important insect, was reportedly a serious

problem in Fiji, Indonesia, Malaysia, and the Niue and Palau Islands. The distribution of both pests is shown in Table 19.

Table 19. Distribution of major sweet potato diseases and insects.

Country/ territory	Witches' broom	Fusarium wilt	Scab	Nema- tode	Virus	Stem borer	Weevil
Bangladesh	+	-	+	(-)	+	(-)	+++
Cook Is.	(-)	-	+	(-)	(-)	-	+
Fiji	-	+++	+++	+	+	+++	+++
Guam	-	-	-	(-)	-	(-)	+++
India	+	(-)	+	(-)	(-)	(-)	+++
Indonesia	+	(+)	+++	(-)	+	+++	+++
Japan	-	+++	(-)	+	+	-	-
Korea	-	+	(-)	(-)	+	-	(-)
Malaysia	-	+	+	(-)	+	+++	+++
New Zealand	(-)	+		+	(-)	-	-
Niue	-	-	-	-	(-)	+++	+++
Palau	(-)	+++	+++	(-)	(-)	+++	+++
Papua New Guinea	+	-	+++	(+++)	(+)	(+)	(+++)
Philippines	+	(+)	+++	+	+	+	+++
Ponape	-	-	+++	-	-	(-)	-
Puerto Rico	-	-	(-)	+	+	+	+++
Sri Lanka	-	-	-	(-)	-	+	+++
Tahiti	-	-	-	-	-	-	+
Taiwan	+	+	+	(-)	+	(+++)	+++
Thailand	(-)	(-)	(+)	(+)	(-)	(+++)	+++
Tonga	+	+	+++	+	+	+	+
USA	(-)	(+++)	(-)	+	+	(+)	+++
Vanuatu	+++		+				+

Note: - = no; (-) = no or don't know
+ = yes, but not serious; (++) = yes or don't know
+++= very serous; (+++) = yes or very serious
Source: AVRDC survey, 1982.

Environmental constraints:

Drought and excessive rainfall were listed as the two most important environmental constraints in Asia and the Pacific. Damage or retarded growth due to frost or low temperatures was ranked third in Japan, Korea, and the highlands of Papua New Guinea and Indonesia. Seventy-seven percent of all respondents indicated that sweet potato is frequently grown under dry or drought conditions, and 79% felt that there was a need to develop drought tolerant cultivars in Asia and the Pacific.

Flooding or excessive soil moisture was also reported to be a serious problem for sweet potato grown in Asia and the Pacific. Twenty nine percent of all respondents reported that crops were frequently flooded, and 44% felt strongly that there was a need to develop cultivars adapted to wet conditions.

The current status of varietal improvement programs:

Although varietal improvement was recognized by respondents as the most important research priority for sweet potatoes in Asia and the Pacific, very few varietal improvement programs are actually being conducted in the region's tropical areas. According to survey data, about 300,000 true sweet potato seeds are screened each year in Asia and the Pacific. Except for those screened in Taiwan and the Phillipines, only about 7,500 are screened in the tropics. This figure may help to explain the consistently low yields of sweet potato in tropical Asia. In addition, many countries and territories have rigorous quarantine laws restricting the introduction of foreign plant materials. Very few research programs outside of the international centers are working to develop cultivars and cultural practices suited to tropical environments. Taiwan's average sweet potato yields in the hot, wet season are only one-third those of the cool, dry season (Calkins et al., 1977).

Conclusions

There is ample room for improvement of sweet potato in the tropics. By comparing yields on experimental stations with yields in farmers' fields, Villareal (1982) showed that sweet potato has the largest yield improvement potential of any field crop in Asia. A traditional crop which is already adapted to tropical environments and already familiar to farmers, sweet potato could become an important source of energy and nutrition. Its current status, however, will require a systematic approach involving close international cooperation. Current sweet potato production and utilization patterns in the countries surveyed suggest the development of two distinctly different utilization types:

For human consumption:

Types should be bred for use as a snack or supplementary food with improved or nutritional content and eating and marketing qualities. For some parts of Asia, they should be bred for maximum yield and response to higher management inputs. The snack type of sweet potato popular in Japan and Taiwan may also prove important, particularly in urban areas. New varieties should have the following characteristics: 1) good storage and marketing qualities, 2) good eating qualities and nutritional content, 3) early maturity and high yield, and 4) resistance to major diseases and insect pests, and tolerance of environmental stresses.

For animal feed and industrial use:

These types should be bred for high yield and tolerance to major environmental and biological stresses. As a subsistence crop well-adapted to Asia and Oceania, sweet potato has a better chance than cereal crops to being developed as a major energy source. Although the yield potential of sweet potato in tropical Asia and the Pacific has yet to be clearly demonstrated, cultivars have been developed at AVRDC which under good conditions are capable of producing 46 t/ha, and 13 t/ha of dry matter. Even in extremely hot, wet conditions (over 1,000mm of

precipitation and a 27° C mean temperature during a four-month growing period), they can yield over 20 t/ha.

International Cooperation

Distribution

In 1983 a total of 415 sets of sweet potato planting material were sent to 259 cooperators in 22 countries. Unless other forms of germplasm were specifically requested, only meristem cultures were distributed to international cooperators after August 1983.

Germplasm Collection

In 1983 AVRDC was officially designated the international repository for sweet potato germplasm in Asia and the Pacific by the International Board for Plant Genetic Resources (IBPGR). In cooperation with the IBPGR, collection and maintenance programs are being conducted by national collection centers throughout Asia and the Pacific. A post-entry quarantine greenhouse, whose construction is funded by the IBPGR, will be used for assembling the collected vegetative germplasm.

Indonesia

In Padang, 38 superior clones were selected from 3,200 seeds which were provided by AVRDC in 1981. Five elite clones derived from AVRDC materials are now being evaluated against local cultivars in replicated trials.

Malaysia

Tan Swee Lian, Root Crop Breeder at MARDI, reported that 680 true seeds from AVRDC had been selected in seedling screenings and evaluated in 1982 and 1983 in single-row and preliminary yield trials. Of the 93 clones tested in the preliminary trials, only three outyielded the local check by more than 20%. Their yields, however, were not statistically different from those of the check. If plant quarantine problems can be solved, the introduction of elite vegetative clones will make it easier for national programs to select locally-adapted, higher-yielding cultivars.

The Phillipines

AVRDC sweet potato lines introduce by Mr. Camilo Nuestro were sent for evaluation to Eusebio Alava of the Don Severino Agricultural College. Four AVRDC selections produced 36 to 70 t/ha under normal

conditions, and without topping (Table 20). Selection CN 1028-15, which produced 70.3 t/ha of marketable roots, had also proven to be an exellent yielder in Taiwan and Tahiti.

Table 20. Root yield of AVRDC sweet potato selections/accessions with and without topping in the Philippines.[z]

Entry	Without topping	Topping interval		
		3 week	4 week	5 week
CN 1028-15	70.3	47.6	56.3	69.8
CN 942-47	58.7	30.2	33.3	35.4
CN 1038-16	42.2	20.8	34.4	41.7
Tainan #17	36.5	29.2	41.6	46.8

[z] Data supplied by Mr. E. V. Alva at the Root Crop Center, Don Severino Agricultural College, Indang, Philippines. Experiments conducted from August to December, 1983. Replicated 3 times.

South Africa

C.P.D. Plooy reported that 36 AVRDC breeding lines had been evaluated in preliminary trials held in 1982. Six of them were advanced to the subsequent comparative trials, and two of the best are now being evaluated at four different sites.

Tahiti

J.L. Reboul of GERDAT/IRAT reported that a new set of AVRDC sweet potato selections had performed exceptionally well in Tahiti. In 140 days they had yielded from 40 to 88 t/ha, compared with only 15 t/ha for local check Vareau (Table 21). Cultivars CN 942-47 and CN 1038-16 were rated more highly in organoleptic tests than was the local check.

Table 21. Total root yield of AVRDC and local sweet potato cultivars in Tahiti[z].

Entry	Total root yield			Eating[y] quality
	112 days (t/ha)	140 days (t/ha)	156 days (t/ha)	
CN 1028-15	61.1	88.2	98.7	2
CN 1108-13	54.4	56.6	69.5	2
CN 942-47	54.4	49.0	70.3	1
CN 1038-16	43.1	46.2	53.0	1
AIS 0122-2	44.7	41.1	35.0	3
I 444	42.2	38.8	41.9	2
Vareau (local check)	23.7	15.0	36.6	2

[z] Transplanted on June 6, 1983 and harvested from September 27 (112 days) to November 14, 1983 (156 days). Replicated 4 times. Reported by Mr. J. L. Reboul, Tahiti.

[y] Rated from 1-5 scale.

Sweet Potato Pathology

A Survey for Feathery Mottle Virus in AVRDC Fields

Introduction

Three viruses have been reported to occur on sweet potato in Taiwan - SPV-A, SPV-N, and a white fly transmitted virus known as SPV-B. The first two have been identified as flexible rod type viruses belonging to the PVY group. One of them, SPV-A, reacts serologically with feathery mottle virus (FMV), a common sweet potato virus found in many countries; SPV-A and FMV appear to be either identical or closely related strains. The relationship of SPV-N to any of the other known sweet potato viruses has yet to be established, however. Since it does not react serologically with FMV-AS, is not transmissible by aphids, and has a host range which includes tobacco, it is considered to be distinct from FMV. SPV-B, like SPV-N, does not react serologically with FMV-AS, and the nature of its virus particle remains unknown.

This study was designed to determine whether SPV-A is present in AVRDC fields, and to learn what type of symptoms are associated with its presence.

Materials and Methods

A survey was conducted from May through November of 1983. A total of 221 leaf samples were collected from plants showing virus-like symptoms such as mottle, mosaic, spotting, necrosis, discoloration, vein banding, curling of the leaves, stunt, and bushiness.

One leaf from each plant showing any of these symptoms was homogenized (1:10) in ELISA extraction buffer (pH 7.4) and tested by ELISA using FMV antiserum supplied by Moyer, USA. Both the conjugate and the gamma-globulin were used at a dilution of 1:500.

To determine whether the possibility of latent infection should be considered when screening sweet potatoes for FMV infection, an additional 83 samples were collected from symptomless plants.

Results

The virus symptom most frequently encountered on sweet potatoes in AVRDC fields was mottling, followed by spotting (yellow, chlorotic, and

necrotic), and red rings. In many cases several symptoms could be observed on the same plant, and even on the same leaf.

Of the 221 leaf samples collected from plants with various prominent virus symptoms, only 125 (56%) reacted with FMV-AS (Table 1).

Of leaves with only one type of symptom, 63% of those showing spots, 51% of those with mottle, and 46% of those with red rings gave positive ELISA reactions with FMV-AS. Of other less frequently ecountered symptom types, only plants with necrosis, mosaic, and yellow and red leaf discoloration reacted with FMV-AS. No reaction was elicited by leaves of stunted or bushy plants, nor was any elicited by plants with smaller or brown leaves.

Table 1. Detection of SPV-A in leaves of sweet potato plants with and without symptoms.

Symptom description	No. of samples collected	Positive reaction with FMV-AS by ELISA	% positive
Plants with symptoms	221	125	57
Leaves with one symptom type	158	77	48
Mottle	59	30	51
Spots (chlorotic, yellow, necrotic)	32	20	63
Red rings	28	13	46
Red discoloration	19	8	42
Yellow discoloration	4	3	75
Mosaic	6	2	33
Necrosis	4	1	25
Small size	4	0	0
Browning	2	0	0
Leaves with more than one symptom	60	48	
Stunt of whole plant	1	0	
Bushiness of whole plant	2	0	
Plants with no symptoms	83	3	
Total number of plants tested	304	128	

On the basis of these tests it can be assumed that such symptoms as mottling, spots, mosaic, red rings, and yellow and red leaf discoloration can all be associated with the presence of SPV-A. The failure of some of the leaf samples showing these symptoms to react with FMV-AS may simply mean that viruses with symptoms similar to those of SPV-A were present in AVRDC sweet potato plantings (Table 2), or that SPV-A was unevenly distributed within the plant. The latter possibility is supported by evidence that SPV-A was not always detected in the tubers of plants whose leaves reacted positively with FMV-AS (Table 2). Both possibilities will be further investigated. Of the symptomless plants which were tested, 4% were found to be infected with SPV-A. Levels of latent infection, however, may have been somewhat higher.

Table 2. Detection of SPV-A in the roots and tubers of sweet potato plants showing virus-like symptoms.

Plant part tested[a]	No. of samples collected	Positive reaction with FMV-AS by ELISA	% Positive
Leaves	82	60	73
Tubers	82	16[b]	20

[a] Leaves and tubers tested were collected from the same plants.
[b] In only eight cases did both leaves and tubers of the same plant react positively with FMV-AS.

Conclusions

Before truly conclusive results can be obtained, the sampling method must be made more reliable. SPV-A cannot be as reliably detected on tubers as an leaves. Viruses other than SPV-A are likely to be present in AVRDC sweet potato plantings.

Sweet Potato Entomology

Identification of Sources of Weevil Resistance

Introduction

Sweetpotato weevil (Cylas formicarius formicarius F) is the most destructive insect pest of sweet potato in the tropics. The larvae and adults feed on sweet potato roots and vines. Although weevil feeding does not reduce root yield, even the slightest feeding greatly reduces root quality. In order to control this insect cheaply and effectively, AVRDC has initiated a screening program to identify weevil-resistant sweet potato accessions. Described here are the results obtained in 1983.

Materials and Methods

Resistance screening trials were conducted at AVRDC headquarters in southern Taiwan and on Penghu Island, in the Taiwan Strait.

AVRDC:

The accessions tested were grown in a sweet potato weevil nursery planted between two weevil source rows, where a susceptible cultivar had been planted ten weeks earlier and then infested with laboratory-reared weevils. All accessions were grown according to standard AVRDC cultural practices, but no insecticide was applied. At harvest, roots were cut open, and the number of weevils inside was counted. The percentage of damaged roots was assessed by separately weighing the damaged and healthy portions of each root. The number of weevils feeding within the crowns was also recorded. In each test the mean number of insects (larvae + pupae + adults) per kilogram of roots and the mean percentage of roots damaged were both subjected to a statistical analysis based on mean (x) and standard deviation (sd). Accessions with insect numbers or a percentage of damaged roots less than $\bar{x}$ - 2sd were rated as highly resistant (HR), those between $\bar{x}$ - 1sd and $\bar{x}$ - 2sd as moderately resistant (MR), those between $\bar{x}$ and $\bar{x}$ - 1sd as posessing low levels of resistance (LR), those with between $\bar{x}$ and $\bar{x}$ + 2sd as susceptible (S), and those with more than $\bar{x}$+2sd as highly susceptible (HS). Some data were also analyzed by Duncan's Multiple Range Test.

Penghu:

Penghu Island tests were conducted in a similar fashion, except that no weevil source rows were maintained. Instead, laboratory reared weevils were released three times at weekly intervals from six until nine weeks after transplanting. Evaluative procedures were similar to those used in tests at AVRDC.

In 1983, three sets of materials were screened at each location. At AVRDC they were planted in September and October of 1982 and harvested in March of 1983. On Penghu they were planted in April and harvested in October and November.

Results

AVRDC first test:

One of four entries (accession I 955) was not damaged. Two other accessions (I 413 and I 416) were damaged less than susceptible check I 57 (Table 1). Although accession I 955 appeared promising, weevil population pressures in this test were low, and since the resistance of sweet potato cultivars varies widely from location to location and season to season, this accession will be tested several more times before being utilized in AVRDC's breeding program.

Table 1. Weevil resistance of selected sweet potato accessions.[z,y]

Accession	No. weevils per kg roots	Damaged roots %	Yield t/ha
I 413	1.80b	1.87bc	13.02b
I 416	3.81ab	5.01ab	12.00b
I 955	0.00b	0.00c	11.60b
I 57	7.41a	7.86a	15.8a

[z] Planting date: September 10, 1982; harvest date: February 1, 1983; plot size: 1 x 5 m.

[y] Data shown are means of 14 replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level.

AVRDC second test:

Included in this test were two standard susceptible (I 157 and I 117) and two standard resistant (I 123 and I 152) check accessions. The remaining accessions had shown moderate levels of resistance to weevil in previous tests.

Nine accessions showed levels of insect damage similar to that of AVRDC's standard resistant entry I 152 (Table 2). Since the weevil population was rather low, these accessions will be rescreened in 1983-84 to confirm their resistance.

Table 2. Weevil resistance of selected sweet potato accessions.[z,y]

Accession	No. weevils per kg roots	Damaged roots %	Yield t/ha
I 409	0.26bc	0.60b	10.0efgh
I 411	0.12bc	0.22b	10.6def
I 412	0.50bc	0.80b	4.8klm
I 421	0.00c	0.00b	4.1klm
I 426	0.04c	0.24b	6.2ijklm
I 432	0.22bc	0.70b	16.3ab
I 434	0.57bc	1.67b	7.9fghijk
I 436	0.00c	0.00b	2.5m
I 437	0.00c	0.00b	2.5m
I 152[x]	0.08c	0.80b	10.3defg
I 57[w]	2.83bc	2.68b	13.4bcd

[z] Planting date: September 10, 1982; harvest date: February 1, 1983; plot size: 1 x 5 m.
[y] Data shown are means of ten replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level.
[x] Resistant check.
[w] Susceptible check.

AVRDC third test:

The 234 entries included in this test were new accessions received from Papua New Guinea. They were planted along with five standard susceptible and three promising resistant lines. When the roots were dissected no weevil infestation was found. The roots were small, and there were no cracks in the soil, a condition which would have favored sweet potato weevil infestation. Frequent rains may have been responsible for the lack of soil cracks.

Penghu first test:

The entries included in this test were those which had shown promising levels of resistance in the first two tests conducted at AVRDC. Of the 13 entries included, only 6, including 2 susceptible and 1 standard resistant check, gave 1 kg or more roots per plot in 3 or more replicates. Only these entries were evaluated. Although accession I 955 was not damaged in the first test at AVRDC, it was heavily damaged in this test, and was actually more susceptible than the susceptible checks (Table 3). AVRDC's standard resistant check was the least damaged in this test. In similar screening tests, I 955 was the least damaged entry, and I 152 was one of the most damaged.

Penghu second test:

Of the 90 accessions included in this two-replicate test, 23 entries which yielded 1 kg or more in both replicates were evaluated for

weevil infestation. All entries were damaged by weevil. Nine entries were less damaged, and were rated as possessing low levels of resistance. All nine will be retested in confirmatory screenings.

Table 3. Performance of sweet potato accessions selected for resistance to sweet potato weevil at Penghu island[z-w].

Accession	No. weevils/kg roots	Damaged roots (%)
I 955	65.2a	34.7ab
I 432	25.1b	53.0a
I 949	19.1b	36.4ab
I 117[x]	7.7b	33.7b
I 57[x]	6.7b	35.0ab
I 152[w]	5.1b	27.2b

[z] Planting date: April 1, 1983; harvest date: October 1; plot size: 1 x 5 m.
[y] Data are means of three replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level.
[x] Standard susceptible.
[w] Standard resistant.

Penghu third test:

A total of 545 newly received accessions were planted in this test. Only 46 of them yielded 1 kg or more per plot, and all 46 were free of weevil infestation. Many of them had small roots. Severe vineborer (Omphisa anastomasalis) infestation of most entries probably reduced the size of tuberous roots and lessened the chances of weevil infestation.

Conclusions

Although AVRDC has been screening sweet potato germplasm for over eight years, a reliable source of weevil resistance has yet to be identified. As with similar research being conducted elsewhere, levels of weevil infestation vary greatly from place to place and season to season.

Screening of New Germplasm for Additional Sources of Resistance to Vineborer

Introduction

The new sweet potato accessions AVRDC received from Papua New Guinea in 1982 were planted on Penghu Island during the spring of 1983,

primarily so that they could be screened for resistance to sweet potato weevil. Since sweet potato vineborer (Omphisa anastomasalis) also infests sweet potato during the spring and summer, all accessions were observed for stemborer infestation as well.

Materials and Methods

A 0.5 ha field was rototilled and worked into beds. Stem cuttings of each entry, including those of two known resistant and two susceptible checks, were planted in single rows on 1 x 5 m beds. Standard AVRDC cultural practices were followed, but no insecticide was applied. A week before the crop was to be harvested, each entry was observed for vine borer infestation, which can be easily found by looking for holes left in the crown by escaping adults or by searching the crown area for frass left by insects feeding within the stem. Vineborer infested plants also have hollow vines. The total number of plants, the number of plants infested by vine borer, and damage estimates were subjected to a statistical analysis similar to that used to rate sweet potato weevil resistance in the previous experiment.

Results and Conclusions

When the 528 entries being screened at Penghu for sweet potato weevil resistance (Penghu third test) were also observed for vineborer damage, the following accessions were found to be free of damage: I 669, I 691, I 721, I 722, I 725, I 744, I 761, I 764, I 781, I 813, I 814, I 826, I 830, I 848, I 870, I 884, I 885, and I 933.

I 92, one of the AVRDC's standard resistant accessions, was also free of damage. The average damage rate for 528 entries was 29.9%.

To ascertain the stability of their resistance, damage-free entries will be rescreened in a multireplicate experiment at Penghu Island.

Sweet Potato Physiology

Evaluation of Varietal Differences in Flooding Tolerance

Introduction

Flooding, especially when it coincides with the critical stages of storage root formation, is a major factor limiting the productivity of sweet potato. Although varietal differences in storage root formation under flooding are not clear, it has been reported that AVRDC accessions I-428 and I-429, are flooding tolerant. Described below is an evaluation under greenhouse conditions of these two accessions, two local cultivars, and one AVRDC breeding line.

Materials and Methods

Terminal 30 cm leaf cuttings of I-428, I-429, TN-57, TN-63, and CN-1108-13 were planted in clay pots (20 cm) filled with sand, soil, sterilized soil, or a vermiculite growth medium. They were then grown under field conditions, and from the seventh to the eighth week after planting they were flooded to 2 cm above the soil surface. Redox potentials were measured one day before flooding, and every one to three days after the second day of flooding. A split-split plot design was used with four replicates (five cuttings per replicate).

Results

Immediately after flooding the redox potential changed from oxidation to reduction. This change was quickest in the soils, but sand and vermiculite returned to the oxidative form more quickly after flooding than did the soils, which at that point had the lowest redox potential. Although flooding increased fibrous root growth and the numbers of knotted roots, it significantly decreased vein length, leaf number and area, and fresh and dry weight, and increased storage root parameters as well (Table 1). Plants grown in sand and vermiculite had better storage root formation, but there was no interaction between flooding and growth medium. More storage roots rotted, however, when plants were grown in sand and vermiculite. Storage root formation, as measured by root number and root fresh and dry weights, showed significant interactions between flooding and variety. Both CN-1108-13

and TN-63 had the highest storage root yields. Interestingly, the dry matter content of storage roots was unaffected by flooding or by growth medium. Flooded plants showed highly significant correlations between leaf area and storage root formation (Table 2).

Table 1. Effect of flooding on sweet potato growth and yield.

	Leaf area (cm^2/plant)	Stge root no./plant	Rot root no./plant	Dry weight (g/plant) top	Fibr root	Stge root
Main-plot (treatment)						
Flood	2755*[z]	1.61***	0.98***	25***	3.8**	3.4***
Non-flood	5740	4.74	0.03	50	1.9	27.6
Sub-plot (medium)						
Sand	3631b[y]	3.36b	0.77a	39ns	3.3ns	16.1ab
Soil	4512a	2.31c	0.27b	37	2.7	11.0
Sterilized soil	4449a	2.92b	0.37b	39	2.6	12.5b
Vermiculite	4397a	4.10a	0.62b	34	2.8	22.4a
Sub-sub-plot (entry)						
CN-1108-13	4322b	2.56b	0.31c	40b	2.7b	23.0a
I-428	3344b	3.03b	0.69a	32c	2.0b	12.6b
I-429	3805b	3.93a	0.64ab	27c	2.9b	12.6b
TN-57	5672a	3.61a	0.50abc	47a	4.5a	19.7a
TN-63	4095b	2.74b	0.39bc	40b	2.0b	9.5b
Interaction						
MP x SP	*	ns	**	*	ns	**
MP x SSP	ns	ns	ns	ns	ns	ns
MP x SSP	ns	+	ns	ns	ns	ns
MP x SP x SSP	ns	+	ns	ns	ns	ns

[z] Significant difference at 10%(+), 5%(*),1%(**) or 0.1%(***) level, F test.
[y] Mean separation within columns by DMRT, 5% level.

Table 2. Correlation coefficients (r) of leaf area with storage root number, and fresh and dry weights.

Storage root	Flood (df=18)	Non-flood (df=18)	Total (df=38)
Number	0.53*[z]	-0.13	0.57***
Fresh weight	0.60**	0.18	0.65***
Dry weight	0.42+	0.18	0.62***

[z] Significant difference at 10%(+), 5%(*), 1%(**) or 0.1%(***) level, F test.

Conclusions

Although I-428 and I-429 had been previously reported as flooding tolerant, they gave poor storage root yields in these conditions. AVRDC improved line CN-1108-13 and local cultivar TN-57 were considered flooding tolerant on the basis of storage root formation. Both maintained a high leaf area and a high leaf number under flooding conditions, which suggests that these two parameters could perhaps be used as indicators of flooding tolerance.

Effect of Temperature on Flooding Tolerance

Introduction

Flooding and high temperatures adversely affect sweet potato yields. Both can result in abnormal resipratory responses in the roots and abnormal photosynthetic processes in the shoot. It is uncertain, however, which condition inhibits yields most. This study was designed to determine which is most harmful, and precisely what effect it has on yields.

Materials and Methods

The same entries used in the previous experiment to test varietal responses to flooding were used in this experiment. Single leaf cuttings (blade-petiole-root systems) were planted in plastic pots (i.d. 6 cm) filled with soil, and were grown in the greenhouse for six weeks before being transferred to various temperature regimes at AVRDC and at the NTU phytotron. Leaf cuttings were grown at 20 and 15°C, 25 and 20°C, or 30 and 25°C day and night temperatures at the NTU phytotron, and at 34 and 25°C or 39 and 25°C day and night termperatures at AVRDC. All cuttings were flooded for one week immediately after being transferred to the temperature treatment, and were grown there for three weeks before being harvested. A split-split plot design was used, with three replicates and three cuttings per replicate.

Results

Leaf cuttings grown at 34 and 25° C day and night temperatures had the highest blade dry weight, but this parameter did not show any varietal differences due to flooding. Leaf cuttings grown at 25 and 34°C or 25 and 20°C day and night temperatures had more and larger storage roots (Table 3). Flooded plants had substantially smaller and fewer roots. Poorest storage root formation occurred when plants were flooded at 39°/25°C day and night temperatures. Day and night temperatures of 20°C and 15°C also resulted in poor storage root formation. Cultivar TN-57's storage roots remained large and numerous in all treatments. The poor root storage formation of single leaf cuttings (blade-petiole-root systems) of CN-1108-13 may be paralleled by the performance of stem cuttings.

Conclusions

Flooding greatly retards storage root formation, and its adverse effects are greatly aggravated by day and night temperatures of 39 and 25°C.

Table 3. Effect of flooding and temperature on the root formation of leaf cuttings (blade-petiole-root systems).

	Stge root no./plant	Dry wt. (g/plant) Fibr root	Dry wt. (g/plant) Stge root	Stge root dry wt. (g/root)
Main-plot (temp °C)				
20/15 (day/night)	0.76b	0.42c	0.43b	0.56b
25/20 (day/night)	0.96a	0.40c	0.59a	0.55b
30/25 (day/night)	0.79b	0.32d	0.53ab	0.60b
34/25 (max/min)	0.71b	0.57a	0.62a	0.82a
39/25 (max/min)	0.44c	0.51b	0.25c	0.55b
Sub-plot (flooding)				
Flood	0.62***[y]	0.41***	0.34***	0.51***
Non-flood	0.85	0.48	0.63	0.70
Sub-sub-plot (entry)				
CN-1108-13	0.19d	0.59a	0.05d	0.25c
I-428	0.77b	0.39c	0.61b	0.77a
I-429	0.53c	0.53b	0.31c	0.60b
TN-57	1.13a	0.35cd	0.83a	0.74a
TN-63	1.04a	0.34d	0.61b	0.57c
Interaction				
MP x SP	ns[y]	**	+	ns
MP x SSP	ns	**	**	+
SP x SSP	ns	*	***	**

[z] Mean separation within columns by DMRT, 5% level.
[y] Significant difference at 10%(+), 5%(*), 1%(**), or 0.1%(***) level, F test.

Effect of Flooding on Storage Root Formation of Two Different Rooting Types

Introduction

Sweet potato's storage root yield is determined by both the size and number of its storage roots. Storage root number is in turn determined by the number of nodes on the underground vein and the number of adventitious roots on each node. Some varieties have many small storage roots, and others have fewer but larger storage roots. This study was designed to compare the performance of these two types under flooded and non-flooded conditions.

Materials and Methods

Thirty centimeter terminal cuttings of CN1108-13, CN1121-312, and TN-63 were planted in 4 cm i.d. clay pots. All plants were placed in a

greenhouse. Stem cuttings were flooded from the seventh to the eighth week after planting, and growth parameters were measured at the eleventh week after planting. Leaf cuttings were flooded from the sixth to the seventh week after planting, and were harvested three weeks later. A split-plot design was used, with flooding and non-flooding as the main plots. There were four replicates, with six plants per replicate.

Results

On the basis of previous reports, both CN1121-130 and CN 1121-312 had been classified as "numerous" storage root types, and CN 1108-13 and TN 63 as an "average" storage root type (Table 4). In this experiment, however, only CN 1121-312 had numerous storage roots. It gave the highest yields in both the flooded and non-flooded treatments. Its ability to form large numbers of storage roots was due more to the ability of the roots in each node to enlarge than to the large number of nodes, as had been previously suggested. In experiments with leaf cuttings, CN1121-312 had the highest storage root number and yield under both flooded and non-flooded conditions (Table 5).

Table 4. Effect of flooding on storage root formation and on underground vein node number and internode length.

	Stge root no./plant	Pigment root no./plant	Undergnd node no./plant	Undergnd internode length (cm)	Dry wt. (g/plant) Top	Fibr root	Stge root	Pigment root
Main-plot (treatment)								
Flood	0.1***[z]	0.9*	3.6	3.1	15.5***	2.1+	0.03***	0.07***
Non-flood	1.2	2.7	3.9	2.9	42.1	1.6	6.22	0.48
Sub-plot (entry)								
CN-1108-13	0.6b[y]	1.1b	3.3b	3.0b	41.2	2.9a	1.7a	0.3
CN-1121-130	0.3b	2.4a	4.3a	2.5b	27.6	1.6bc	0.9b	0.4
CN-1121-312	1.4a	1.9ab	3.2b	3.6a	26.1	0.9c	9.2a	0.2
TN-63	0.3b	1.9ab	4.1a	2.9b	30.3	1.9b	0.8b	0.2
Interaction MP x SP	ns	**	*	ns	ns	ns	***	**

[z] Significant difference at 10%(+), 5%(*), 1%(**) or 0.1%(***) level, F test.
[y] Mean separation within columns by DMRT, 5% level.

Table 5. Effect of flooding on storage root formation of leaf cuttings.

	Stge root no./plant	Dry weight (g/plant) Blade	Petiole	Top	Fibr root	Stge root
Main-plot (treatment)						
Flood	0.26***[z]	0.42	0.46	0.90	0.45**	0.09***
Non-flood	0.55	0.45	0.45	0.95	0.51	0.33
Sub-plot (entry)						
CN-1108-13	0.09c[y]	0.48b	0.55b	1.09a	0.62a	0.08b
CN-1121-130	0.19c	0.45b	0.44c	0.89b	0.44c	0.08b
CN-1131-312	0.80a	0.31c	0.20d	0.56c	0.31d	0.36a
TN-63	0.54b	0.51a	0.62a	1.15a	0.53b	0.33a
Interaction MP x SP	*	ns	ns	ns	ns	*

[z] Significant difference at 5%(*), 1%(**) or 0.1%(***) level, F test.
[y] Mean separation within columns by DMRT, 5% level.

Conclusions

Varieties able to form numerous storage roots appear to have a high yield potential, a potential which hinges more upon the ability of the root to enlarge than upon the number of nodes found on underground veins. This type of sweet potato had higher yields under both flooded and non-flooded conditions.

Evaluation of Wet Season Storage Root Yield and Yield Components

Introduction

The varietal differences in flooding tolerance found in the previous experiment were attributed partially to the ability of the root to enlarge under flooded conditions. The present study was designed to examine such differences under field conditions during the wet season, and to learn more about how yield components are affected by flooding.

Materials and Methods

On June 9, 1983, twenty stem cuttings of each of two accessions from North Carolina (I 428 and I 429), two local cultivars (TN 57 and TN 63), and three AVRDC breeding lines (CN 1108-13, CN 1121-130, and CN 1121-312) were planted in 5 m^2 plots. A split-plot design was employed, with four types of flooding as main plots, and entries as sub-plots. Each treatment was replicated four times. Flooding treatments consisted of an unflooded check, a plot flooded from July 22 through 29, a second plot flooded from July 22 through 29 and August 25 through September 1, and a third plot flooded from September 29 through October 5. Samples were taken on August 19 (70 DAP), on September 22 (105 DAP), on October 13 (120 DAP), and on November 3 (147 DAP). Five plants from each treatment were measured for vein length, fresh and dry weights of the tops, marketable and non-marketable storage root weight, and numbers of storage roots, pencil roots, and rotted roots. The soil's pH and electrical conductivity were also measured one day before flooding, three and six days after the initial flooding had begun, and at 30 and 64 days after its completion.

Results

AVRDC breeding line CN 1121-312 yielded more than CN 1108-13 or TN-57 when harvested at 126 or 147 DAP. The remaining entries gave significantly lower yields (Table 6). Flooding reduced the storage root yields of all entries, but increased the formation of fibrous roots. Storage root yield showed strong interactions between early flooding and entry. Plants were able to recover storage root yield after flooding, and long dry periods after flooding tended to reduced the differences between the performance of flooded and non-flooded plants. (c.f. Table

6, 147 DAP). Late flooding resulted in a high incidence of rotted storage roots. Storage root dry matter content was unaffected by flooding.

Multiple regression and path analyses of storage root yield and its yield components revealed that in most cases both storage root number and storage root size contributed more than 90% of storage root yields (Table 7). The greater residual contribution of late flooded plants can be attributed to high incidences of rotted roots. Increased numbers of storage roots often compensated for reductions in storage root size caused by flooding (Table 8).

Table 6. Effect of flooding on biological and marketable storage root yields (t/ha) of sweet potato harvested at different days after planting (DAP)[z].

	70 DAP	105 DAP		126 DAP		147 DAP	
	Biol.	Market	Biol.	Market	Biol.	Market	Biol.
Main-plot (treatment)							
Flood I	2.1b[y]	2.3b	6.3b	7.4b	10.6b	15.5	18.8
Flood I+II	-	2.0b	5.8b	6.6b	9.9b	14.0	16.6
Flood III	-	-	-	5.8b	9.6b	12.8	15.5
No flood	8.1a	7.2a	12.3a	12.9a	16.6a	21.5	24.3
Sub-plot (entry)							
I-428	1.4c[y]	0.8c	3.9d	3.1b	6.5c	6.5c	9.9c
I-429	2.3c	0.3c	2.4d	2.5d	6.0c	6.9c	9.5c
CN-1108-13	6.9b	9.8a	13.3b	15.7b	16.9b	28.4ab	29.8b
CN-1121-130	0.9c	0.4c	3.7d	2.8d	6.9c	4.3c	8.3c
CN-1121-312	10.0a	11.9a	21.4a	19.8a	25.3a	33.7a	36.9a
TN-57	8.4ab	3.3b	9.9c	11.0c	15.1b	23.0b	26.6b
TN-63	1.0c	0.2c	2.3d	2.6d	5.1c	8.2c	9.8c
Interaction MP x SP	***[x]	***	***	*	**	ns	ns

[z] Planted on June 9, Flooded on July 22-29 (Flood I), Aug. 25-Sept. 1 (Flood II), Sept. 29-Oct. 5 (Flood III).
[y] Mean separation within columns by DMRT, 5% level.
[x] Significant difference at 5%(*), 1%(**) or 0.1%(***) level.

Table 7. Multiple regression and path analyses for the storage root yield of sweet potatoes flooded and harvested at various times.

DAP	Flooding	Yield = $aX_1 + bX_2$ = Residue			Contribution (%) to the yield		
		a	b	Residue	Stge root size (X_1)	Stge root no. (X_2)	Residue
70	Flood I	4.3	3.2	- 13.1	61.3	26.2	12.5
	No Flood	6.7	5.2	- 29.7	38.2	57.4	4.3
105	Flood I	9.6	5.1	- 46.6	52.7	40.4	6.9
	Flood I+II	5.8	6.6	32.2	28.0	65.3	6.7
	No Flood	12.5	5.4	- 68.2	20.2	75.3	4.0
126	Flood I	13.7	4.9	- 65.9	38.5	53.5	8.0
	Flood I+II	13.8	4.7	- 63.7	58.3	36.8	4.9
	Flood III	15.5	2.4	- 46.7	58.2	11.7	30.1
	No Flood	18.2	5.4	- 98.9	19.5	69.8	10.7
147	Flood I	18.2	6.2	-112.0	15.6	76.2	8.2
	Flood I+II	23.1	5.6	-129.6	32.8	60.2	7.0
	Flood III	20.3	1.8	- 47.1	23.9	40.7	35.4
	No Flood	23.7	7.6	-181.1	19.8	73.2	7.0

By maintaining large numbers of good-sized storage roots, AVRDC breeding line CN 1121-312 gave the highest yields (Table 8). Breeding line CN 1108-13 also gave good yields, probably because of its large root size. Although TN 57 had a fair number of storage roots, they were smaller than those of CN 1108-13 or CN 1121-13.

Analyses using orthogonal contrasts of data recorded at 70 DAP revealed that the three AVRDC breeding lines gave better yields than did accessions I 428 and I 429 under both flooded and non-flooded conditions (Table 9).

Although under flooded conditions CN 1121-312 and CN 1121-130, both of which had smaller but more numerous storage roots, yielded more than CN 1108-13, which had larger but fewer storage roots, these two accessions tended to have lower yields under non-flooded conditions.

Table 8. Effect of flooding on storage root number and size (g/root).

	70 DAP		105 DAP		126 DAP		147 DAP	
	No.	Size	No.	Size	No.	Size	No.	Size
Main-plot (treatment)								
Flood I	3.4b[z]	17.1b	5.3	32.1b	5.5ab	56.9ab	6.6	88.4
Flood I+II	-	-	5.0	27.7b	5.7ab	49.4b	6.0	82.7
Flood III	-	-	-	-	5.0b	68.7ab	5.2	104.3
No Flood	5.8a	30.0a	6.4	57.7a	6.2a	79.5a	7.4	99.1
Sub-plot (entry)								
I-428	3.1c	12.9bc	5.0bc	23.7c	5.0c	36.9d	5.8b	49.8cd
I-429	3.7c	18.8b	4.5c	14.5c	4.8c	39.2d	5.9b	49.7cd
CN-1108-13	4.4bc	41.1a	4.9bc	80.7a	3.7c	134.0a	4.3bc	219.2a
CN-1121-130	3.6c	7.5c	5.9b	17.1c	6.8b	29.9d	7.7a	32.1d
CN-1121-312	8.0a	37.5a	9.2a	72.8a	8.2a	99.1b	8.1a	135.2b
TN-57	6.1b	37.1a	6.1b	45.0b	6.9b	65.8c	8.4a	90.4c
TN-63	3.2c	10.1bc	3.3d	20.3c	3.8c	40.3d	3.8c	72.0cd
Interaction								
MP x SP	ns	**	**	***	*	***	ns	ns

[z] Mean separation within columns by DMRT, 5% level.

Table 9. Values of orthogonal contrasts of storage root yields and the "t" values of plants harvested at 70 days after planting.

Contrast	Value (g/plant)	"t" value
1. (4 accessions)-(3 breeding lines) under flood	- 74	-2.97**[z]
2. (4 accessions)-(3 breeding lines) under no flood	- 87	-3.49**
3. (CN-1121-130)-(CN-1121-312) under flood	-216	-4.70***
4. (CN-1121-130)-(CN-1121-312) under no flood	-336	-7.29***
5. (CN-1121-130 & CN-1121-312)-(CN-1108-13) under flood	78	1.82+
6. (CN-1121-130 & CN-1121-312)-(CN-1108-13) under no flood	-336	-7.29***
7. (Interaction between flood and comparison of (CN-1121-130 & CN-1121-312) and (CN-1108-13)	458	4.06***

[z] Significant difference at 10%(+), 1%(**) or 0.1%(***) level.

Conclusions

There are varietal differences in storage root yield under wet season conditions, and varieties with smaller, more numerous storage roots tend to maintain high yields under such conditions. AVRDC breeding line CN 1121-312 has especially high yield potential under flooded conditions.

Sweet Potato Incompatibility

Introduction

Both self-incompatibility and cross-incompatibility exist in sweet potato, and both have seriously hampered breeding programs. Fujise (1964) and Wang (1964) found five (I through V) and eleven (A through K) cross-incompatible groups, respectively, so that breeders can have a better idea of determining the cross-incompatible and self-incompatibile groups to which a particular parent belongs. This study attempted to classify AVRDC sweet potato accessions and breeding lines on the basis of these two classification systems and to reconcile the differences between the two.

Materials and Methods

Representative varieties from Wang's and Fujise's classifications, along with 58 AVRDC accessions and breeding lines, were pollinated between late December and May. To prevent insect visitation, flowers were emasculated and covered with small paper bags the day before anthesis. Pollinations were made on the next day. Fujise's classifications were represented by the following cultivars: A - I 965 (Kyushu 48), B - I 235 (Norin 5), C - I 966 (Tsukumoaka), D - I 172 (American Y.S.), E - I 676 (Kokei 14), F - I 979 (Tinian), G - I 977 (Kyukei 17-3028), H - I 164 (Tainung 56), I - I 976 (F 53-6), J - I 978 (FV 62-41), and K - I 968 (Kyukei 7492-2). Wang's classifications were represented by the following cultivars: I - I 297 (Kagoshima), II - I 298 (Taipei), III - I 170 (Okinawa 100), IV - I 154 (Tainung 10), and V - I 157 (Tainung 27).

Each of AVRDC's accessions and breeding lines was self-pollinated and cross-pollinated with Fujise's and Wang's cross-incompatibility groups. Representative varieties of Fujise's and Wang's groups were also selfed or crossed among themselves. Reciprocal pollinations were made for each cross.

Flowers were collected three hours after pollination. Collected stigmas were fixed in FAA solutions. They were later softened with 8 N NaOH for three hours, placed on glass slides, and stained with 0.5% aniline blue. The stigmas were pressed with a cover-glass and observed under a flourescent microscope. At least five stigmas were observed for selfing or crossing.

Results

Entries which failed to flower, which flowered non-synchronously,

or which had little pollen on their stigmas after pollination were not included in these results.

Fujise's groups A, C, and H were self-compatible, and groups B, D, an J were self-incompatible. Wang's groups II, III, IV, and IV were all self-incompatible. Various groups from both classifications were successfully combined in 65 different combinations. Many groups from both classifications were compatible. One cross and its reciprocal (II x B) were both incompatible, other crosses were self-incompatible in one direction and somewhat compatible in the other; others were compatible in both directions (Table 10).

Only 4 of 27 successful crossings of AVRDC accessions and breeding lines were self-compatible. Among 235 successful combinations including AVRDC entries and members of Fujise's and Wang's groups, 59 were found to be cross-incompatible. Some crosses which are incompatible in one direction may be compatible in the other direction.

Table 10. Compability relationships between Fujise's (1964) and Wang's (1964) incompability classifications.

♀	♂		♂	♀	
	Incompat.	Compat.		Incompat.	Compat.
I		A,B,C,F,	I		A,B,C,H,J,K
II	B,C	A,D,F,H,J	II	B,G	A,D,F,H,J
III	G,H	A,B,C,D,F,J	III	D,F	A,H,J
IV	D,G	A,B,C,F,J	IV	B,C,F,J	
V	B,G	A,C,D,F,J	V	D	B,C,F,G,J

Conclusions

Although most entries are self-incompatible, three varieties from Fujise's classification and four AVRDC entries were self-compatible. Several cross-incompatible combinations were found between the two classifications, but most cross combinations were compatible. Crosses which are compatible in one direction may not be compatible in the other direction.

Fifty-nine combinations of AVRDC entries with varieties from both classifications were found to be incompatible. More detailed information is available upon request.

Legume Crops Program

Mungbean Breeding

Germplasm Evaluation

Introduction

New mungbean accessions are routinely evaluated to identify high yielding lines for inclusion in the International Mungbean Nursery (IMN) and for use in AVRDC's breeding program.

Materials and Methods

In March, July, and September a total of eight accessions (six preliminary selections for uniform maturity, two improved cultivars from the Philippines, and one AVRDC breeding line released in Fiji) were evaluated in replicated trials against two checks (V 3476 for high yield and uniform maturity, and V 3726 for uniform maturity).

Results

As shown in Table 1, four entries produced yields comparable to those of the high yielding check V 3476 in at least one season. The first harvest of V 6083 made up a significantly higher percentage of its total yield than did the first harvest of V 3476.

Conclusions

V 6017 (Pag-asa 2) from the Philippines is yellow-seeded and relatively high yielding, and will be included in the 12th IMN. V 6083 (Okl. 5579-8) from the USA was selected as a source for uniform maturity for AVRDC's breeding program. The other two high yield potential lines, V 6094 (Pag-asa 3) and VC 1000-45-B (Station 46), will be further evaluated in 1984.

Hybridization

Introduction

Hybridization is still the backbone of AVRDC's mungbean breeding program, and has so far proven to be the best way to create the genetic recombinations needed for further selection.

Table 1. New mungbean germplasm selected for yield potential and/or uniform maturity during 1983 at AVRDC.

AVRDC no.	Variety name	Yield (t/ha)				% 1st harvest[z]				100 seed wt. (g)[y]	Disease[x]		Lodging[w]
		spring	summer	fall	mean	spring	summer	fall	mean		CLS	PM	
V 6017	Pag-asa 2	2.39	1.61	1.01-	1.67	67	85-	38-	63-	4.7	MS	MS	2.3
V 6094	Pag-asa 3	2.09	1.24-	1.22	1.52-	48-	73-	51	57-	3.9-	MS	VS	3.1-
V 6083	Okl. 5579-8	2.12	0.92-	1.07-	1.37-	83+	100+	47	77	5.4+	VS	VS	2.7-
VC 1000-45-B	Station 46	-	1.73	0.93-	***	***	74-	***	***	4.9	MR	MR	2.3
V 3476 (CK)	Pag-asa 1	2.29	1.80	1.41	1.83	71	91	59	73	4.8	VS	VS	1.5
V 3726 (CK)	Varsha	1.91-	1.04-	1.20-	1.38-	88+	99+	72	86+	6.1+	VS	VS	2.8-
Mean for 10 entries		1.9	1.16	1.13	1.38	72	91	52	68	4.2			2.5
CV (%)		8.5	10.1	9.5	9.4	6.4	3.3	17.2	5.2	6.7			21.2
LSD (.05)		0.28	0.20	0.19	0.21	8.0	5.2	15.5	5.8	0.5			0.9

[z] Expressed as a percentage of total yield.
[y] Average of 3 seasons.
[x] Cercospora leaf spot (CLS) was rated in summer and fall, and powdery mildew (PM) was rated in spring and fall in the disease nurseries.
MS = moderately susceptible, VS = very susceptible, MR = moderately resistant
[w] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging.
+,- : means in the same colums are significantly greater (+) or less (-) than V 3476 at 0.05.
*** Data unavailable

Materials and Method

In spring, nineteen breeding lines and six accessions, and thirteen breeding lines and five accessions in summer, were selected for high yield, disease resistance (Cercospora leaf spot and powdery mildew), uniform maturity, lodging resistance, and beanfly resistance. To combine these characteristics or increase the level of a specific characteristic, single, double, and three-way crosses were made among or between parental lines and the F_1 from the spring crosses.

Results and Conclusions

A total of 176 single or multiple crosses were made. An additional eight single crosses were made to incorporate beanfly resistance, and four backcrosses were made to study the inheritance of resistance to Cercospora leaf spot (Table 2).

Table 2. Mungbean crosses made in 1983 at AVRDC.

Type of crosses	Spring	Summer	Total
Single cross	111 (8)[z]	37	148
3-way cross	-	17	17
Double cross	-	20	20
Back cross	4[y]	-	4
Total	115	74	189

[z] Crosses made for the entomologist to incorporate beanfly resistance.
[y] Crosses made for inheritance study of the resistance to Cercospora leaf spot by pathologist.

Conclusions

New crosses will help recover superior genotypes with ideal combinations of high yields, uniform maturity, lodging tolerance, and multiple resistance to diseases or insects.

Yield Trials

Introduction

One of the primary objectives of AVRDC's mungbean breeding program is to develop widely adaptable, high and stable yielding genotypes with uniform maturity, resistance to lodging, disease and insect resistance, and good seed quality. Promising breeding selections are evaluated at several yield trials in three successive seasons. All yield trial

entries were also tested over three seasons for disease resistance, and in the fall for photoperiod sensitivity.

Materials and Methods

Yield trials conducted in 1983 included the International Mungbean Nursery (IMN), the Elite Yield Trials (EYT), the Advanced Yield Trial (AYT), the Intermediate Yield Trial (IYT), and the Preliminary Yield Trial (PYT). The number of entries, dates of sowing and harvest, plot size, experimental design, and number of replications for each trial are shown in Table 3. The population density was 400,000 plants/ha in spring and fall, and 250,000 plants/ha in summer. Standard AVRDC cultural practices were followed.

Table 3. Mungbean yield trials conducted during 1983, AVRDC.

Type of trial	No. of entries (check)[z]	Sowing date	Harvesting date 1st	2nd	3rd	Plot size (m^2)	Experimental design	No. of reps.
Spring planting								
IMN	20	3/2	5/16	6/7	6/22	18	SPD	4
EYT	22 (2)	3/2	5/16	6/6	6/21	18	RCBD	5
AYT	26 (2)	3/3	5/19	6/16	6/27	12	RCBD	4
IYT	49 (2)	3/3	5/19	6/21		6	Lattice	3
PYT-I	64 (1)	3/3	5/19	6/20		6	Lattice	3
PYT-II	169 (1)	3/3	5/19	6/20		6	Lattice	2
Summer planting								
IMN	20	7/12	9/24	10/7		18	SPD	4
EYT	22 (2)	7/12	9/23	10/6		18	RCBD	5
AYT	26 (2)	7/13	9/25	10/13		12	RCBD	4
IYT	49 (2)	7/13	9/28	10/14		6	Lattice	3
PTY-I	64 (1)	7/13	9/26	10/14		6	Lattice	3
PYT-II	81 (1)	7/7	9/13	9/30		6	Lattice	2
PYT-III	64 (1)	7/7	9/12	10/3		6	Lattice	2
Fall planting								
EYT	22 (2)	9/9	11/9	11/28		18	RCBD	5
AYT	26 (2)	9/9	11/14	11/28		12	RCBD	4
ITY	49 (2)	9/10	11/14	11/29		6	Lattice	3
PYT-I	64 (1)	9/10	11/14	11/28		6	Lattice	3
PYT-II	81 (1)	9/10	11/14	12/1		6	Lattice	2
PYT-III	64 (1)	9/14	11/14	12/1		6	Lattice	2
PYT-IV	90 (1)	9/22	12/2	12/20		6	RCBD	2

[z] V 3476 and V 3726 in EYT, V 3476 and VC 1973 A in AYT and IYT, and V 3476 in PYT's.

Results

The average yield of the 20 IMN entries (9 cultivars from 6 different countries and 11 AVRDC breeding lines) was 2.02 t/ha in spring

and 1.75 t/ha in summer. As shown in Table 4, eight AVRDC breeding lines outyielded the highest yielding check cultivar V 3476, which produced an average of 2.01 t/ha for two seasons. The highest yield, 2.73 t/ha, was produced by VC 2768 A in summer. High yielding AVRDC lines showed better disease resistance and larger seed size than did V 3476. Uniform maturity, expressed as the percentage of the first harvest over the total harvest, was significantly poorer for VC 1482 C and VC 2719 A, but for the other six breeding lines it was comparable to that of V 3476.

The average yield of the 22 EYT entries was 2.25 t/ha in spring, 2.15 t/ha in summer, and 1.24 t/ha in fall. The highest yield, 2.85 t/ha, was produced in summer by VC 2768 A, which also had the highest yield in 1982's EYT and 1983's IMN. This breeding line was also rated as moderately resistant to both Cercospora leaf spot and powdery mildew, and was comparable to V 3476 in terms of uniform maturity and lodging tolerance. The yields and other important characteristics of the twelve breeding lines which outyielded the higher yielding check cultivar (V 3476) are shown in Table 5.

The yields of AYT entries were generally low, especially in the spring trial. The seven breeding lines which averaged over 1.6 t/ha over three seasons, as compared to the high yielding check V 3476's 1.44 t/ha, are listed in Table 6.

Over the three seasons, fifteen IYT's breeding lines yielded an average of 1.81 t/ha to 2.03 t/ha, and in at least one season, significantly outyielded V 3476, the higher yielding check cultivar, which produced 1.56 t/ha in spring, 1.80 t/ha in summer, and 1.43 t/ha in the fall (Table 7).

Table 4. High yielding lines in the 11th International Mungbean Nursery, spring and summer 1983, AVRDC.

AVRDC no.	Parentage or variety name	Yield (t/ha) spring	summer	Mean	% 1st harvest[z]	Disease[y] CLS	PM	100 seed wt. (g)[x]	Lodging[w]
VC 2764 A	VC 1481 A/VC 1628 A	2.30	2.46+	2.38+	69	MR	MR	5.5+	1.8
VC 2768 A	VC 1482 A/VC 1628 A	1.98	2.73+	2.35+	72	MR	MR	5.8+	1.4
VC 1482 C	EG-MD-6D/ML-3	2.08	2.52+	2.30+	65-	MR	MR	4.7	1.0-
VC 2778 A	VC 1560 C/VC 1628 A	2.19	2.29+	2.24	73	MS	MS	6.1+	2.0
VC 1628 A	CES 1D-21/PHLV 18	2.24	2.14	2.19	73	VS	VS	5.4+	1.4
VC 1562 A	BPI. glab. 3/VC 1394	1.93	2.36+	2.14	69	MR	MR	6.1+	2.9+
VC 2755 A	VC 1177 B/VC 1647 A	2.09	2.11	2.10	72	MS	VS	6.7+	2.3
VC 2719 A	Shanhua 1/VC 1163A	2.11	1.99	2.05	65-	MR	MR	4.8	1.2
V 3476 (CK)	CES 1D-21	2.11	1.91	2.01	75	VS	VS	4.7	1.9
Mean of 20 entries		2.02	1.75	1.91	75			5.1	2.6
CV (%)		10.7	8.1	9.5	5.9			3.8	25.2
LSD (.05)		0.31	0.20	0.26	6.3			0.3	0.9

[z] Expressed as a percentage of total yield; mean of two seasons

[y] Cercospora leaf spot (CLS) was rated in summer and fall, and powdery mildew (PM) was rated in spring and fall in the disease nurseries.
MS = moderately susceptible, VS = very susceptible, MR = moderately resistant

[x] Average of spring and summer.

[w] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging, average of spring and summer.

+,- : means in the same colums are significantly greater (+) or less (-) than V 3476 at 0.05.

Table 5. Performance of twelve selected lines from elite yield trials over three seasons, 1983, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st Harvest[z]	Disease[y]		Photo-period sensi-tivity[x]	100 seed wt. (g)[w]	Lodging[v]
	Spring	Summer	Fall	Mean		CLS	PM			
VC 2768 A	2.42+	2.85+	1.38	2.22+	77	MR	MR	8	6.2+	1.7
VC 2768 B	2.49+	2.53+	1.25	2.09+	74	MR	MR	9	6.3+	2.0
VC 2307 A	2.50+	2.42+	1.28	2.07+	69-	MS	MR	9	4.4-	2.0
VC 1482 E	2.22	2.54+	1.42	2.06+	70-	MR	MR	9	4.8	1.2
VC 1647 B	2.12	2.53+	1.36	2.00+	70-	MS	MS	2	5.7+	1.8
VC 1000 C	2.06	2.66+	1.26	1.99	73	MR	MR	1	5.2+	2.5+
VC 2750 A	2.23	2.25+	1.46	1.98	71	MR	HR	11	5.5+	3.1+
VC 2778 A	2.35+	2.31+	1.27	1.98	76	MS	MS	13	6.2+	2.4
VC 2764 B	2.30	2.33+	1.30	1.97	77	MR	MR	10	5.7+	2.2
VC 2764 A	2.20	2.38+	1.30	1.96	77	MR	MR	10	6.7+	2.2
VC 2572 A	2.62+	1.97	1.18	1.92	72	MS	MS	8	5.7+	2.1
VC 1628 A	2.53+	1.94	1.29	1.92	73	VS	VS	10	5.8+	1.7
V 3476 (CK)	2.07	1.93	1.29	1.76	79	VS	VS	11	4.9	1.7
Mean of 22 entries	2.25	2.15	1.24	1.88	75				5.7	2.3
CV (%)	10.0	8.2	13.2	10.2	9.4				3.4	25.7
LSD (.05)	0.28	0.22	0.21	0.24	8.7				0.24	0.73

[z] Expressed as a percentage of total yield, average of 3 seasons.
[y] Cercospora leaf spot (CLS) was rated in the disease nurseries in summer and fall, and powdery mildew (PM) in spring and fall; HR = highly resistant, MR = moderately resistant, MS = moderately susceptible, VS = very susceptible.
[x] Scored on the basis of delay in days to flowering under 16 hour photoperiod compared to 12 hour photoperiod.
[w] Average of 3 seasons.
[v] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging, average of spring and summer.
+,-: means in the same columns are significantly greater (+) or less (-) than the check at 0.05.

Table 6. Performance of high yielding lines from the advanced yield trial over three seasons, 1983, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st Harvest[z]	Disease[y]		Photo-period sensi-tivity[x]	100 seed wt. (g)[w]	Lodging[v]
	Spring	Summer	Fall	Mean		CLS	PM			
VC 2802 A	1.77+	2.09	1.44+	1.77+	77	MS	MR	7	5.4+	1.5
VC 2764-17-B-1-B	1.53+	2.32+	1.42	1.76+	78	MR	MS	12	5.7+	1.2
VC 2771-2B-5-B	1.50+	2.22+	1.43+	1.72+	78	MR	MR	14	6.0+	1.7
VC 1482 C-15-1-B	1.26	2.42+	1.44+	1.71+	78	MR	MR	13	4.8	1.0
VC 2754-3B-2-B	1.42	2.29+	1.33	1.68	73-	MR	MR	16	6.3+	1.8
VC 2762-B-45-1-B	1.45	2.28+	1.30	1.68	72-	HR	MR	18	5.8+	1.1
VC 2778 C	1.35	2.28+	1.23	1.62	76	MR	MR	16	6.3+	1.5
V 3476 (CK)	1.22	1.87	1.22	1.44	85	VS	VS	11	4.7	1.2
Mean of 26 entries	1.40	1.91	1.23	1.51	79				5.8	2.5
CV (%)	12.6	11.5	11.8	12.1	8.3				4.4	27.1
LSD (.05)	0.25	0.31	0.21	0.25	9.1				3.5	0.9

[z] Expressed as a percentage of total yield, average of 3 seasons.
[y] Cercospora leaf spot (CLS) was rated in the disease nurseries in summer and fall, and powdery mildew (PM) in spring and fall; HR = highly resistant, MR = moderately resistant, MS = moderately susceptible, VS = very susceptible.
[x] Scored on the basis of delay in days to flowering under 16 hour photoperiod compared to 12 hour photoperiod.
[w] Average of 3 seasons.
[v] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging, average of spring and summer.
+,-: means in the same columns are significantly greater (+) or less (-) than the check at 0.05.

Table 7. Performance of high yielding lines from the intermediate yield trial over three seasons, 1983, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st Harvest[z]	Disease[y]		Photo-period sensi-tivity[x]	100 seed wt. (g)[w]	Lodging[v]
	Spring	Summer	Fall	Mean		CLS	PM			
VC 3012-5-2B-2-B	2.15+	2.33+	1.63+	2.03+	75-	MR	MR	25	4.8	1.3
VC 3031-3B-1-B	2.13+	2.32+	1.61+	2.02+	76-	MR	MR	15	5.4+	2.0
VC 3061-2-1-1-2B	1.93+	2.62+	1.42	1.99+	77	MS	MR	1	5.9+	1.4
VC 3011-12-B-2-2-B	1.86+	2.45+	1.59+	1.97+	75-	MR	MR	16	6.5+	2.2
VC 3108-2B-1-2B	1.76	2.52+	1.57	1.95+	76-	MS	MS	16	5.3	1.7
VC 2917-B-1-B-4-2B	1.85+	2.28+	1.55	1.89+	75-	MR	VS	2	5.3	1.4
VC 2770-B-15-1-B	1.80+	2.35+	1.50	1.88+	80	MS	MS	9	6.5+	1.8
VC 2762-B-67-B-1-B	1.85+	2.19+	1.57	1.87	71-	MR	MR	7	4.9	1.6
VC 3199-3B-1-B	1.86+	2.26+	1.44	1.85	82	MR	HR	12	6.2+	2.5-
VC 2764-11-2B-9-B	1.80+	2.29+	1.46	1.85	74-	MS	MS	8	6.2+	2.0
VC 3116-16-2B-2-B	2.03+	2.04	1.45	1.84	77	MR	MR	0	6.1+	2.2
VC 3011-12-B-2-1-B	1.74	2.15+	1.59+	1.83	77	MR	MS	17	6.9+	2.4-
VC 2789-B-2B(S)-4-B	1.93+	2.11+	1.43	1.82	74-	MS	MR	0	5.6+	1.6
VC 3112-B-1-1-2B	1.85+	2.08	1.50	1.81	79	MS	MS	2	5.7+	2.2
VC 2777-B-B(S)-3-B	2.01+	2.01	1.41	1.81	74-	MR	MR	0	6.6+	2.3
V 3476 (CK)	1.56	1.80	1.43	1.60	85	VS	VS	11	5.0	1.4
Mean of 49 entries	1.73	1.93	1.44	1.70	78				5.8	2.3
CV (%)	7.4	9.9	6.6	8.6	6.8				4.1	26.8
LSD (.05)	0.21	0.31	0.15	0.28	8.5				0.4	1.0

[z] Expressed as a percentage of total yield, average of 3 seasons.

[y] Cercospora leaf spot (CLS) was rated in the disease nurseries in summer and fall, and powdery mildew (PM) in spring and fall; HR = highly resistant, MR = moderately resistant, MS = moderately susceptible, VS = very susceptible.

[x] Scored on the basis of delay in days to flowering under 16 hour photoperiod compared to 12 hour photoperiod.

[w] Average of 3 seasons.

[v] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging, average of spring and summer.

+,-: means in the same columns are significantly greater (+) or less (-) than the check at 0.05.

In addition to the high yielding selections, six lines, each from the EYT, and the AYT and seven lines from the IYT were selected for disease resistance, uniform maturity, or photoperiod insensitivity.

Twenty lines from PYT-I, 21 lines from PYT-11, and 19 lines from PYT-III were selected for high yield, disease resistance, or uniform maturity.

The PYT-IV conducted in the fall performed very poorly due to severe infection of root disease complex, and, a few exceptionally poor yielding lines, it will be re-evaluated in 1984.

In most of trials, yields were highly significantly correlated with the number of pods per plant, lodging resistance, and visual ratings on general performance (Table 8).

Conclusions

Breeding lines have been substantially improved in yield potential, disease resistance, and seed size, but further improvement is needed in uniform maturity. High yielding selections from high level yield trials will be included in the next IMN and widely distributed to cooperators

Table 8. Correlation coefficients between yield and other characters from various yield trials conducted at AVRDC during 1983.

Season	Type of trial	% 1st harvest	Plant height	Days to 1st flowering	Days to 1st maturity	Days to mean maturity	Pods/ plant	Seeds/ pod	Seed weight	Lodging	General rating	Seed quality
Spring	IMN	-0.12	0.43**	-0.11	0.18	0.24*	0.32**	0.07	0.08	0.17	0.64**	0.07
	EYT	-0.26**	0.32**	-0.21**	-0.01	0.25**	0.32**	0.09	0.01	0.03	0.47**	-0.03
	AYT	0.12	0.25*	-0.18	-0.19	-0.13	0.52**	0.01	0.19	0.15	0.29*	0.21*
	ITY	-0.19*	0.22*	-0.25**	0.18	0.19*	0.37**	0.04	0.04	-0.18	0.23*	0.11
	PYT-I	-0.42**	0.13	-0.23*	-0.23*	0.42**	0.35**	0.04	0.20*	0.02	0.43**	0.17
	PYT-II	0.25*	0.77**	-0.68**	-0.58**	-0.25*	0.50**	0.23*	0.00	-0.53**	0.74**	-0.08
Summer	IMN	-0.87**	0.08	0.37**	0.50**	0.87**	0.51**	-0.36**	0.58**	-0.78**	0.82**	0.55**
	EYT	-0.42**	0.21*	0.07	0.26**	0.42**	0.52**	0.13	-0.11	-0.63**	0.59**	0.03
	AYT	-0.61**	-0.12	0.28**	0.21*	0.61**	0.52**	0.14	-0.09	-0.69**	0.53**	0.31**
	IYT	-0.01	0.13	0.06	0.02	0.01	0.39**	0.19*	0.08	na	0.58**	0.18
	PYT-I	-0.41**	0.20*	0.30**	0.17	0.41**	0.21*	0.06	0.22*	-0.67**	0.65**	0.25
	PYT-II	-0.09	-0.10	-0.05	-0.04	0.09	0.35**	0.03	0.12	-0.48**	0.49**	0.21*
	PYT-III	-0.03	-0.16	-0.08	-0.12	0.03	0.52**	-0.04	0.22*	-0.52**	0.41**	0.24*
Fall	EYT	-0.03	0.02	0.02	0.02	0.04	0.20*	0.21*	-0.20*	-0.18	0.09	-0.16
	AYT	0.02	-0.37**	0.09	-0.13	-0.10	0.18	0.14	-0.18	-0.59**	0.18	-0.21*
	IYT	-0.04	0.00	-0.15	-0.14	-0.07	0.29**	0.11	-0.14	-0.25**	0.13	-0.06
	PYT-I	-0.18	0.41**	0.02	0.02	0.12	0.32**	0.28**	0.01	0.04	0.45**	0.03
	PYT-II	-0.03	-0.16	-0.08	-0.12	0.03	0.52**	-0.04	0.22*	-0.52**	0.41**	0.24*
	PYT-III	-0.09	0.05	-0.07	0.19	0.19	0.32**	0.17	-0.15	na	0.55**	-0.07

in different countries. Selections from low level yield trials will be progressively advanced to higher levels. The highly significant positive correlations between yield and number of pods/plant, lodging tolerance, and general ratings indicate that these characteristics can be effectively used as selection criteria when actual yield data is not available. Selections with more pods per plant will be used in future hybridization.

Performance of Breeding Lines Under No-Management

Introduction

In most countries mungbean is still grown with little or no management. The objectives of this experiment were to identify genotypes with high yield potentials under minimum management conditions, and to determine whether breeding lines selected under good management conditions are also appropriate for no-management conditions.

Materials and Methods

The 20 breeding lines and 2 check cultivars entered in the Elite Yield Trial were planted on land adjacent to the spring and summer EYT's. An RCB design was used with three replications. Planting dates and spacings were the same as in EYTs. Plot size was 6 x 3 m for both the spring and summer trials. The only management practice was post-emergence thinning to adjust the population density.

Results

The average yield of 22 entries under no-management conditions was 0.96 t/ha, compared to 2.20 t/ha under proper management. Eight breeding lines averaged between 1.05 and 1.32 t/ha, but high yielding check V 3476 averaged only 0.81 t/ha (Table 9). Yield reduction under no-management conditions averaged 56.4% over two seasons, and was due mainly to a decreased number of pods per plant, and to a lesser degree to smaller seeds and fewer seeds per pod (Table 10). A highly significant positive correlation was noted between yields under good management and no-management conditions (Fig. 1).

Conclusions

Breeding lines have been identified which are able to produce more than 1 t/ha under no-management conditions. The highly significant positive correlation between yields under good management and no-management conditions indicates that under these experimental conditions lines selected under good management conditions may also be suitable for no-management conditions.

Table 9. The performance of high yielding lines under optimum management and no-management, spring and summer, 1983, AVRDC.

AVRDC no.	Yield (t/ha)						Mean yield reduction under no-management (%)
	Optimum management			No-management			
	Spring	Summer	Mean	Spring	Summer	Mean	
VC 2768 A	2.42 ab	2.85 a	2.64 a	0.64 ab	2.00 a	1.32 a	1.32 (50.0)
VC 1000 C	2.06 b	2.66 ab	2.36 a	0.86 a	1.69 b	1.28 a	1.08 (45.8)
VC 2778 A	2.35 a	2.31 c	2.33 a	0.84 ab	1.49 b	1.17 a	1.16 (49.8)
VC 2768 B	2.49 a	2.53 bc	2.51 a	0.65 ab	1.58 b	1.12 a	1.40 (55.8)
VC 2755 A	2.43 a	1.89 d	2.16 ab	0.73 ab	1.44 b	1.09 ab	1.07 (49.5)
VC 2764 B	2.30 ab	2.33 c	2.32 a	0.72 ab	1.42 b	1.07 ab	1.25 (53.9)
VC 2764 A	2.20 ab	2.38 c	2.29 ab	0.65 ab	1.44 b	1.05 ab	1.24 (54.1)
VC 1482 E	2.22 ab	2.54 bc	2.38 a	0.53 b	1.56 b	1.05 ab	1.33 (55.9)
V 3476 (CK)	2.07 b	1.93 d	2.00 b	0.58 ab	1.03 c	0.81 b	1.19 (59.5)
Mean of 22 entries	2.25	2.15	2.20	0.65	1.26	0.96	1.24 (56.4)
CV (%)	10.0	8.2	9.2	25.5	11.5	16.3	
LSD (.05)	0.28	0.22	0.25	0.27	0.24	0.25	

* Means in the same columns followed by the same letter are not significantly different at the 5% level.

Table 10. Mungbean yields and agronomic characters under optimum management and no-management, spring and summer, 1983, AVRDC[z].

Character	Optimum management			No-management			Mean difference (%)
	Spring	Summer	Mean	Spring	Summer	Mean	
Grain yield (t/ha)	2.25	2.15	2.20	0.65	1.26	0.96	1.24 (56.4)
Plant height (cm)	53	87	70	52	86	69	1 (1.4)
Days to 1st flowering	53	37	45	51	37	44	1 (2.2)
Days to 1st maturity	72	57	65	70	57	64	1 (1.6)
Days to mean maturity	92	78	85	77	76	77	8 (9.4)
% 1st harvest	71	71	71	93	79	86	-15 (21.1)
Pods/plant	13.2	16.9	15.1	5.0	11.0	8.0	7.1 (47.0)
Seeds/pod	10.5	10.4	10.5	10.0	10.0	10.0	0.5 (4.8)
100 seed weight (g)	6.0	5.5	5.8	5.6	5.1	5.4	0.4 (6.9)

[z] Data are means of the same 22 entries from separate trials.

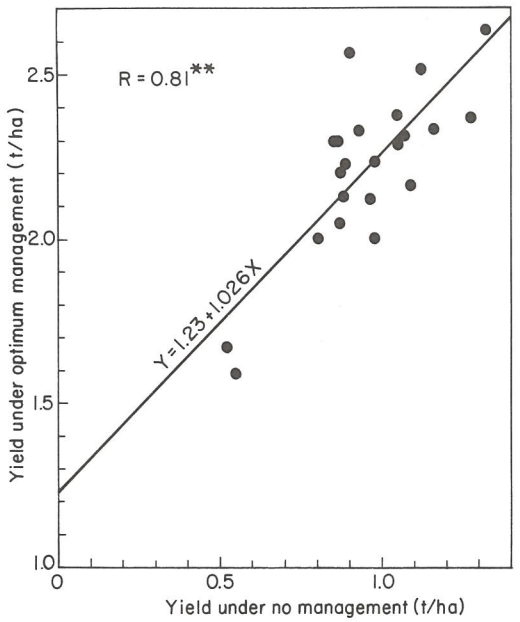


Fig. 1.
Mean yields of 22 mungbean lines under optimum and minimum management at AVRDC, spring and summer 1983.

Evaluation of Disease-Resistant Lines

Introduction

In most countries Cercospora leaf spot (CLS) and powdery mildew are the two most important mungbean diseases. To identify resistance sources and develop lines with multiple disease resistance, all breeding lines and selected accessions are routinely evaluated over three seasons for resistance to these two diseases.

Materials and Methods

A total of 326 breeding lines and 17 accessions were evaluated in the spring, as were 301 breeding lines and 17 accessions in the summer and 302 breeding lines and 19 accessions in the fall. Spring, summer and fall crops were planted on March 10, July 7, and September 7, respectively. Each entry was planted in two replications of single row plots 2 to 3 m long, with 0.5 m between rows. In the spring and fall susceptible check cultivars V 1944 and in summer V 2010 were planted in a 1 m band across the rows to separate test plots. Resistant check V 2773 was planted in every sixth row. CLS resistance levels in the summer and fall and PM resistance levels in the spring and fall were rated under natural epiphytotic conditions. Lines showing resistance levels higher than that of V 2773, similar to that of V 2773, between those of V 2773 and V 1944 or V 2010, and similar to that of V 1944 or V 2010 were rated highly resistant, moderately resistant, moderately susceptible and very susceptible, respectively.

Results

Of the 238 breeding lines and 17 accessions evaluated over three seasons, six breeding lines and one accession (V 4281) were consistently rated as highly resistant to both diseases, and 70 breeding lines were rated as moderately to highly resistant (Table 11). The six breeding lines highly resistant to both diseases are listed in Table 12.

Table 11. Frequency distribution of disease ratings of 238 breeding lines and 17 accessions tested at AVRDC over 3 seasons in 1983.

Powdery mildew \ Cercospora leaf spot	Breeding lines/accessions HR	MR	MS	VS	Total
HR	6/1	5/0	1/0	2/0	14/1
MR	6/0	59/0	47/0	9/0	121/0
MS	0/0	18/1	37/1	27/1	82/3
VS	0/0	1/0	14/1	6/12	21/13
Total	12/1	83/1	99/2	44/13	238/17

Table 12. Agronomic characteristics of breeding lines highly resistant to both Cercospora leaf spot and powdery mildew, 1983, AVRDC.

Selection no.	Parentage	Yield (t/ha) Spring	Summer	Fall	Mean	% 1st harvest Sp	Su	Fa	Photoperiod sensitivity	Yield trial
VC 1560 D	BPI.glab.3/VC 1301	1.7	1.6	1.1	1.5	75	63	86	10	EYT
VC 2720 A	Shanhua 1/VC 1168 A	2.1	1.9	1.1	1.7	62	75	79	12	EYT
VC 1560 D-7-2B-1-B	BPI.glad.3/VC 1301	1.5	1.2	1.4	1.4	82	69	84	8	IYT
VC 2719-B-18-B-3-B	Shanhua 1/VC 1163 A	1.8	1.4	1.2	1.5	69	82	65	8	IYT
VC 3178-3B-2-B	CES 1D-21/VC 1210 A	1.8	2.5	1.5	2.0	85	64	85	10	PYT-I
VC 3021-2-2B-1-B	VC 1210 A/VC 1560 A	1.2	1.8	1.2	1.4	97	50	92	na	PYT-II

Conclusions

VC 1560 D and VC 2720 A will be used as resistance sources, and the other four lines will be further evaluated for agronomic characteristics and to confirm their disease resistance.

Photoperiod Sensitivity of Breeding Lines

Introduction

Photoperiod restricts mungbean's range of adaptation, and incorporating photoperiod insensitivity would allow AVRDC breeding lines to be used over a wide range of latitudes. Although photoperiod sensitive lines are usually eliminated in earlier selections, the sensitivity levels of advanced breeding lines are routinely confirmed in subsequent trials.

Materials and Methods

One hundred and fifty eight breeding lines and 18 selected accessions were planted on September 7 under both an extended 16 hour photoperiod and natural daylength in 2 m single row plots with 0.5 m between rows. Test plots were separated by 1 m bands of insensitive check cultivar V 1944. The number of days to flowering was recorded when 50% of the plants in a plot started flowering. Plant height and number of days to maturity were also recorded.

Results

Flowering was delayed under a 16 hour photoperiod by 0 to 30 days (Table 13). Additional rating criteria were delays in maturity of no more than 4 days and increases in plant height of no more than 50%. Lines rated as photoperiod insensitive are listed in Table 14.

The number of days to flowering of these entries ranged from 46 to 58 in spring, 31 to 40 days in summer, and 27 to 41 days in fall. Correlation coefficients of the number of days to flowering in the yield trials with the number of days flowering was delayed under a 16 hour photoperiod were not significant in spring (r = 0.12) nor in fall (r = 0.00), but were highly significant in summer (r = 0.36**).

Table 13. Frequency distribution of the delays in flowering of 158 breeding lines and 18 accessions grown at AVRDC under a 16 hour photoperiod and natural day length in the fall of 1983.

Delay in the number of days to flowering under a 16 hour photoperiod (sensitivity score)	0-4 (0)	5-8 (1)	9-16 (2)	17-19 (3)	25-30 (4)	Total
Breeding lines	24	21	86	25	2	158
Accessions	2	5	8	2	1	18
Total	26	26	94	27	3	176

Note: the natural day length at AVRDC (23°N) during the experiment was less than 12 hours.

Conclusions

Most AVRDC breeding lines are relatively insensitive to changes in photoperiod.

The number of days to flowering in summer, which was lower than in spring and less in genotypic variation than in spring and fall, was highly significantly correlated to the delay in flowering under a 16 hour photoperiod. This indicates that temperature or daylength times temperature interactions also have an effect on plant development.

Table 14. Yields and disease resistance of photoperiod insensitive mungbean lines in AVRDC, 1983.

Selection no.	Parentage or variety name	Yield (t/ha)				% 1st harvest			Disease		Yield trial (entry no.)
		Spring	Summer	Fall	Mean	Sp	Su	Fa	CLS	PM	
VC 1000 C	EG-MG-16/ML-3	2.06	2.66	1.26	1.99	65	68	76	MR	MR	EYT (1)
VC 1562 A	BPI.glab.3/VC 1394	1.93	2.36	-	2.14	71	66	-	MR	MR	IMN (12)
VC 1973 A	CES 1D-21/EG-MG-16	2.22	1.88	1.17	1.76	75	82	77	MS	MS	EYT (7)
VC 2523 A	VC 1209 A/PHLV 18	2.17	1.59	-	1.89	57	85	-	VS	MS	IMN (15)
VC 2719 A	Shanhua 1/VC 1163 A	2.34	2.06	1.07	1.82	58	71	79	MR	MR	EYT (10)
VC 2804-9-B-2-B	VC 2635/VC 1000 A	1.52	1.36	1.00	1.29	88	86	89	MS	MS	AYT (23)
VC 2777-B-B(S)-3-B	VC 1560 C/VC 1000 A	2.01	2.02	1.41	1.81	73	77	71	MR	MR	IYT (13)
VC 2917-B-1-B-4-2B	VC 2790/VC 2745	1.85	2.28	1.55	1.89	77	76	72	MR	VS	IYT (21)
VC 3061-2-1-1-2B	VC 1574 A/VC 1973 A	1.93	2.62	1.42	1.99	71	78	82	MS	MR	IYT (34)
VC 3112-B-1-1-2B	VC 1973 A/VC 1000 A	1.85	2.08	1.50	1.81	75	80	82	MS	MS	IYT (43)
VC 3116-28-2B-1-B	VC 1973 A/VC 1482 C	1.92	2.63	1.59	2.05	75	64	71	MR	MS	PYT-I (52)
VC 3116-28-2B-2-B	VC 1973 A/VC 1482 C	2.10	2.29	1.45	1.95	80	74	74	MS	MS	PYT-I (53)
V 1381	MG 50-10A(G)	1.56	1.37	-	1.48	83	94	-	VS	VS	IMN (1)
V 3726	Varsha	2.08	1.11	0.95	1.38	71	92	96	VS	VS	EYT (22)

Inheritance of the Lobed Leaflet Characteristics

Introduction

Mungbean leaves are usually entire trifoliolate, but some lines are lobed trifoliolate. The lobed leaflet character was previously reported (AVRDC's 1979 Progress Report) to be controlled by a single dominant gene. Later, however, it was observed that this character was not determined by simple dominance, and the present study was designed to learn its precise mode of inheritance.

Materials and Methods

VC 1973 A was used as the entire leaflet parent, and a single plant selection (V 2773-S) from V 2773 as the lobed leaflet parent. On July 4, parents were planted in a greenhouse in five 20 cm diameter clay pots with three plants per pot. Reciprocal crosses were made from August 15 through August 20. Both the parents and the F_1's were planted on August 30. Four kinds of backcrosses in all possible combinations were made from October 1 through October 15. The F_2 seeds were collected from the open-pollinated pods of the F_1 plants. The parents, F_1's, BC's, and F_2's were planted on November 1, and segregation for the leaflet characters was observed on January 15, 1984.

Results

All of the F_1's from reciprocal crosses were slightly lobed, but VC 1973 A (P_1) was entire trifoliate and V 2773-S (P_2) was deeply lobed. Segregations in F_2 and backcross generations would seem to confirm that the lobed leaflet character is controlled by a single incompletely dominant gene (Table 15).

Table 15. Segregation for leaflet characters in parents, F_1, F_2 and BC generations derived from cross between VC 1973 A and V 2773-S (greenhouse) at AVRDC during 1983 and 1984.

Generations		Segregation for leaflet characters			Expected ratio	X^2-value
		Entire	Slightly lobed	Deeply lobed		
P1 (VC 1973 A)		20				
P2 (V 2773-S)				19		
F_1	P1/P2		16			
	P2/P1		12			
F_2	P1/P2	10	36	14	1:2:1	2.94
	P2/P1	11	38	12	1:2:1	3.71
BC_1	P1//P1/P2	10	13		1:1	1.19
	P1//P2/P1	10	10		1:1	0.00
	P2//P1/P2		13	8	1:1	1.19
	P2//P2/P1		12	9	1:1	0.43

Conclusions

It seems likely that the lobed leaflet character is controlled by a single incompletely dominant gene. It should be rather simple, then, to transfer this character to other lines by continuously backcrossing heterozygous individuals to recipient parents and then developing isogenic lines after the desired number of backcrosses.

Development of Isogenic Lines With Desired Leaflet Characteristics

Introduction

Because poor light penetration of the leaf canopy has been identified as an important limitation of mungbean's yield potential, isogenic lines with entire trifoliolate, lobed trifoliolate, and multiple leaflets (usually nine) are being produced to assess their possible advantages.

Materials and Methods

VC 1628 A and VC 1973 A, two entire trifoliolate breeding lines, were used as recipient parents. Selections from V 2773 and V 5926 were the donor parents for lobed leaflets and multifoliolate leaflets, respectively. Initial crosses for both leaflet characters were made in the spring of 1982. For lobed leaflets, which are inherited by incomplete monogenic dominance, the heterozygous plants were continuously backcrossed with the recipient parents, but alternating selfings and backcrosses were used to transfer the monogenic recessive multifoliolate leaflet character.

Results

By the fall of 1983, homozygous individuals with lobed leaflets had been recovered from the selfings of BC_4, and third-generation backcrosses were made for multiple leaflets.

Conclusions

Isogenic lines with lobed leaflets will be ready for evaluation by the summer of 1984, but those with multiple leaflets will take 5 additional seasons for one more backcross and final fixation.

International Cooperation

Seed Distribution

During 1983 seeds of 1,675 breeding lines and 1,379 accessions were distributed to 160 cooperators in 60 countries. An additional 34

packets of breeding lines were distributed by AVRDC's Phillipine Outreach Program to 23 cooperators in the Philippines.

International Mungbean Nurseries (IMN)

In 1982 AVRDC sent cooperators 48 sets of the tenth IMN, which consisted of 9 selected cultivars from national programs and 11 AVRDC breeding lines. In 1983, one cultivar developed by a national program and four AVRDC breeding lines which had been entered in the tenth IMN were replaced with other cultivars, and the 11th IMN was distributed to 47 cooperators in 20 countries.

Performance data from the tenth IMN was received from 21 trials. The mean yield of the 20 entries over 21 locations was 1.05 t/ha, and the highest average yield of 1.19 t/ha was produced by VC 2778 A. Five AVRDC breeding lines (VC 1973 A, VC 1647 B, VC 2523 A, VC 2764 A, and VC 1628 C) all outyielded the highest yielding national cultivar (V 3476), which averaged 1.11 t/ha.

Australia

Dr. Stan Putland reported that after a series of trials a selection from AVRDC mungbean accession V 1388 (EG-MG-7) had been released in 1982 to farmers in the Northern Territory under the name King. The new variety was producing up to 20% more than Berken, the standard local variety.

Brunei

Sinaut Agricultural Training Center evaluated seven AVRDC breeding lines against Pag-Asa 1 and Pag-Asa 2. Those which outyielded high yielding check cultivar Pag-Asa 2 are shown in Table 16.

India

Dr. J. L. Tickoo of the Indian Agricultural Research Institute (IARI), reported that three IARI breeding lines which are progeny of AVRDC lines had performed well in All India Co-ordinated Trials for the last two years. In the Kharif 1982 trials, Pusa 105, which is a selection from VC 1137-2B, was the top yielding entry in 29 locations.

Indonesia

One AVRDC breeding line (VC 1089 A) and a selection from another, V 2773 (ML-3), have been officially approved for release, and have been named Manyar and Nuri, respectively.

According to Omar O. Hidayat of the Sukamandi Research Institute

for Food Crops, after four years of multilocation trials Manyar and Nuri had produced overall mean yields of 1.03 and 1.09 t/ha, 15% and 22% more than Bhakti, the standard local variety (Table 17). They also possess more resistance to rust and Cercospora leaf spot than does Bhakti.

Eight AVRDC breeding lines evaluated at Lawan, East Java, Indonesia yielded an average of 765 kg/ha. The three lines which produced more than 833 kg/ha are listed in Table 18.

Table 16. Performance of selected AVRDC mungbean lines at Jalan Tutong, Brunei, 1983.[z]

AVRDC no.	Yield (kg/ha)	Plant height (cm)	Days to 1st maturity	Pods/ plant	Seeds/ pod	Cercospora leaf spot	Lodging
VC 1973 A	979	74.5	53	50.5	11.5	2.5	4.0
V 3476	872	85.5	54	42.0	12.0	2.5	2.0
VC 1482 C	772	76.0	52	38.0	12.2	2.5	1.5
VC 2778 A	668	80.5	52	33.5	12.5	2.5	2.5
Pag-asa 2 (CK)	643	101.5	54	34.0	13.4	4.0	3.5
Mean of 7 entries	662	85.9	53.4	35.2	12.5	3.0	3.2
CV (%)	21.7						
LSD (.05)	351.6						

[z]Sown: June 15, 1983
Harvested: August 18 and 30, 1983
Plot size: 12 m^2 (2 rows x 6m x 1m)
No. of reps: 2
Population density: 100,000 plants/ha
Cooperator: Ramon F. Santiago
Institute: Sinaut Agricultural Training Center, Mile 21
Latitude: 4°N-4°5'N
Longitude: 114°4'-115°23'E
Elevation: 21 m
Season: Wet summer
Mean temperatures during the crop season: 23.0°C (min), 33.4°C (max)
Rainfall during the crop season: 481.7 mm

Table 17. Yields (kg/ha) and disease rating of two new mungbean cultivars in multilocational trials in Indonesia[z].

Location	Season*	Nuri (V 2773)	Manyar (VC 1089 A)	Bhakti (check)
Sukamandi	DS '78	1,563	1,339	1,135
	PWS '79	1,050	1,270	1,170
Indramayu	DS '79	1,024	1,110	760
	PWS '80	1,410	1,465	941
Sumber	WS '80	1,225	867	1,235
Cipeundau	WS '80	758	604	459
Sulang	PWS '81	802	786	733
Karawang	WS '82	956	839	772
Mean		1,099	1,035	901
Disease reaction	CLS	MR	R	S
	Rust	MR	MR	MS

[z] Data received from Dr. Omar O. Hidayat, AARD/SURIF, Sukamandi.
* DS = dry season, PWS = post-wet season and WS = wet season.

Table 18. Three high yielding AVRDC mungbean breeding lines at Lawang, East Java, Indonesia, 1983.

AVRDC no.	Yield (kg/ha)	Days to 1st maturity	Pods/ plant	Seeds/ pod	100 seed wt. (g)	Powdery mildew
VC 1210 A	889	60	8	10.3	6.8	-
VC 1973 A	840	60	6	10.8	7.2	5
VC 2778 A	833	60	9	10.4	7.4	5
Mean of 8 entries	765	61	6.6	10.5	7.1	
CV (%)	17.4					
LSD (.05)	195					

Peru

Twenty one AVRDC mungbean lines were evaluated against a local variety. Five AVRDC breeding lines produced more than 750 kg/ha, compared with the local check's 386 kg/ha (Table 19).

Table 19. Performance[z] of selected AVRDC mungbean lines at Chiclayo, Peru, 1983.

AVRDC no.	Yield (kg/ha)	Days to 1st maturity	Pods/ plant	Seeds/ pod	100 seed wt. (g)	Powdery mildew	Virus
VC 2778 A	791	57	24.1	11.7	7.8	2.0	1.0
VC 1089 A	779	59	26.0	11.8	6.2	1.3	1.0
VC 1560 D	766	64	31.9	11.5	7.2	2.0	1.0
VC 1974 A	752	61	20.0	11.3	6.4	1.3	-
VC 1973 A	751	61	25.9	11.1	7.2	1.3	1.0
Criollo Local (check)	386	57	-	13.2	7.4	2.0	2.0
Mean of 22 entries	640	61	24.7	11.5	6.7	1.6	1.2
CV (%)	24.4						
LSD (.05)	257						

[z]Sown: June 1, 1983
Harvested: August 25, 1983
Plot size: 13 m^2 (4 rows x 5 m x 0.65 m)
No. of reps: 3
Population density: -
Cooperator: Marco Antonio Neciosup Gallardo, Semillas Pervanas S.R.L. Divicion de Investigacion, Apartado 537
Latitude: 6°44'S
Longitude: 79°48'W
Elevation: 37 m
Season: Summer-Fall
Mean temperatures during the crop season: 20.4°C (min), 28.4°C (max)
Rainfall during the crop season: 6.4 mm (furrow irrigation)

Sri Lanka

A selection from VC 1131-B-12-2B was recommended by the Department of Agriculture and released to farmers under the name "Type 77".

According to Drs. S. J. B. A. Jayasekera and N. Vignarajah, the new variety gave in six locations 19% higher mean yields than local check MI-4 in Yala in 1980, and 34% higher in Maha in 1980/81 (Table 20). This new variety is also reported to have a wide spectrum of adaptability in Sri Lanka, and is reportedly resistant to charcoal rot caused by Macrophomina phaseolina and tolerant of mungbean yellow mosaic virus.

Table 20. Yields (t/ha) of Type 77 in the National Multi-location Testing Program, Sri Lanka.

Location	Yala 1980		Maha 1980/81	
	Type 77	MI-4	Type 77	MI-4
Maha Illupallama	2.14	1.80	1.34	0.90
Wanathavillu	0.69	0.39	0.86	0.82
Alutharama	1.57	1.18	0.87	0.79
Kilinochchi	0.73	0.45	1.63	0.93
Thirunelvely	1.75	1.79	1.66	1.29
Angunakolapellessa	0.79	0.85	0.42	0.35
Mean	1.28	1.08	1.13	0.85

Sudan

Mr. Mukhtar Kenani of WSARP reported that 20 AVRDC breeding lines and 2 accessions produced a mean yield of only 586 kg/ha. The six high yielding lines are shown in Table 21.

Tanzania

Dr. Joseph K. Mlingo, Grain Legume Breeder at the Tanzanian Agricultural Research Institute, reported that AVRDC accession V 1380 (EG-MD-6D) which had shown good performance over many locations in Tanzania, has been released as an adapted variety and named "Imara", meaning 'stable'.

USA

In 1983 the Sacramento Valley Milling Co. evaluated 279 AVRDC mungbean accessions and breeding lines. From this preliminary evaluation 30 promising lines were selected for further evaluation in replicated trials in 1984, and an additional 40 lines representing a broad range of potential genetic diversity were selected for use in improving local commercial varieties.

Vietnam

Dr. Vo-Tong Xuan of the University of Cantho, Haugiang evaluated 25 mungbean introductions, most of which had come from AVRDC. Agronomic characteristics of the highest yielding lines are shown in Table 22.

Table 21. High yielding AVRDC mungbean lines at Kadugil/Tello, Sudan, 1983.[z]

AVRDC no.	Yield (kg/ha)	Plant height (cm)	Days to 1st maturity	Pods/ plant	Seeds/ pod	100 seed wt. (g)
VC 2768 A	759	28	47	33.5	10.5	5.9
VC 1973 A	701	32	47	31.3	8.8	6.3
VC 2764 B	693	29	49	38.0	8.8	5.9
VC 2572 A	693	29	49	36.3	8.8	5.7
VC 2763 A	692	29	49	39.3	9.5	5.7
Mean of 22 entries	586	29	48	36.2	9.3	5.8
CV (%)	31.1	8.7	4.1	23.9	13.7	7.4
LSD (.05)	257.0	3.6	2.8	12.2	1.8	6.0

[z]Sown: July 9, 1983
Harvested: September 21, October 6, 24, 1983
Plot size: 10 m^2 (4 rows x 5 m x 0.5 m)
Number of reps: 4
Cooperator: Mukhtar Kenani
Institute: WSARP, Khartoum
Latitude: 11°00'N
Longitude: 29°43'E
Elevation: 501 m
Mean temperature during the crop season: 15.0-23.3°C (min)
25.5-37.7°C (max)
Rainfall during the crop season: 244.5 mm

Table 22. Performance of AVRDC mungbean lines at Haugiang, SR. Vietnam, 1983.[z]

AVRDC no.	Yield (t/ha)	Plant height (cm)	Days to 1st maturity	Pods/ plant	Seeds/ pod	100 seed wt. (g)	CLS rating
V 2984	2.70	83	57	30.2	11.9	4.0	3
VC 2768 A	2.66	70	74	17.2	12.3	5.5	1
V 2010	2.46	82	72	12.9	12.3	6.2	5
VC 1482 C	2.37	68	65	20.4	11.5	5.4	1
VC 2764 A	2.34	74	67	14.9	12.2	5.6	2
VC 1168 B	2.19	66	69	14.2	11.4	5.8	2
VC 1973 A	2.19	79	66	14.3	12.5	6.5	2
Mo Angiang (CK)	1.75	86	78	15.4	12.1	6.3	3
Mean of 25 entries	2.00	74.8	66.8	16.9	11.8	5.5	2.3
CV (%)	15.8	5.4	-	3.2	5.2	13.8	-
LSD (.05)	0.52	7.3	-	4.9	1.0	0.3	-

[z]Sown: March 3, 1983
Harvested: April 30 and May 20, 1983
Plot size: 3.6 m^2 (2 rows x 4.5 m x 0.4 m)
Number of reps: 3
Population density: 250,000 plants/ha
Cooperator: Dr. Vo-Tong Xuan, University of Cantho, Haugiang
Latitude: 10°02'N
Longitude: 105°47'E
Elevation: 3 m
Mean temperature during the crop season: 28.0°C (min), 35.4°C (max)

Zambia

Mr. C. J. Crubb, Shell Chemical (Zambia) Ltd. reported that AVRDC breeding line VC 1647 A has been doing exceptionally well, and has almost entirely replaced the local varieties.

Mungbean Pathology

Identification of Six Virus Isolates From Mungbean in Taiwan

Introduction

Virus-like symptoms have frequently been observed on mungbean at AVRDC. The present study was an attempt to isolate and identify the virus(es) causing these symptoms. After their importance has been assessed, these viruses may need to be considered in AVRDC's resistance breeding program.

Materials and Methods

Fifty-three leaf samples from plants showing mosaic, mottle, yellowing, vein clearing, vein banding, necrotic or chlorotic spots, necrosis, malformation, blistering, or leaf rolling were collected from AVRDC fields, homogenized in 0.01 M phosphate buffer, pH 7.0, and inoculated to Chenopodium amaranticolor. Where local lesions appeared, three successive single local lesion transfers were made.

For host range studies the isolates were inoculated to 3 plants each of 35 cultivars belonging to 21 plant species. The host range included many of the plant species and cultivars used by Hampton et al. for distinguishing legume viruses. Plants were kept in a greenhouse five weeks for symptom observation. Symptomless plants and those showing only weak symptoms were back-inoculated to Chenopodium amaranticolor.

Particle shape was determined electron-microscopically from leaf dips (5 minutes in 2% uranylacetate).

For serological examination, the pure isolates were tested by ELISA against antisera to the following 14 viruses: bean yellow mosaic virus (BYMV), bean common mosaic virus (BCMV), soybean mosaic virus (SMV), blackgram mottle virus (BgMV), blackeye cowpea mosaic virus (BlCMV), peanut stunt virus (PSV), cowpea mosaic virus-S (CPMV-S), southern bean mosaic virus (SBMV), cowpea chlorotic mottle virus (CCMV), soybean stunt virus (SSV), bean golden mosaic virus (BGMV), cucumber mosaic-Y (CMV-Y), "peanut mosaic virus (TARI)," and cowpea mottle virus.

Results and Discussion

So far only six of the pure isolates have been selected for host range studies and further identification. Results of host range studies are listed in Table 1. Although the list is not yet complete, it appears that isolates M2, M4, and M25 have a very similar host range, and and one which is different from that of M26, M27, or M48.

Unlike the first three isolates, M26, M27, and M48 are able to systemically infect cucumber and produce mosaic symptoms on N. glutinosa.

Electron microscopic examination of leaf dip preparations revealed flexible rod-type viruses approximately 700-800 nm long (typical of the PVY group) in M2, M4, and M25. Spherical particles were found in leaf dips of M26, M27, and M48.

In ELISA, isolates M2, M4, and M 25 reacted identically: each gave a positive reaction with antisera to B1CMV, BCMV, and "Peanut Mosaic Virus Tari". It can be assumed, then, that all three are identical or closely related to B1CMV. Their reaction to both BCMV and "PM-TARI" can be explained by their close serological relationship with B1CMV.

Isolates M26, M27, and M48 reacted only with CMV-Antiserum, and are therefore believed to be CMV or a strain of it.

Conclusions

Cucumber mosaic virus has frequently been reported on mungbean and may be considered one of its more important viruses, especially in light of its high rate of seed transmission. Thus, AVRDC should consider including CMV in its resistance breeding program.

The importance of the other virus, believed to be B1CMV, has not yet been established. If found to be important in Southeast Asia, it too should be included in AVRDC's resistance breeding program.

Mungbean Entomology

Screening Accessions for Resistance to Beanfly

Introduction

Beanflies (Opiomyia phaseoli, O. centrosematis, and Melanogromyza sojae) are important pests of legumes in tropical and subtropical Asia, Africa, and Oceania. All mungbean germplasm received since 1979, when three accessions with moderate to high levels of beanfly resistance had been identified, was screened with material that had either been missing or multiplied in insufficient quantities for earlier screenings.

Materials and Methods

Materials were screened in September and October, when the beanfly population at AVRDC is relatively high. A 0.4 ha field was divided into nine 7.5 m wide varietal testing blocks separated by 2.25 m wide insect source blocks. To maintain the insect population, soybean, mungbean, and snap bean were planted in the source blocks two weeks before the beginning of the experiment. The test blocks were then rototilled and worked into 75 cm wide raised beds. Every three days, 170 accessions were planted in 2 m strips, with 42 entries per test block. The first week's accessions were seeded adjacent to the insect source block, and each subsequent week's accessions were planted in the neighboring row.

Four weeks after germination the plants from each plot were uprooted and dissected, and the numbers of larvae and pupae found in each plant were recorded. The number of insect damaged plants was also recorded.

At each sampling date the mean number of insects (larvae + pupae) found in each ten-plant sample was subjected to a statistical analysis based on mean ($\bar{x}$) and standard deviation (SD). Accessions with a number of insects less than $\bar{x}$ - 2SD were rated as highly resistant (HR), those with between $\bar{x}$- 1SD and $\bar{x}$ - 2SD as moderately resistant(MR), those with between $\bar{x}$ and $\bar{x}$ - 1SD as possessing low levels of resistance (LR), those with between $\bar{x}$ and $\bar{x}$ + 2SD as susceptible (S), and those with more than $\bar{x}$ + 2SD as highly susceptible (HS). Since previous studies have shown a highly significant positive correlation between insect number and the percentage of damaged plants, in this study only the mean number of insects was used as a measure of resistance.

Results

Of the 675 accessions tested, 2 were rated as HR, 85 as MR, 281 as LR, 280 as S, and 27 as HS (Table 1). The performance of the two highly resistant accessions and the one most suceptible is summarized in Table 2.

Table 1. Relative beanfly resistance of selected mungbean accessions.

Resistance category	No. of accessions
Highly resistant (HR)	2
Moderately resistant (MR)	85
Low resistance (LR)	281
Susceptible (S)	280
Highly susceptible	27

Table 2. Performance of selected mungbean accessions for resistance to beanflies.[z]

Accession No.	No. of larvae+pupae /10 plants	Resistance rating
V5246	0	HR
V5425	0	HR
V5283	16	HS

[z] Accessions were selected from 4 screenings planted from September 20 through to October 7, and were evaluated four weeks after germination.

Conclusions

The 87 entries rated moderately to highly resistant were then rescreened in the spring of 1983 in Indonesia, where the beanfly population pressure is much higher than at AVRDC.

Rescreening of Selected Accessions for Resistance to Beanfly in Indonesia

Introduction

A total of 222 mungbean accessions with moderate levels of beanfly resistance had been identified in a preliminary mass screening conducted at AVRDC in 1982. Since beanfly populations are higher in Indonesia than in Taiwan, these accessions were rescreened for beanfly resistance at the P. T. Patra Tani Soybean Estate near Palembang.

Materials and Methods

In March of 1983 a 0.1 ha field was rototilled and worked into beds. Each accession was planted on a 2 x 0.75 m bed. Standard AVRDC cultural practices were followed except that no insecticide was applied, the percentage of dead plants was calculated at four weeks after planting.

Results and Conclusions

All entries were infested by beanflies. Their average mortality rate was 92%, and ranged from 12% to 100%. A relative resistance ranking is shown in Table 3. Accession V1160, a natural tetraploid of mungbean, was the least damaged in tests at AVRDC and in Indonesia.

The 15 highly resistant accessions will be studied further so that their resistance mechanisms can be characterized before they are used in AVRDC's breeding program.

Table 3. Relative resistance reaction of mungbean accessions selected for resistance to beanflies in Indonesia.[z]

Resistance category	% dead plants	Number of accessions
HR	< 68	15
MR	69 - 80	9
LR	81 - 92	36
S	> 93	162

[z] P. T. Patra Tani, Palembang, Sumatra, Indonesia.

Screening of Segregating Populations for Beanfly Resistance

Introduction

In late 1979 three mungbean accessions were found which showed moderate levels of resistance to beanflies (Ophiomyia phaesoli, O. centrosematis, and Melanagromyza sojae). In 1980 and 1981 AVRDC's mungbean breeders made crosses between these resistant accessions and V 2184, a high yielding cultivar which is susceptible to beanflies. Crosses were also made between the resistant accessions and AVRDC's new breeding lines, which have high yield potentials and resistance to important diseases. Since the beanfly population pressure at AVRDC is rather low, the selection of truly resistant materials requires repeated testing. In 1983 two screenings were conducted for beanfly resistance, one at AVRDC and the other at the AVRDC Thailand Outreach Program's (TOP) experimental farm in Kamphaeng Saen, where the beanfly population is often high enough to cause plant mortality.

Materials and Methods

Thailand:

In December of 1982, 756 segregating materials and 7 resistant and susceptible checks were planted in single rows on 0.75 x 2 m beds. Beanfly resistance was evaluated by periodically counting the beanfly killed plants until six weeks after planting. Entries with minimal levels of plant mortality were harvested, and their seed was saved for future testing.

AVRDC:

This test included 70 segregating materials selected from earlier tests. Because one of the beanfly resistant parents has a black seed coat which segregated into varying densities of black spots on a green background, seeds of each entry were sorted according seed coat color before planting. Each entry was planted in a single row on 0.75 x 10 m beds. Four weeks after germination each was evaluated for beanfly resistance by uprooting ten plants and recording the beanfly damage found within their stems.

Results

Thailand:

Most of the 756 entries were infested by beanfly . Mortality rates ranged from 0 to 100%. A total of 129 entries with a mortality rate of less than 5% were selected for future testing at TOP.

AVRDC:

The percentage of beanfly damaged plants ranged from 0 to 70%. Because the beanfly population pressure was low, no selections were made. All entries will be rescreened in the fall of 1984 for beanfly resistance and improved agronomic characteristics.

Evaluation of Insecticides for Beanfly Control

Introduction

Beanflies are the most destructive insect pests of mungbean in tropical and subtropical Asia, and insecticides are presently the only practical control method available. AVRDC has an ongoing project to screen insecticides for their ability to control beanflies on mungbean. Described here are the results of 1983's tests.

Materials and Methods

The methodology used in these tests was identical to that described

in AVRDC's publication "Vegetable Pest Control: Insecticide Evaluation Tests." The test included nine insecticide treatments and one untreated check. Insecticides were chosen on the basis of their efficacy during the previous year's test. An effort was made to include chemicals with modes of action different from those of insecticides presently in use. Each chemical was sprayed on four 3 x 3.3 m plots once a week for up to five weeks after planting. Each treatment was replicated four times.

Efficacy was evaluated three and five weeks after germination by uprooting 30 plant samples from each plot, and then cutting the plants open to count the number of larvae and pupae inside. The number of plants showing beanfly damage was also recorded all data were then analyzed by Duncan's Multiple Range Test.

Results and Conclusions

All insecticides gave effective control of beanflies (Table 4). Omethoate, the standard insecticide, still gave the best control. MK936, a newer avernectin-type compound, gave control as good as that afforded by omethoate or carbofuran spray, especially when it was applied at a rate of 18 g a.i./ha. In general, the insect population was rather low.

Table 4. Evaluation of insecticides for the control of beanflies on mungbean.[z-u]

Insecticides	Rate kg ai/ha	No. of beanfly maggots+pupae per 30 plants samples		Damaged plants %	
		10/28	11/11	10/28	11/11
MK936 0.36SL	0.0045	2.75b	1.25b	26.650bc	20.025b
MK936 0.36SL	0.0090	2.75b	1.00b	30.825b	16.350bc
MK936 0.36SL	0.0180	1.25b	0.25b	15.825cde	15.825bc
Carbofuran 40.64SP	0.5000	0.50b	0.25b	5.825de	12.500bc
Fenthion 50EC	0.5000	0.50b	1.50b	12.475de	11.675bc
Cypermethrin 5EC	0.0500	1.00b	1.50b	20.000bcd	18.350b
Omethoate 50EC	0.1250	0.50b	0.25b	4.975e	11.675bc
Omethoate 50EC	0.2500	0.25b	0.75b	10.000de	15.825bc
Omethoate 50EC	0.5000	0 b	0.25b	3.325e	4.150c
Control	-	13.00a	14.00a	59.175a	55.000a

[z] Variety: Tainan #3.
[y] Planting date: 10/4/83.
[x] Insecticides sprayed: 10/11, 10/14, 10/17, 10/21, 10/28, 11/4, 11/11/83.
[w] Sampling dates: 10/28 and 11/11.
[v] Data shown is mean of four replicates. Means in each column followed by the same letter are not significantly different at the 5% level.
[u] Plot size: 10 square meters (1/1000ha).

Mungbean Physiology

Screening for Drought Tolerance

Introduction

In the rainfed areas of the humid tropics mungbean is often grown before or after a rice crop. Frequent drought stress due to scarce or erratic rainfall can greatly reduce yield if these occur at the critical growth stage. To stabilize productivity under drought stress, it is important to develop varieties which possess adaptive mechanisms. This study investigated varietal differences in some of the growth responses of mungbean to drought stress under both greenhouse and field conditions.

Materials and Methods

In the first experiment 13 AVRDC breeding lines and 11 accessions were grown in the greenhouse in four 30 x 100 x 135 cm wooden boxes. Two boxes were for the control, and the other two were for the drought stress treatment. Seven days after being sown in sand-filled trays, seedlings were transplanted to the wooden boxes, where they were watered daily for seven days, and then not watered again for the remaining 34 days of the experimental period. Each cultivar's height, dry weight, and leaf area were periodically measured during those 34 days, and later its root dry weight (RDW), specific leaf weight (SLW), leaf area duration (LAD), height growth rate (HGR), and leaf lamina expansion rate (LER) were calculated.

The same 24 entries were planted in the field under three watering regimes: 1) well irrigated throughout the experiment, 2) furrow irrigation at ten days after sowing, and 4) no irrigation during the entire period. A split plot design was used, with irrigation treatments as main plots and entries as sub plots. Each treatment was replicated three times. Plants were grown in 1 x 4 m plots, with 5 cm between plants and 50 cm between rows. Samples were taken at 8, 15, 30, 60, and 80 days after planting. Crop growth rate (CGR) and relative growth rate (RGR) were later calculated for each entry. No seeds germinated in the non-irrigated treatment, and data from that plot are thus not included here.

Results

Under greenhouse conditions mean leaf lamina expansion rate was reduced from the control's 8.65 cm^2/day to 1.57 cm^2/day for the drought stressed plants (Table 1). Drought stress decreased the mean leaf area duration from 31.4 dm^2/day to 9.3 dm^2/day, but increased the SLW from 2.4 mg/cm^2 to 12.0 mg/cm^2.

Height growth rate and root dry weight were also substantially reduced by the drought stress. Analysis of variance revealed that although there were significant differences in RDW, SLW, and LAD between the control and the drought stressed treatment, and also among entries, there were no significant interactions between treatments and entries.

Drought stress in the field substantially reduced crop growth rate, but only slightly reduced relative growth rate (Table 1). Since CGR is a product of net assimilation rate and leaf area index, this reduction was probably due to reduced leaf area (Table 2). There were varietal differences in CGR between drought stressed and non-stressed plants, and there were also varietal differences in RGR among the plants irrigated at planting. There were no sigificant interactions, however, between treatment and entries. No varieties seemed to grow well under drought conditions.

Table 1. Effect of drought stress on mungbean growth[z].

Treatment	CGR (g/m^2/day)	RGR (g/g/day)
Control	7.12a[y]	0.238a
Irrigation at sowing	5.10b	0.216b
Irrigation at 10 days after sowing	1.32c	0.229a

[z] Measured at 15 and 30 days after planting.
[y] Mean separation within columns by DMRT, 5% level.

Table 2. Effect of drought stress on selected growth parameters.

Treatment	RDW (mg/plant)	SLW (mg/cm^2)	LAD (dm^2/day)	HGR (cm^2/day)	LER (cm^2/day)
Control	151	7.8	31.4	0.31	7.95
Drought	61**[z]	12.0*	9.3**	0.06**	1.57*

[z] Significant difference at 1% (**) or 5% (*) level, F test.

Conclusions

Drought stress under greenhouse and field conditions substantially reduced the growth of all varieties tested. None appeared tolerant. Reduced leaf area seemed to be a good indication of drought stress.

Growth and Yield Characteristics of Multiple Leaflet and Lobate Leaflet Mungbean Lines

Introduction

Mungbean's yield can be improved either by increasing the total dry matter production per unit area or by diverting more photosynthate to the part of the plant which will be harvested. This study was designed to test the hypothesis that a cultivar with more leaves and smaller leaflets could produce higher yields. Theoretically, the greater amounts of light reaching the lower part of the canopy should increase such a cultivar's potential for dry matter production.

Materials and Methods

Cultivars V-2773 (normal trifoliate leaf), V-2773S (lobate trifoliate leaf), and V-5926 (nine-leaflet leaf) were sown on September 20, 1983 at a rate of 200,000, 250,000, 300,000, 400,000, and 500,000 plants per hectare. An RCB design was used with four replications. Each 2.5 x 5 m plot had 10 cm between plants and 10 cm between rows. Light transmission in the canopy, leaf area index (LAI), crop growth rate (CGR), and net assimilation rate (NAR) were evaluated at 35 and 55 days after emergence (DAE). Plants were harvested on November 28, at 64 DAE.

Results

Nine-leaflet cultivar V-5926 tended to have a high LAI and good light penetration in the canopy (Figure 1). As reported in AVRDC's 1982 progress report, however, these qualities did not give it a hight CGR or a high biological yield (Table 3). Its NAR appeared to be the lowest of all four entries, regardless of population density. Since CGR is positively related to the product of LAI and NAR, nine-leaflet cultivar V-5926's low net photosynthetic activities may be responsible for its low NAR.

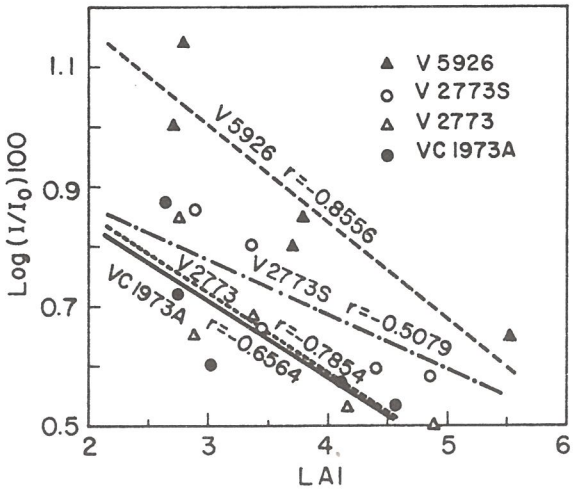


Fig. 1.
The relationship between relative light intensity, i.e. light intensity at the bottom (I) and top (Io) of the canopy, and LAI at 35 days after emergence.

Table 3. Estimates of CGR, LAI, seed yield, biological yield, and harvest index (55 DAE).[z]

Entry	Density (x10^5plants/ha)	CGR	LAI	Seed yield (t/ha)	Biol. yield (t/ha)	Harvest index
V-5926	5.0	9.2abc[y]	5.63a	1.06a	6.95a	0.39
	4.0	13.6a	4.82ab	1.00ab	5.88ab	0.36
	3.0	7.6a	4.05abc	0.51c	4.47bc	0.45
	2.5	11.7ab	3.56bc	0.58bc	3.92c	0.35
	2.0	5.3c	2.45c	0.76abc	3.28c	0.33
V-2773S	5.0	16.7	4.43a	1.48	10.69a	0.38
	4.0	13.4	3.20b	2.38	8.53ab	0.39
	3.0	12.4	3.18b	1.25	7.93ab	0.41
	2.5	12.1	3.14b	1.30	5.92b	0.38
	2.0	11.7	2.77b	1.18	6.15b	0.38
V-2773	5.0	19.9a	5.57a	1.44	10.54	0.39
	4.0	15.1ab	4.22ab	1.47	9.09	0.37
	3.0	14.6ab	3.73bc	1.45	6.66	0.37
	2.5	11.2ab	2.95bc	1.26	7.15	0.40
	2.0	8.3bc	2.37c	1.45	6.19	0.38
VC-1973A	5.0	13.7	4.76	1.77	7.23a	0.48
	4.0	15.3	4.31	1.66	5.58ab	0.49
	3.0	17.4	3.70	1.52	6.86ab	0.43
	2.5	12.9	2.78	1.54	5.25b	0.47
	2.0	9.8	2.30	1.66	5.43ab	0.48

[z] CGR and LAI were measured at 35 and 55 days after emergence.
[y] Mean separation within columns of the same entry by DMRT, 5% level.

The growth parameters of lobate leaflet V-2773S and normal leaflet V-2773 seemed identical. Light penetration was similar for both. As in 1982's experiment, V-2773 had more pods but smaller seeds than V-2773S. Thus, the differences in seed yield were insignificant. Normal leaflet VC 1973A had a slightly lower LAI, CGR, and biological yield than did V-2773 or V-2773S. Its harvest index and seed yield, however, were higher, just as in 1982's experiment.

Conclusions

This study confirmed that nine-leaflet V-5926 has good light penetration in the canopy. Its photosynthetic potential must be further improved, however, before it can fully utilize that light for increased dry matter production. Lobate leaflet cultivar V-2773S did not seem to have improved light penetration. Although increasing potential total dry matter production by improving light penetration in the canopy would seem to be a good way of increasing seed yield, the results of this and the previous year's experiments would suggest that optimum partitioning of photosynthate still contributes far more to the high yields of these three lines.

Soybean Breeding

Evaluation of New Germplasm

Introduction

Newly received germplasm and germplasm evaluated in 1982 observational trials were further evaluated in replicated trials to determine their usefulness for varietal improvement.

Materials and Methods

On February 10, June 28, and September 17, forty accessions were planted with local checks Shih Shih and KS #8. A 6 x 7 lattice design was used with two replications, and two rows in each 1 x 3 m plot. Suggested AVRDC cultural practices were followed.

Results and Conclusions

The number of days to maturity ranged from 80 to 125 in the February planting, 69 to 124 in the June planting, and 71 to 116 in the September planting. Of those entries reported as high yielding and early maturing in 1982 observational trials, five gave consistently high yields (Table 1). Fourteen entries with high yield and/or early maturity were selected for further evaluation (Table 1).

Table 1. High yielding and/or early maturing accessions selected from 1983's preliminary yield trials.

Acc. no.	P.I. No. or name	Days to maturity			Yield (t/ha)		
		Feb.	June	Sept.	Feb.	June	Sept.
G 10327	134306	112	96	86	5.0	4.0	1.5
G 10274	130401	112	99	84	4.4	3.9	1.4
G 10294[z]	131503	112	97	86	4.3	3.4	2.0
G 10223	P 27	116	104	94	4.1	3.9	2.5
G 10153[z]	Su Tou #1	102	98	83	4.1	3.7	1.1
G 10296	131702 G	107	97	91	4.1	3.8	2.4
G 10273	130204	111	99	85	4.0	3.6	2.1
G 10343[z]	253656 A	93	70	72	3.0	1.9	1.0
G 10146[z]	SJ 239	103	114	100	2.7	2.5	3.3
G 10209	408258	92	82	74	2.5	3.4	1.6
G 10212	417414 B	97	83	78	2.5	3.3	0.9
G 10150	Hei Loung 11	93	84	84	2.5	2.6	2.0
G 10210	408287	92	80	77	2.2	3.0	1.3
G 10191	40778 B	91	82	80	2.0	3.3	1.9
G 10313[z]	132802	122	93	91	2.3	2.5	3.2

[z] Observed as either high yielding or early maturing and high yielding in 1982.

Hybridization Program

In 1983, emphasis was placed on developing beanfly resistance, on incorporating resistance to soybean mosaic virus (SMV) into selected cultivars produced by various national research programs, and on combining resistance/tolerance to soybean rust, bacterial pustule, and downy mildew. A total of 1,023 seeds were obtained from 94 crosses between 59 parents (Table 2). Seeds from ten of those crosses were planted in a greenhouse, and the F_1 seeds collected.

Seeds from agronomically superior F_3 plants were given to AVRDC's entomologist for beanfly resistance screening. In the future, the improvement of high-yielding AGS lines through backcrossing will become a major priority. Such crosses will fix resistance to beanfly, rust, bacterial pustule, SMV, and downy mildew.

Table 2. Crosses made in 1983.

Objective	No. of crosses
Resistance to beanfly	6
Resistance to SMV	59
Improvement of vegetable soybean	15
Concentrated pod set at the apical stem	2
Resistance to soybean rust, bacterial pustule and downy mildew	12
Total	94

A total of 59 parents were used - 16 AVRDC breeding lines and 43 accessions.

Observation of New Vegetable Soybean Selections

Vegetable soybean is a good source of protein, and can be grown even during the rainy season when most other vegetables are unavailable. When processed for export, it can provide employment opportunities in rural areas.

Materials and Methods

A total of 51 vegetable soybean accessions obtained from ten Japanese seed companies were planted in single-replicate observational trials. Each was planted in two 5 m rows and observed for major agronomic characteristics.

Results and Conclusions

Most entries flowered in about 30 days and matured in 80 to 90 days. One hundred-seed weight ranged from 15 to 42 g. On the basis of plant type, pod size, the number of pods per plant, and the number of seeds per pod, cultivars Tancho, Ryokukou, Nakate Kaori, and Taisho Shiroge appear to be the most suitable vegetable-type cultivars for fall planting. These cultivars had 100-seed weights of 28, 41.7, 32.7, and 29.5 g, respectively. Further selections will be made for February and June plantings.

Breeding for Photoperiod Insensitivity

Introduction

Previous crosses involving photoperiod insensitive selections had been advanced without selection until the F_4 generation, and thereafter disruptive seasonal selections had been made for yield, disease resistance, and other desirable characteristics. The highest yielding selections were then screened for photoperiod response at the advanced yield trial stage. Since the few photoperiod-insensitive selections available showed fairly low levels of insensitivity, it was decided to screen for photoperiod response in the early generations and then select for other traits at later stage.

Materials and Methods

On February 8, F_1 seeds from 31 crosses which had at least one photoperiod insensitive parent were planted in 1 x 0.5 m plots. The photoperiod was artificially extended to 16 hours. Under artificial lighting, the light intensity at the plant canopy was about 58 to 64 $\mu E\ m^{-2}s^{-1}$ PAR. All of the single plants which flowered and matured were harvested and advanced. Selected F^2 plants were harvested, and the F^3 seed planted on September 18 was again grown under an artificially extended photoperiod.

Results and Conclusions

From 30 crosses, a total of 849 plants matured and were advanced to F_3 pedigree rows. Some rows proved to be homozygous for photoperiodic response, but others are still segregating.

The homozygous photoperiod-insensitive breeding lines identified in the F_3 generation will be multiplied and will then be evaluated for yield in three seasons. Further breeding will focus on the development of pedigrees which are both photoperiod-insensitive and high-yielding.

Preliminary and Intermediate Yield Trials

Introduction

Promising selections from preliminary yield trials (PYT's), the first stage in a series of replicated trials, must undergo intermediate yield trials (IYT's). Both the PYT's and the IYT's are conducted during all three cropping seasons of a single year. Lines selected from the IYT's are then entered in advanced yield trials (AYT's).

Materials and Methods

The PYT's were conducted in four groups, and the IYT's in two. Details of experimental design and planting dates are shown in Table 3. Plots size for the PYT's and IYT's was 2 x 3 m and 2 x 4.5 m, respectively, with four rows in each plot. Both trials were replicated twice. Selections were based on yield, earliness, adaptability to more than one season, seed quality, and resistance to diseases.

Table 3. Planting date and experimental design of PYTs and IYTs.

Experiment	Design	Date of planting		
		Spring	Summer	Autumn
PYT I	10 x 10 double lattice	Feb 10	July 8	Sept 17
PYT II	13 x 13 double lattice	March 1	June 28	Sept 17
PYT III	11 x 11 double lattice	March 1	July 13	Sept 15
PYT IV	13 x 13 double lattice	March 1	July 13	Sept 15
IYT I	6 x 6 double lattice	Feb 10	July 8	Sept 13
IYT II	9 x 10 rectangular lattice	Feb 10	July 8	Sept 13

Results and Conclusions

Spring plantings of PYT I and IYT's I and II were planted earlier than usual and had excellent germination, but PYT's I, II, III, and IV were planted on March 1 and encountered heavy rain. As a result, their plant stands were only 184,000 plants per ha, compared with PYT I's 369,000 plants per ha. This difference in plant density had a dramatic effect on yield; although PYT I yields in the spring averaged 3.1 t/ha, with one line yielding 4.4 t/ha, the average yields of PTY's II, III, and IV were about 1.0 t/ha, and the highest yields were around 2.0 t/ha. Selected examples of high yielding and early maturing selections are shown in Tables 4 and 5.

A number of selections were chosen which on the basis of visual evaluation showed field resistance to soybean rust during the spring cropping season (Table 6). Thirty-four selections from the IYT's were moved to advanced yield trials, and 78 selections from the PYT's were advanced to the IYT.

Table 4. PYT selections with high yield potential and/or early maturity.

Pedigree designation	Yield (t/ha)			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
GC 80107-54Y	4.4	3.1	2.5	111	101	90
GC 80107-34	4.1	3.1	2.7	111	104	85
GC 70057-1-6	3.6	3.0	2.8	113	108	89
GC 50218-10-7-6	3.6	2.9	3.0	115	96	89
GC 50299-7-6-7	3.6	2.7	2.6	110	94	85
GC 50009-K54G	3.5	2.8	2.7	110	107	90
TN 15 (CK)	2.6	1.1	1.6	100	92	80
LSD 0.05	0.5	0.7	0.9	4	7	5

Table 5. IYT selections with high yield potential and/or early maturity.

Pedigree designation	Yield (t/ha)			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
GC 60011-4-6-11-6	3.8	3.1	2.7	101	100	90
GC 50030-3-5-7-6-6	3.5	3.0	3.0	109	100	87
GC 60034-4-6-6-7-6	3.4	3.0	2.7	109	101	85
GC 60120-6-7-6-7	3.4	3.9	2.1	110	92	85
GC 50227-5-27-6-8	3.2	3.4	2.4	108	93	83
GC 60009-2-8-6-6	3.2	3.0	2.6	114	98	84
GC 60012-6-7	3.1	3.1	1.9	103	81	81
GC 60049-5-9-6-12	3.0	3.1	2.0	103	82	82
Shih Shih (CK)	2.1	2.9	1.7	100	88	82
LSD 0.05	0.6	0.7	0.5	5	9	4

Table 6. PYT and IYT selections with field resistance to soybean rust.

Cross designation	Yield (t/ha)			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
GC 50106-47-6-6-6	1.5	2.8	2.7	93	97	90
GC 50223-9-10-6-6	1.3	3.6	1.4	97	89	94
GC 50228-1-44-6-7	1.0	2.9	1.2	101	95	81
GC 50245-8-1-12-6-9	1.3	3.0	2.6	102	97	91
GC 50261-1-20-6E-7	1.5	3.3	1.3	95	91	84
GC 50265-2-9-6-8	1.2	3.0	2.1	95	95	86
GC 60053-7-7-6-8	1.1	2.3	2.2	94	93	89
GC 60053-8-6-8[z]	3.0	2.5	1.9	106	103	83
GC 60056-6-14-6-10	1.3	3.0	1.7	93	93	82
GC 60062-8-13-7-10	0.9	3.1	2.4	99	90	83
GC 60066-87A-16-2-7 -6-6-10	1.2	2.9	2.4	96	93	90
GC 60066-106A-6-7-6-11	1.6	3.1	2.5	96	93	87
GC 60074-6-6-8	1.0	2.8	1.8	98	94	88

[z] Except for this entry from the IYT, all the entries in the spring season were from the PYT, in which the germination and plant stand were poor due to heavy rains following planting. Hence the low yields during the spring.

Advanced Yield Trials

Introduction

Promising new selections from other breeding programs are entered in the advanced yield trials (AYT's) with selections from either preliminary or intermediate yield trials. Outstanding AYT entries are then entered in the AVRDC Soybean Evaluation Trial (ASET).

Materials and Methods

A total of 37 AGS lines were evaluated in three AYTs - 16 in AYT 1, 13 in AYT 2, and 8 in AYT 3. Shih Shih and TN #15 were used as checks in AYT's 1 and 2, and KS #3 and TN #15 were used in AYT 3. Ten new accessions were evaluated in AYT 4 in the summer (July 8) and autumn (September 9) plantings only. AGS 129 and AGS 182 were used as checks for AYT 4. AYT's 1, 2, and 3 were planted in the spring (February 4), summer (July 8) and autumn (September 9). An RCB design was used with four replications. Suggested AVRDC cultural practices were followed, and in each season observations were made of the number of days to flowering and maturity; plant height at flowering and harvest; the number of plants at harvest; the number of pods and branches per plant; seed quality and 100-seed weight; and lodging, shattering, and disease incidence.

Results

Entries with high yields and/or early maturity are shown in Table 7. Five significantly outyielded check cultivar TN #15 in the spring season. Except for AGS 216, none of the entries were infected by downy mildew. Seventeen of those evaluated in the autumn had 5 to 11% soybean rust infected foliage, and the others were infected at a rate of 6 to 25%. Resistant check AGS 182 was infected at a rate of 23%. During the fall, target leaf spot caused by Corynespora Cassiicola (Berk and Curt.) Wei was observed. This disease has been known to cause yield losses of up to 32%. The following 7 AYT entries showed no symptoms: G 10451, and AGS 192, 206, 209, 217, 218, and 227. On a rating scale in which 0 = no symptoms and 5 = very severe disease symptoms, there were 7 entries rated 0, 25 rated 1, 11 rated 2, 9 rated 3, 1 rated 4, and 3 rated 5. The three highly susceptible entries were AGS 199, 202, and 207.

Conclusions

New AGS entries had higher yield potentials, earlier maturity, and better multiple disease resistance than did any of the check cultivars.

Table 7. Disease ratings of entries selected from 1983 AYT's for high yield and/or early maturity in one or more seasons.

Entry No.	Yield (t/ha)[y]			Days to maturity[y]			Rust %	Target Leaf spot[x]
	Spring	Summer	Autumn	Spring	Summer	Autumn		
AYT-1								
AGS 204	3.1a	2.2ad	1.6a-d	111ab	90abc	84bc	9	3
AGS 200	2.9ab	2.1bd	1.7a	105cd	82i	84b	6	1
AGS 205	2.2hi	2.4a	1.1e-g	95f	92ab	76efg	18	3
TN #15 (CK)	2.6ef	1.9d	1.2d-g	103e	86fgh	76fg	21	2
AYT-2								
AGS 208	3.4a	2.4bc	1.6a-e	110gh	96abc	84g	12	4
AGS 215	3.3ab	2.3cd	1.9a-c	115cde	97ab	91ab	6	1
AGS 216	3.1ab	2.8a	1.7a-d	120a	100a	88de	11	3
AGS 219	2.8bcd	2.4bc	1.7a-d	107hi	90cd	80h	25	2
TN #15 (CK)	2.6cde	1.6g	1.3e	105i	89d	76i	13	2
AYT-3								
AGS 222	3.1ab	2.2a-d	1.9ab	108ef	97bc	91abc	4	3
AGS 227	3.2ab	2.2a-c	2.0ab	114ab	93d	91ab	1	0
TN #15 (CK)	2.9ab	1.6f	1.3cd	107fg	87e	81e	11	3
AYT-4[z]								
G 10452	-	2.8a	2.3a	-	98c	93d	6	1
G 10467	-	2.6a	2.0a-c	-	105b	95c	5	2
G 10468	-	2.6a	1.8b-d	-	109b	95c	6	2
G 10458	-	2.5a	1.4ef	-	95cd	87f	14	3
G 10470	-	2.5a	1.4ef	-	95cd	86f	14	1
AGS 129 (CK)	-	2.7a	1.7c-e	-	90d	87f	11	1
AGS 182 (CK)	-	1.2d	1.2f	-	84e	77g	23	1

[z] AYT-4 was not planted in the spring season.
[y] Means within columns followed by the same letter are not significantly different at the 5% level.
[x] Rating 0 = no symptom and 5 = severe symptoms.

Mutation Breeding

Introduction

Since cultivar AGS 2 (G 2120) is highly sensitive to photoperiod, and therefore flowers quite late when planted in the spring season, it cannot be harvested before the rainy season. Following irradiation, one selection made in 1982 from a segregating population of AGS 2 flowered and matured earlier than did AGS 2 itself. Another appeared resistant to soybean rust. Still others had larger seeds than did AGS 2. Described below are the results of further yield testing and selection of the early maturing mutant.

Materials and Methods

A total of 463 single plants selected from the M_4 generation were evaluated in a preliminary yield trial with no replications. The trial

was planted on January 26 in 1 x 3 m plots, with two rows per plot. Heavy rains at harvest time caused most entries to begin sprouting in the field. Thirty-eight entries with good seed quality were advanced to summer and autumn PYT's. Major growth and yield parameters were measured, and the protein and oil contents of the summer crop were also analyzed. Cultivars AGS 2, AGS 129, Shih Shih, and KS #8 served as checks.

Results

During the spring season, the mean number of days to flowering and maturity of the mutant lines was 70 ± 2.4, and 119 ± 1.3. The check, AGS 2, flowered at 89 days after planting (DAP), but did not mature until 130 DAP. Shih Shih, another check, flowered at 56 DAP and matured at 105 DAP. Mutant line 35-5 yielded 3.7 t/ha, and 37 others yielded 3.0 t/ha or more, compared to Shih Shih's 2.0 t/ha. Data obtained from summer and autumn season PYT's indicated that the number of days to flowering and maturity were similar to those seen for the M_3 and M_4 generations, suggesting that these two variables were fairly stable (Table 8). Yield per day was the parameter which varied most; it ranged from 16-3's 27.2 kg/ha to 20-4's 34.7kg/ha. The mean yield per day of the selected mutant lines was 30.4 kg/ha, compared to AGS 2's 23.3 kg/ha and Shih-Shih's 19 kg/ha. Selected mutant lines had protein contents as high as 45%, and oil contents as high as 20.9% (Table 8).

Table 8. Mean values of agronomic traits of selected M_6 lines planted in summer and autumn seasons.

Variable	Mean for mutant lines		Checks					
			AGS 2		KS #8		Shih Shih	
	Summer (Su)	Autumn (Au)	Su	Au	Su	Au	Su	Au
Yield t/ha	2.5±0.2	2.2±0.2	2.3	2.3	1.9	2.3	1.5	1.3
Days to flowering	38 ±0.2	40.3±0.8	31	50	37	35	33	36
Days to maturity	82 ±0.0	87 ±0.4	100	105	97	90	78	89
100 seed weight g	6.4±0.4	6.5±0.4	6.5	7.5	20	25	17	12
Yield/day/ha	30.4±2.4	25.4±2.3	23.3	21.3	20	26	19	15
Protein %	42.7±1.2	NA[z]	NA		NA		NA	
Oil content	18.6±0.7	NA	NA		NA		NA	

Note: Days to flowering in M_3 = 37±1.6; M_4 = 38±1.1.
Days to maturity in M_3 = 92±8.1; M_4 = 90±1.4.
[z] NA: Data not available.

Conclusions

Selected mutant lines are stable for number of days to flowering and number of days to maturity. Some combine high yield potentials with high protein or oil contents. Selected lines will be further screened in multi-replicate, multi-locational tests.

Selection for Soybean Rust Resistance

Introduction

Soybean rust is one of the most important disease problems of soybean in the tropics and subtropics. This study was designed to identify potentially rust tolerant selections for further confirmatory screenings.

Materials and Methods

A total of 130, 16, 253, and 18 pedigrees were planted from the F_8, F_9, F_{10}, and F_{11} generations. F_8 and F_{10} generations were planted in 1 x 3 m plots with two rows per plot. The first one-meter square in each plot was sprayed with a fungicide, the second was left as a border, and the third was left as an untreated control. F_9 and F_{11} generations were planted in a 1 x 5 m plot with 2 rows per plot. Two meters at either end were used as sprayed and unsprayed treatments, with the middle one-meter strip used to separate them. The percentage of rust infected foliage for each pedigree was assessed at the R_6 growth stage. One row each of G 8586 and G 8587 served as field resistant checks, and susceptible checks TK #5 and Shih Shih were planted every tenth row. The percentages of rust infected foliage found in the F_8, F_9, F_{10}, and F_{11} pedigrees were recorded at 73, 79, 47, and 79 DAP, respectively.

Results

Even without fungicide spray, some genotypes showed negligible levels of soybean rust infection (0 rating). With fungicide spray many genotypes moved from higher to lower rust severity ratings (Table 9).

Table 9. Soybean rust severity on various generations of selected pedigrees.

Generation	Without fungicide spray					With fungicide spray				
	% rust infected foliage					% rust infected foliage				
	0	1-5	6-10	11-15	>15	0	1-5	6-10	11-15	>15
F_8[z]	2	97	23	8	0	12	104	14	0	0
F_9[y]	0	7	9	0	0	2	14	0	0	0
F_{10}[z]	0	196	40	17	0	42	181	25	5	0
F_{11}[y]	0	2	2	0	14	2	0	4	2	10

[z] Planted on September 22.
[y] Planted on September 14.

Pedigrees GC 60031-2-8-6y-30 and GC 60058-10-6-6-8LG-31 had '0' ratings in both sprayed and unsprayed plots. Over four generations, 73 of 417 genotypes had a severity rating of one percent or less. (Soybean rust

ratings of the check cultivars are shown in Table 10.) Those 73 pedigrees will be further evaluated for yield. Despite higher levels of soybean rust incidence, the following 10 pedigrees had good pod set and seed filling: GC 60020-8-7-13, -14 -18, and -22; GC 60058-10-7-9-9y-14 and -24; GC 60058-8-3-6-10-39, -41, and -43; and GC 60087-7-9-6-12-47.

Table 10. Soybean rust severity of check cultivars.

Check Cultivar	Without fungicide spray				With fungicide spray			
	% rust infected foliage				% rust infected foliage			
	Pedigree generation							
	F_8	F_9	F_{10}	F_{11}	F_8	F_9	F_{10}	F_{11}
TK#5	10	20	5	20	5	3	1	3
G 8586	2	5	0	5	1	3	0	3
G 8587	1	3	1	3	0	3	0	3
Shih Shih	10	25	5	25	8	20	1	20

Conclusions

A total of 108 potentially rust tolerant breeding lines (lines with proportions of rust infected foliage ranging from 0 to 4% without fungicide applications) were selected for further intensive screening and yield evaluation in 1984.

Response of Two Soybean Cultivars to Varied Inputs in Three Locations

Introduction

Soybean production in the tropics and subtropics is limited by weeds, moisture, pests, and diseases. This study was designed to determine the response of two genotypes to a varying factorial combination of management inputs, and to determine the specific combination of inputs that would obtain a maximum economic yield. This was the first in a series of such experiments to be conducted in different seasons and locations.

Materials and Methods

A 2^5 factorial design was replicated twice at AVRDC. Narrow leaflet AGS 129 and broad leaflet AGS 154 were the two genotypes. Other variables were herbicide versus no herbicide, irrigation versus no irrigation, insecticide versus no insecticide and fungicide versus no fungicide. At Chishan and Pingtung, the irrigated versus non-irrigated treatments were deleted, and a 2^4 factorial design was used with two replications. At AVRDC, the plot size was similar to that used for the AYT's. Observations were made of plant height at the R_1 and R_8 stages,

the number of pods per plant, 100 seed weight, and grain yield per plot. The experiment was planted on September 23, 1983 at AVRDC, on October 7 at Chishan, and on October 4 at Pingtung. At AVRDC, the Center's suggested cultural practices were followed, and in Chishan and Pingtung seeds were planted using the no-tillage rice stubble method. Plot size was 3.6 x 7.2 m at Pingtung and 2.4 x 7.2 m at Chishan. The effective harvest plot size at Pingtung was 3 x 6 m, and at Chishan it was 1.8 x 6 m. In both locations rows were planted 30 cm apart, with 15 cm between hills and two seeds per hill.

Results

AVRDC:

Although AGS 154 yielded an average of 12% more than AGS 129, the yields of both varieties were significantly influenced by all five variables (Table 11). Herbicide application increased the yields of AGS 129 by 40%, and insecticide application increased its yields by 87%. Herbicide application increased the yields of AGS 154 by only 18% over those of the no herbicide treatment, compared to a 71% increase for AGS 129 (Table 12). Insecticide application appeared to be the most important single factor in increasing autumn yields at AVRDC. AGS 154 was able to yield about 24% more when insecticide was applied than was AGS 129 (Table 13).

Table 11. Effects of management practices upon the yield and yield components of soybean cultivars AGS 129 and AGS 154.

Factors	No. of pods/ plant	100-seed wt. (gm)	Yield (kg/ha)
Cultivars			
AGS 129	12.45	14.77	1065.38
AGS 154	16.88	11.77	1196.28
LSD 5%	1.60	0.49	113.56
1%	2.14	0.66	NS
Irrigation			
With	13.82	13.47	1066.72
Without	15.51	12.69	1194.94
LSD 5%	1.60	0.49	113.56
1%	NS	0.66	NS
Herbicide			
With	16.71	12.74	1321.81
Without	12.63	13.42	939.84
LSD 5%	1.60	0.49	113.56
1%	2.14	0.66	152.52
Insecticide			
With	16.76	13.65	1448.22
Without	12.58	12.50	775.43
LSD 5%	1.60	0.49	113.56
1%	2.14	0.66	152.52
Fungicide			
With	14.20	12.38	1030.41
Without	15.13	13.79	1231.25
LSD 5%	NS	0.49	113.56
1%	NS	0.66	152.52

Table 12. Significant interactions of selected management practices, and their effects on soybean yield.

Factors			Yield kg/ha
Cultivars	Herbicide		
AGS 129	With		1346.06
AGS 129	Without		784.68
AGS 154	With		1297.56
AGS 154	Without		1095.00
LSD 5%			160.59
1%			215.70
Herbicide	Insecticide		
With	With		1728.18
With	Without		915.43
Without	With		1244.25
Without	Without		635.43
LSD 5%			160.59
1%			215.70
Irrigation	Herbicide	Insecticide	
With	With	With	1748.12
With	With	Without	940.62
With	Without	With	962.25
With	Without	Without	615.87
Without	With	With	1708.25
Without	With	Without	890.25
Without	Without	With	1526.25
Without	Without	Without	655.00
LSD 5%			227.12
1%			305.04

Table 13. Significant interactions of selected management practices, and their effects on the yields of cultivars AGS 129 and AGS 154.

Factors		Yield (kg/ha)		
		AGS 129	AGS 154	Average
Irrigation	Herbicide			
With	With	1447.37	1241.37	1344.37
With	Without	629.87	948.25	798.06
Without	With	1244.75	1353.75	1299.25
Without	Without	939.50	1241.75	1090.62
LSD 5%		227.12	227.12	160.59
1%		305.04	305.04	215.70
Irrigation	Insecticide			
With	With	1349.75	1360.62	1355.18
With	Without	727.50	829.00	778.25
Without	With	1441.00	1793.50	1617.25
Without	Without	734.32	802.00	772.62
LSD 5%		227.12	227.12	160.59
1%		305.04	305.04	215.70

Chishan:

Of these four factors, significant differences were noted only in genotype (Table 14). AGS 129 had larger seeds and was higher yielding, less lodging-prone, and earlier maturing, than AGS 154. Since the farmer had uniformly mulched all plots with rice straw, as was his practice, levels of weed infestation were negligible. Insect and disease incidences were also negligible, and, as a result, no inputs had a significant effect.

Table 14. Significant differences observed between two cultivars at Chishan.

Cultivar	Yield t/ha	Plants ha	Days to maturity	100 seed wt. (g)	Lodging score
AGS 129	2.93	311,100	92	16	2
AGS 154	2.66	369,000	98	14	5
Differences between cultivars significant at P>F	0.0086	0.0086	0.0001	0.0048	0.0001

Pingtung:

Unlike at AVRDC and Chishan, herbicide application was the only factor to significantly affect yield. It produced yield increases of 11.4% (Table 15). As at Chishan, all plots were uniformly mulched with rice straw. In plots where no herbicide had been applied, however, barnyard grass (Echinocloa crusgalli Beauv. var. formosensis Ohwi), goose grass (Eleusine indica (L.) Gaertn), and cutleaf ground cherry (Physalis angulata L.) had overtaken the soybean. There were significant differences between cultivars for number of plants and a few other characters (Table 16). The differences between the two cultivars in earliness, lodging resistance, and seed size were similar to those noted at Chisan.

Conclusions

Insecticide and herbicide applications appeared to have more effect than did other inputs. Some genotypes gave higher yields at all loca-

Table 15. Grain yield variations at Pingtung due to herbicide application.

Treatment	Yield (t/ha)
No herbicide	1,910
With herbicide	2,127
Differences between treatments significant at P>F	0.0042

Table 16. Significant differences observed between two cultivars at Pingtung.

Cultivar	Plants/ ha	Pods/ plant	100 seed wt. (g)	Days to maturity	Lodging score
AGS 129	371,000	19	17	92	1
AGS 154	411,000	26	14	97	5
Differences between cultivars significant at P>F	0.0242	0.0002	0.0001	0.0001	0.0001

tions, but the influence of environment will be further examined by conducting similar experiments in the spring and summer of 1984.

Effect of Continuous Cropping Upon Soybean Growth and Yield

Introduction

Continuous cropping of soybean on the same piece of land is common in Indonesia. A three-season experiment was initiated in 1983 to assess the impact of this practice on grain yield and to learn more about problems that might be associated with the practice.

Materials and Methods

AGS 129 (narrow leaflet type) and AGS 154 (broad leaflet type) were planted in 5 x 10 m plots on January 28, June 14, and September 29. An RCB design was used with four replications. Rows were planted 50 cm apart, with 10 cm between hills and 3 to 4 seeds per hill. Upon emergence, stands were thinned to three plants per hill in the autumn and two plants per hill in the spring and summer.

Results and Conclusions

Three successive crops were successfully harvested from the same piece of land with no significant reductions in yield. Yields of AGS 129 were significantly higher than those of AGS 154 only in the January planting. Varietal differences for the June and September plantings were insignificant (Fig. 1). Both varieties matured later in the February and June plantings than in the September planting. As in 1982, yield/ha/day was similar for both selections. The combined February and June plantings provided 81% and 78% of the total three crop yield for AGS 129 and AGS 154, respectively (Fig. 2). AGS 129 yielded a two-season total of 7.86 t/ha in 295 days, and AGS 154 a total of 7.34 t/ha in 288 days (Fig. 2). The yields of both genotypes were similar in 1982, and the greater number of days to maturity in 1983 was mainly due to the February planting's later maturity.

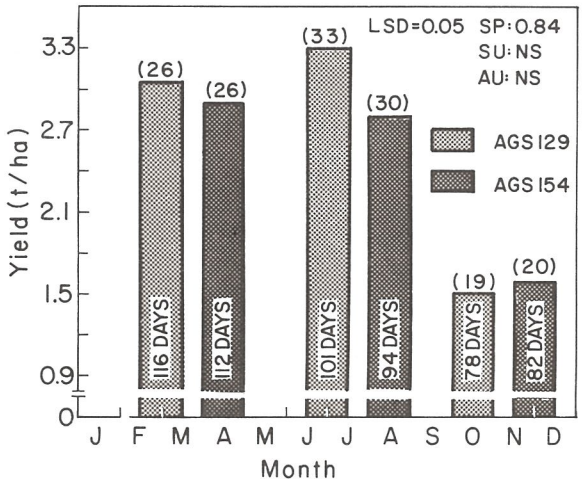


Fig. 1.
Yields of two soybean selections in three consecutive plantings (values in parenthesis are yield/day/ha).

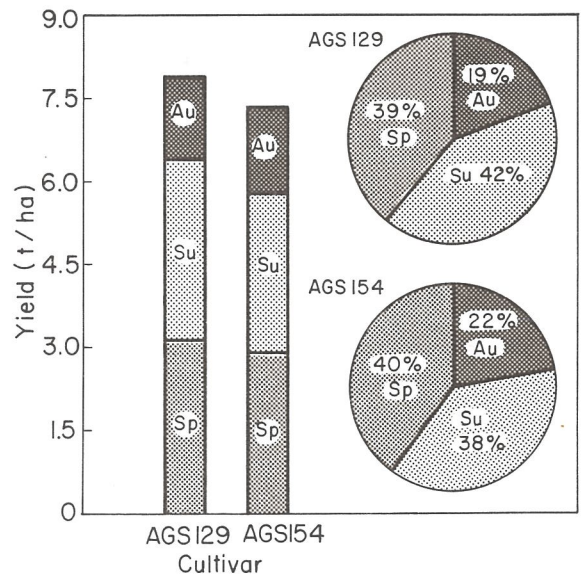


Fig. 2.
Yields of two continuously cropped soybean selections over three seasons.

Effects of Pot Size and Planting Time on Soybean Seed Size

Introduction

When planted at AVRDC, large seeded soybeans from Japan, Korea, or the USA generally produce much smaller seeds than they do when planted at their site of origin. This preliminary experiment was conducted to determine which factors most influence soybean seed size.

Materials and Methods

Large-seeded soybean cultivar Tanbaguro, which has a 100-seed weight of 68 gm, was planted in a greenhouse on March 1, May 9, and July 12. At each planting five different pot sizes were used as subplots. In

addition to 100-seed weight, observations were also made of the number of days to flowering and maturity, the number of pods and seeds per plant, and the total seed weight per plant. Each treatment had five replications.

Results

Although there were significant differences between the three plantings for most characters studied, the differences in 100-seed weight were insignificant. In each case, however, 100-seed weight was 37 to 42 percent less than for the original seed. The highest seed weight per plant was obtained from the May 9 planting, and the highest seed number was obtained from the May 9 and July 12 plantings (Table 17).

Seed weight and number per plant significantly increased with pot size. Plants in the 11.5 cm pot produced the smallest sized seed (100-seed weight 31.5 gm) and plants in the 23 cm pot produced seeds with a 100-seed weight of 46.7 gm (Table 18). Such results suggest that it is possible to vary the seed size by varying inputs.

Table 17. The agronomic characteristics of Tanbaguro when grown in a greenhouse in five different size pots.

Treatment	100 seed wt. (g)	Days to flowering	Days to maturity	Pods/ plant	Seeds/ plant	Seed wt./ plant (g)
T_1	31.5b	40a	163a	6.5d	4.3c	1.69d
T_2	42.0ab	39b	167a	12.0c	9.4b	4.01cd
T_3	47.8a	40ab	164a	15.9bc	13.1b	6.33bc
T_4	46.1a	39b	162a	20.5b	17.4a	7.96ab
T_5	46.7a	39b	166a	27.7a	20.3a	9.48a

Note: T_1: The diameter of pot was 11.5 cm, soil weight 1 kg
T_2: The diameter of pot was 13.5 cm, soil weight 1.5 kg
T_3: The diameter of pot was 17.4 cm, soil weight 2.7 kg
T_4: The diameter of pot was 19 cm, soil weight 3.5 kg
T_5: The diameter of pot was 23 cm, Soil weight 6.5 kg

Table 18. The agronomic characteristics of Tanbaguro when planted at three different planting dates.

Treatment	100 seed wt. (g)	Days to flowering	Days to maturity	Pods/ plant	Seeds/ plant	Seed wt./ plant (g)
P_1	46.0a	42a	139c	6.3c	5.7b	2.62c
P_2	42.8a	36b	203a	29.1a	18.2a	8.14a
P_3	39.6a	42a	150b	14.2b	14.8a	6.64b

Note: P_1: Planted on March 1, 1983
P_2: Planted on May 9, 1983
P_3: Planted on July 12, 1983

Conclusions

Although further confirmatory trials are necessary before more definite conclusions can be reached, it would appear that genotype plays a more inportant role than environment in determining seed size under subtropical conditions.

Genotypic Variations in Shade Tolerance

Introduction

Because soybean is usually cultivated in the tropics and subtropics as an intercrop with annuals or perennial crops, it often encounters varying levels of shading. In this experiment six AVRDC Glycine selections were examined to learn how much their levels of shade tolerance vary.

Materials and Methods

Six AGS entries (AGS 80, 129, 145, 59, 106, and 34) were evaluated in a split plot design with and without nylon net shading. The experiment was conducted with spring (March 1), summer (July 14), and autumn (September 22) plantings in 1 x 3 m plots that had two rows per plot. Each treatment was replicated twice. Observations were made of yield, number of days to flowering and maturity, plant height at the R_1 and R_8 stages, 100 seed weight, seed quality, and lodging resistance. Light transmission was measured with a Lambda LI-185 photometer and a LI-190S quantum sensor. Light intensity in the unshaded treatment averaged 69,000 lux in the summer and 45,000 lux in the autumn, and the light intensity in the shaded treatment averaged 5,416 lux in the summer and 6,875 lux in the autumn.

Results and Conclusions

Significant differences in yield were observed between genotypes and treatments. Shaded treatments gave higher absolute yields in the summer than in the spring or autumn seasons. AGS 34 appeared to be shade tolerant in the spring and autumn, and AGS 106 was most shade tolerant in the summer (Table 19). Simple correlation of yield in netting and no netting treatments was insignificant in both the spring and summer, suggesting that selections for shade tolerance must be made separately.

(Continued on the next page)

Table 19. Yield and percent yield loss of soybean treated with netting, 1983.

Entries	Yield (kg/ha)						% yield reduction due to netting		
	Netting			No netting					
	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
AGS 80	294	1760	908	1630	4165	3142	82	58	71
AGS 129	267	1720	703	1003	4402	2544	73	61	72
AGS 145	376	287	178	1066	1436	967	65	80	82
AGS 59	455	1960	957	944	4322	2531	52	55	62
AGS 106	139	1770	601	436	2214	2795	68	20	78
AGS 34	449	1448	1294	706	4403	3043	36	67	57

Ap = Spring season, Su = Summer season, Au = Autumn season
Note: Light flux density in no netting was 69,000 lux in the summer and 45,000 lux in the autumn while netting treatment itself was 5416 lux and 6875 lux during summer and autumn season respectively.

Screening Genotypes for Intercropping

Introduction

In many Asian countries soybean is often intercropped with corn. This experiment involved the screening of AGS entries in the spring, summer, and autumn seasons to determine which are most suitable for intercropping in each season, and to determine each cultivar's expected intercropping-related yield loss in each season.

Materials and Methods

A 13 x 13 double lattice design was used for both monocropping and intercropping treatments. Local check cultivar Shih Shih was planted with 168 AGS entries. The plot size for monocropping was 1 x 3 m, with two rows per plot and two replications. Plantings were made on March 23, July 14, and September 22. In the intercropped treatment, one row of soybean was alternated with one row of maize (cv. Hawaii Super Sweet). Soybean was planted with 10 cm between plants and 50 cm between rows, and maize was planted with 25 cm between plants and 50 cm between maize and soybean rows. Observations were made of yield, seed quality, lodging number days to R_1 and R_8 stages, and plant height at the R_1 and R_8 stages.

Results

Mean sole-cropped yields were 2.2 t/ha in the spring, 3.0 t/ha in the summer, and 1.8 t/ha in the fall. Intercropped soybean yielded an average of 0.35 t/ha in the spring, 1.4 t/ha in the summer, and 1.1 t/ha in the fall. Intercropped soybean yields ranged from 0.3 to 0.7 t/ha in

the spring, from 0.4 to 2.8 t/ha in the summer, and from 0.3 to 1.8 t/ha in the autumn. Considering the proportion of the land they occupied, intercropped soybeans gave summer yields similar to those they gave when sole cropped. In the spring and autumn, however, the yields of soybean intercropped with corn were reduced considerably. As expected, intercropped soybean plants were taller than when solecropped, and all entries were lodging-prone when they were intercropped.

Conclusions

Among the three seasons in which intercropping was compared, soybean grown in the summer suffered no yield reduction when intercropped with maize. Forteen entries were selected for further evaluation in 1984.

International Cooperation

In 1983, 51 ASETs, 272 breeding lines, 729 accessions, and 38 lines derived from mutation were distributed to 119 cooperators in 43 countries.

The crossing of AGS 2 (G 2120) with an Indonesian cultivar culminated in the selection and release of 'Wilis', an improved higher yielding and earlier maturing cultivar.

The AVRDC Vegetable Soybean Evaluation Trial (AVSET) was held in Taiwan as a regional yield trial conducted at seven locations in the spring, one in the summer, and six in the autumn. (More detailed information can be found in a separate AVSET report). Preliminary results suggest that AGS lines 187, 188, 190, and 191 are acceptable to frozen food factories. Forty kilograms each of AGS 187 and 188 have been given to a frozen food company for intensive evaluation.

In international trials, accessions G 2261 and G 9646 and selections AGS 2, 17, 29, 58, 65, 124, and 129 produced significantly higher yields and/or earlier maturity than local check cultivars (Table 20). National programs in Belize, Haiti, Indonesia, Malawi, Malaysia, Mauritius, Panama, Pakistan, Thailand, Indonesia, and Taiwan plan to re-evaluate selected AGS entries to confirm their superiority over present cultivars, and several of these national programs plan to use AVRDC breeding lines in their varietal improvement programs.

The distinctly different soybean cropping systems found in the 11 ASET countries are shown in Fig. 3.(see page 229)

Ten kilograms of G 2261 were given to IRRI for a cropping systems trial.

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Table 20. Summary of international cooperation results.

Contry location cooperator	Cross no. or name	Yield (t/ha)	Days to maturity	Seed quality	100 seed wt. (gm)	Remarks
Argentina	AGS 58	3.12a				Planted on Nov. 22, 1982
Lat. 32°48'N	G 9646	3.03a				Total no. of entries: 14
Nora Mancuso	AGS 66	2.87ab				
	AGS 130	2.66abc				
	AGS 29	2.58abc				
	AGS 129	2.36abcd				
	AGS 12	2.21abcde				
	Local CK 1	2.79abc				
	Local CK 2	2.77abc				
Belize	G 9646	1.87a	112a	2.8abc	14.5e	Planted on Nov. 25, 1982
Lat. 17°15'N	AGS 2	1.60ab	112a	1.0d	7.6f	Total no. of entries: 12
B. K. Rai	AGS 130	1.58ab	98d	2.5bc	19.0a	(no check)
	AGS 129	1.56ab	109ab	2.0cd	15.3cde	
	AGS 29	1.50ab	103bcd	1.8cd	15.0cde	
Haiti	AGS 17	2.84a	80i	1	17 f	Planted on Oct. 11, 1982
Lat. 19°10'N	CK 1	2.01efg	83f	1	17 f	Total no. of entries: 14
Alt. 5 m	CK 2	1.90fg	84de	1	16 g	
Chew Yun-feng						
Indonesia	AGS 2	1.49a	124a	2.0c	8.5g	Planted on Feb. 21, 1983
Lat. 2°58'S	Local CK 1	0.97bc	100b	3.5abc	11.4ef	Total no. of entries: 14
John Fitzgerald	Local CK 2	0.64bcd	99b	3.8ab	10.6f	
Lat. 6°30S	AGS 2	0.68a	98a		4.3e	Planted on Nov. 13, 1982
Samu-Neguo	Wilis (CK)	0.59abc	94b		5.8de	
Haile-Mariam	Orba (CK)	0.40def	90c		6.0de	Total no. of entries: 14
Ivory coast	AGS 129	1.99a	80		12.1	Planted on Aug. 21, 1982
Lat. 4°	G 9646	1.93a	85		10.8	Total no. of entries: 14
N'Dri Brou Benoit	AGS 29	1.89a	85		15.1	
	G 2261	1.87a	73		15.5	
	AGS 130	1.87a	73		16.7	
	AGS 85	1.84a	74		16.9	
	AGS 17	1.80a	85		14.4	
	AGS 12	1.74a	80		16.0	
	AGS 58	1.73a	74		14.8	
	AGS 2	1.73a	105		9.2	
	AGS 66	1.60a	74		12.2	
	AGS 62	1.24a	80		12.8	
	PS-1 (CK)	2.08a	109		20.0	
	IAC-8 (CK)	1.99a	105		21.3	
Lat. 5°	AGS 129	1.85abc	88		15.4	Planted on July 13, 1982
N'Dri Brou Benoit	AGS 58	1.81abcd	93		16.1	Total no. of entries: 14
	G 2261	1.78abcd	83		16.1	
	AGS 29	1.78abcd	93		14.8	
	AGS 12	1.75abcd	87		16.7	
	PS-1 (CK)	2.25a	112		17.1	
	IAC-8 (CK)	2.09ab	107		16.9	
Kingdom of Tonga	AGS 2	1.51a	184b	1.5ab	12.3e	Planted on Oct. 4, 1982
Lat. 21°12'S	G 9646	1.40a	194a	1.8ab	16.5bcd	Total no. of entries: 12
P. Cheng,	AGS 62	1.38a	98d	1.5a	16.8abcd	(no check)
Moa. Vatuvei						
Malawi	G 9646	3.16a	96b	1.5b	17.1ef	Planted on Dec. 30, 1982
Lat. 14°S	AGS 58	2.98ab	89de	1.8b	23.4a	Total no. of entries: 14
C. E. Maliro	AGS 129	2.94abc	91cd	1.5b	18.6ed	
	ORRIB (CK)	3.17a	95b	2.0b	21.5b	
	Hardee (CK)	2.63cde	96b	1.8b	20.9bc	

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Table 20. (Continued from the previous page) Summary of international cooperation results.

Contry location cooperator	Cross no. or name	Yield (t/ha)	Days to maturity	Seed quality	100 seed wt. (gm)	Remarks
Malaysia	AGS 124	2.77a	91a	2.3b	17.6cd	Planted on May 23, 1983
Lat. 1°29'N	AGS 129	2.55ab	89a	2.0b	18.9abc	Total no. of entries: 12
MacPherson Chia	AGS 66	2.51ab	86a	2.0ab	18.0bc	
	AGS 19	2.40ab	88a	3.0a	18.5bc	
	AGS 79	2.38ab	89a	2.8a	15.3ef	
	AGS 143	2.23ab	75b	2.0b	19.3ab	
	AGS 65	2.22ab	91a	2.0b	18.9abc	
	Local CK 1	2.21ab	92a	3.0a	14.1f	
	Local CK 2	1.38c	89a	3.0a	16.3de	
Lat. 3'N	AGS 143	1.35ab	93d	1.0b	19.6a	Planted on April 13, 1983
Fadelah Abdul	AGS 79	1.08abc	98c	1.0b	15.1fg	Total no. of entries: 12
Aziz	AGS 129	1.07abc	101b	2.3a	19.0ab	
	AGS 19	1.02abc	101b	1.5ab	18.6abc	
	AGS 66	1.01abc	84e	1.0b	13.1h	
	AGS 167	1.00abc	93d	1.5ab	18.8ab	
	AGS 124	0.86abc	101b	1.8ab	17.9bcd	
	AGS 65	0.85abc	104a	1.8ab	18.4abc	
	Palmetto(CK1)	1.39a	101b	1.5ab	17.2cd	
	Calland (CK2)	0.93abc	98c	1.0b	15.6ef	
Lat. 1°29'N	C 9646	1.90a		2.0c	18.2ab	Planted on May 20, 1982
MacPherson Chia	Local CK	1.50b		2.3bc	15.1cd	Total no. of entries: 13
Mauritius	AGS 58	1.35a	89bc	1.0a	19.9ab	Planted on Feb. 2, 1982
Lat. 19°191'S	AGS 29	1.28a	90bc	1.3a	16.4bc	Total no. of entries: 14
Alt. 375m	AGS 17	1.11ab	83bc	1.3a	16.9abc	
D. R. Vencatasamy	G 9646	1.07ab	93ab	1.0a	14.9c	
	AGS 130	1.06ab	84bc	1.0a	20.5ab	
	AGS 12	1.06ab	87bc	1.3a	19.3abc	
	AGS 85	0.86abc	91bc	1.0a	21.5a	
	AGS 62	0.86abc	91bc	1.0a	18.3abc	
	CK 1	0.91abc	93ab	1.0a	17.8abc	
	CK 2	0.6 bc	86bc	1.0a	16.0bc	
Lat. 20°	AGS 58	1.73a	103bcd	2.0b	21.2ab	Planted on Feb. 7, 1983
Jean Lo Yuen Fong	AGS 130	1.68ab	95cde	2.0b	19.8abc	Total no. of entries: 12
	AGS 12	1.58ab	99cde	2.3ab	20.2abc	(no check)
	AGS 17	1.57ab	104bc	2.0b	15.9de	
	AGS 85	1.54ab	90ed	2.5a	21.5a	
	AGS 66	1.53ab	90e	2.0b	14.0e	
	G 9646	1.52ab	114ab	2.0b	16.1de	
	AGS 29	1.38abc	112ab	2.0b	16.4de	
	G 2261	1.36abc	88e	2.0b	18.6bcd	
Pakistan	AGS 65	3.8ab	119bcd	1 e	15 ab	Planted on Jan. 15, 1983
Lat. 25°2'N	AGS 129	3.7ab	116cd	4 a	15 ab	Total no. of entries: 12
M.A. Rajput	AGS 162	3.7ab	116cd	3 bcd	14 bc	
	AGS 79	3.6abc	128ab	3 bcd	13 bc	
	AGS 124	3.5abc	125abc	4 a	15 ab	
	AGS 66	3.4abc	113d	2 de	11 c	
	CK 1	4.4a	128ab	2 de	15 ab	
	CK 2	3.6abc	134a	3.5ab	14 bc	
Panama	AGS 58	2.14a	88bcd	2.8cd	23.8a	Planted on Jan. 1, 1983
Lat. 8°22'N	AGS 29	2.09ab	88bcd	3.0bcd	18.3bcd	Total no. of entries: 14
Gaspar Silvera	AGS 17	1.83abc	84d	2.0d	15.3efg	
	AGS 12	1.68abc	84d	3.5bc	19.5b	
	G 9646	1.68abc	92ab	4.5a	15.5efg	
	Local (CK)	1.62abc	94a	2.8cd	14.5fg	
	Palmetto (CK)	1.01def	94a	3.5bc	16.8def	

(Continued on the next page)

Table 20. (Continued from the previous page) Summary of international cooperation results.

Contry location cooperator	Cross no. or name	Yield (t/ha)	Days to maturity	Seed quality	100 seed wt. (gm)	Remarks
Sudan	AGS 129	0.2 a	94de	3.8bcd	11 ab	Planted on July 6, 1983
Lat. 11°N	AGS 162	0.2 a	90f	3 cd	10 bc	Total no. of entries: 12
WSARP	AGS 79	0.18ab	96cd	3.5bcd	9 c	
	AGS 160	0.18ab	93def	3 cd	9 c	
	AGS 66	0.17ab	95cde	4.3ab	10 bc	
	AGS 143	0.17ab	92ef	4 ab	12 a	
	AGS 124	0.16ab	94de	3.5bcd	10 bc	
	AGS 167	0.15abc	93def	3.8bcd	11 ab	
	AGS 65	0.14abc	98c	4.3ab	9 c	
	CK 1	0.08cd	107b	5 a	9 c	
	CK 2	0.06d	110a	5 a	7 d	
Thailand	AGS 29	1.96a	106a	2.3b	14.0bcd	Planted on Dec. 15, 1982
Lat. 17°12'N	AGS 12	1.78ab	99cd	2.0b	15.8b	Total no. of entries: 14
Anek	AGS 130	1.77ab	104ab	2.3b	20.6a	
Chotiyarnnong	AGS 129	1.74ab	103abc	2.0b	14.5bc	
	AGS 58	1.71ab	101bcd	2.0b	18.5a	
	G 9646	1.67ab	97d	2.0b	11.2d	
	AGS 17	1.67ab	96d	2.0b	13.8bcd	
	AGS 85	1.60ab	98d	2.0b	18.7a	
	SJ 5 (CK)	1.78ab	105a	2.0b	15.4b	
	SJ 2 (CK)	1.60ab	105a	2.0b	11.3d	
Lat. 19°N	AGS 160	0.62a	72c	3.8bc	13.5abc	Planted on July 29, 1983
Alt. 500 m	CK 1	0.44ab	73abc	2.0e	15.0ab	Total no. of entries: 12
Siriporn	CL 2	0.27bc	73abc	2.5de	14.2abc	
Loathertpong						
Uruguay	AGS 66	1.97ab	110cd			Planted on Dec. 16, 1982
Lat. 33°N	AGS 129	1.87abc	105f			Total no. of entries: 14
Yang Chia-Weun	AGS 17	1.76abcd	110cd			
	AGS 130	1.75abcd	106ef			
	AGS 58	1.73abcd	110cd			
	AGS 62	1.72abcd	108cde			
	AGS 85	1.68abcd	100g			
	Palmetto (CK)	2.12a	110cd			
	Local (CK)	1.72abcd	105f			

Indonesia

At the request of Dr. Sumarno, six improved Indonesian cultivars were evaluated for photoperiodic response. All were found to be quite sensitive to variations in photoperiod (Table 21).

Japan

In the summer of 1983, a total of 411 accessions which had been identified at AVRDC as less sensitive to photoperiod were evaluated in the field by Dr. Kiyoya Tateno of the Kyushu University for ten additional characters with the objective of determining the extent of their variability. Results will be reported after the experiment has been repeated in 1984.

Korea

In 1983 a new strategy in generation advance was suggested to the

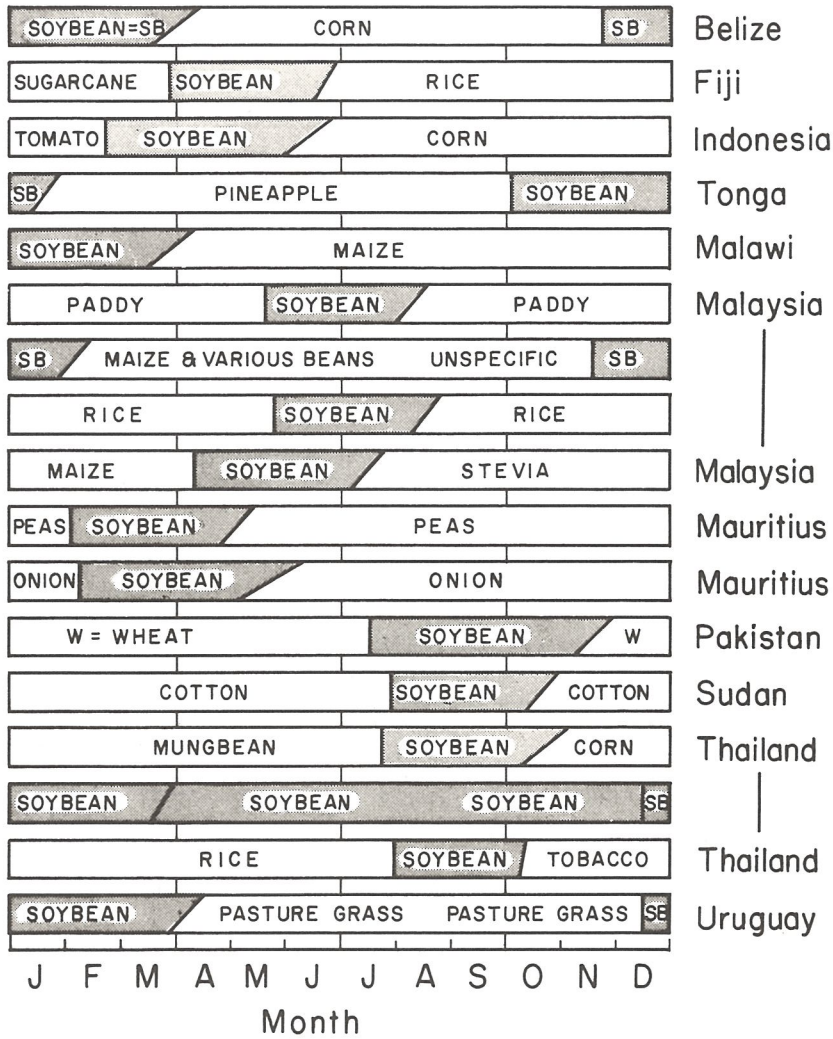

Fig. 3. Soybean cropping systems in ASET trials, 1982-83.

Korean soybean breeding program. Five cross combinations were advanced by the pedigree method and by SSD beginning with the F_3 generation in the spring, the F_4 generation in the summer, and the F_5 generation in the autumn. The F_6 seeds were planted in the spring of 1984, and will be harvested and sent to Korea, reducing even further the time needed to develop a new cultivar in that country. The progress made so far is shown in Table 22.

A total of 37 vegetable soybean cultivars provided by AVRDC were evaluated in a trial planted May 14, 1983. Local check cultivars Hwanggeumkong and Jangyeobkong reached the R_7 stage at 123 and 121 days after planting, but cultivars Willomi and PI.s. 85272, 96093, and 339990 reached the R_7 stage in 102 to 109 days, and had a seed size acceptable for vegetable soybean. Their yield potential, however, needs to be further evaluated.

Table 21. Days to flowering and days to maturity of Indonesian cultivars under 10, 12, 14 and 16 h photoperiods (AVRDC 1982-83).

Cultivar name and AVRDC Acc. No.	(Mean of 2 reps) Mean days to Flowering				Mean days to maturity			
	10h	12h	14h	16h	10h	12h	14h	16h
Orba (G 9046)	35	46	96[z]	-[y]	90	130	-[y]	-
B-3030 (G 10374)	39	92	-	-	101	-	-	-
B-3034 (G 10375)	37	72	-	-	96	150	-	-
LOKON (G 10376)	36	59	79	-	77	138	163	-
Galungkung (G 10377)	36	67	96	-	90	150	163[z]	-
Guntur (G 10378)	34	46	116	-	87	132	-	-

Note: Planted on October 17, 1982. The experiment was terminated 170 days after planting.
[z] Data from one replication only. The plants in the other replication did not flower or mature.
[y] Did not flower or did not mature.

Table 22. Progress in the generation advance of Korean soybean breeding lines at AVRDC in successive seasons of 1983.

Cross No.	Planting method	Planting lines Sp (F_3)	Su (F_4)	Au (F_5)	harvest lines Sp (F_3)	Su (F_4)	Au (F_5)
SS 80016	Pedigree	100	100	97	100	97	95
	SSD	10	10	10	10	10	10
SS 80017	Pedigree	120	120	119	120	119	119
	SSD	12	12	12	12	12	12
SS 80021	Pedigree	100	100	100	100	100	100
	SSD	10	10	10	10	10	10
SS 80071	Pedigree	120	120	115	120	115	114
	SSD	12	12	12	12	12	12
SS 80076	Pedigree	60	60	58	60	58	58
	SSD	6	6	6	6	6	6
Total no. of lines	Pedigree	500	500	489	500	489	486
	SSD	50	50	50	50	50	50

New Zealand

In an observational trial at the Levin Horticultural Research Centre, AVRDC accessions G 9053, G 6466, G 5306, G 9970, G 3968, and G 9971 appeared to be superior to local cultivars Hakucho and Extra Early Oslo. The selected entries will be further evaluated.

Sri Lanka

During the fall of 1982 ten AVRDC breeding lines out-yielded PB-1, the Sri Lankan local check cultivar, by 4 to 39%. Under Sri Lankan

conditions, AVRDC lines matured in 77 to 83 days, compared to 79 days for PB-1 (Table 23).

Table 23. Yield and other agronomic characteristics of high yielding AVRDC selections grown in Sri Lanka during the fall of 1982.

Cross designation	Yield (t/ha)	Days to flowering	Days to maturity	100 seed wt. (g)
GC 60058-18-1-8-7-6	2.6	29	83	14
GC 50106-26-8-6 (AGS 207)	2.4	29	79	13
GC 60102-7-6 (AGS 203)	2.4	29	83	19
GC 60056-6-8-6	2.4	29	82	16
GC 50228-1-23-6-6	2.3	32	79	17
GC 50227-3-19-6	2.2	29	79	19
GC 50228-1-38-6	2.2	34	79	21
GC 50228-2-7-6-6 (AGS 201)	2.2	32	77	16
GC 60082-8-9-6	2.2	29	83	19
GC 50030-2-7-6-6	2.1	32	81	26
Pb-1 (Check)	1.9	30	79	11
Bossier (Check)	1.2	29	79	15

Taiwan

In the Tainan District Agricultural Improvement Station's spring-time evaluation of three AVRDC breeding lines against local checks Shih Shih and H-15, none of the AVRDC entries differred significantly from the checks. In Shieh Chia and Tung Shih trials, however, nine AVRDC entries yielded significantly more than the local checks. In Tung Shih, AVRDC entries matured one week earlier than local check H-15 (Tables 24 and 25).

Table 24. Important agronomic characteristics of early maturing soybean selections planted at Shieh Chia in 1983.

Variety	Days to flowering	Days to maturity	100 seed wt. (g)	Yield (kg/ha)
AGS 151	47	92	13.1	1988a
AGS 145	47	92	16	1988a
AGS 152	47	92	14	1985a
AGS 153	47	92	11	1977a
AGS 150	46	91	10.4	1880a
AGS 138	46	91	10	1835a
AGS 128	46	91	12.3	1795a
AGS 149	46	91	12.2	1795a
AGS 141	47	92	11.2	1695a
H-15 (CK)	49	93	10	1108b

Note: Means followed by the same letters are not significantly different at the 5% level.

Table 25. Important agronomic characteristics of early maturing soybean selections planted in Tung Shih in the spring of 1983.

Variety	Days to flowering	Days to maturity	Yield (kg/ha)
AGS 153	50	91	848a
AGS 152	50	91	808a
AGS 128	50	92	807a
AGS 141	50	92	797a
AGS 138	50	92	786a
AGS 149	50	91	782a
AGS 150	50	91	780a
AGS 151	52	91	723a
AGS 154	50	91	713a
H-15	57	98	367b

Note: Means followed by the same letters are not significantly different at the 5% level.

Soybean Pathology

Identification of Three Virus Isolates Collected from Soybean in Taiwan

Introduction

On the basis of symptoms produced on Cho and Goodman's differential cultivars and on 21 additional plant hosts, it had been suggested that the three isolates (S-74, S-PN, and S-PM) found in previous surveys of Taiwan's soybean growing areas were not SMV, but might be BCMV. In 1983 more host species were inoculated and more serological tests conducted so that the identity of the three isolates could be determined more precisely.

Materials and Methods

Host range:

Three plants each of 57 cultivars belonging to 34 plant species, including many of those plants used by Hampton et al. for distinguishing legume viruses, were inoculated at either the cotyledon or the true leaf stage. They were kept in a greenhouse for five weeks for symptom observation. Plants with no symptoms or weak symptoms were back-inoculated to Chenopodium amaranticolor.

Serology:

The three virus isolates were tested by ELISA against antisera to the following viruses : bean yellow mosaic virus (BYMV), blackgram mottle virus (BlMV), peanut stunt virus (PSV), cowpea mosaic virus Y (CPMV-Y), cowpea mosaic virus S (CPMV-S), soybean mosaic virus (SMV), blackeye cowpea mosaic virus (BlCMV), southern bean mosaic virus (SBMV), bean common mosaic virus (BCMV), peanut mottle virus (PMV), soybean stunt virus (SSV), bean golden mosaic virus (BGMV), and cowpea mottle virus. The isolates were also tested against an antiserum of a virus isolated at the Taiwan Agricultural Research Institute from peanut (PMV-TARI). For all antisera the gamma-globulin and the enzyme conjugates were diluted 1:500.

Electron microscopic observations:

Particle length of isolates S-PM and S-74 was measured from spray preparations (2% phosphotungstic acid, pH 7.0). Two hundred particles

of each isolate were measured directly from the screen with a Siemens Morphomat.

Immunosorbent electron microscopy (ISEM) of the PN-isolate was performed with antisera of BlCMV, cowpea mosaic virus (CAMV), and PMV. For each antiserum two grids were prepared by being floated for five minutes on the diluted (1:1000) antiserum, washed with 40 drops of phosphate buffer, and placed for 15 minutes on a drop of crude juice of PN-infected N. benthamiana. The grids were washed with 40 drops of double-distilled water and stained with five drops of uranylacetate (2%).

Results

Host range reactions were similar for all three isolates (Table 1). The following hosts were found to be immune: Pisum sativum (Perfected Wales, Dark Skin, Perfection); Vigna radiata (V2010, Oklahoma); Capsicum annum (Yolo Wonder); Cucumis melo (Known-You); Cucumis sativus (Chicago Pickling); Datura stramonium (R. Fulton Strain); Lycopersicum esculentum (Marglobe, Fujuka No. 2); Nicotina glutinosa; Nicotiana tabacum (Samsun, Xanthi); Ocimium basilicum; Petunia hybrida (King Henry); Physalia floridana; Trifolium pratense (Kenland); Trifolium repens (New Zealand). The host reactions of the three unknown viruses indicate that they are neither SMV, BYMV, or BCMV.

All three isolates reacted similarly in ELISA tests; a positive reaction was obtained with antisera to BCMV, BlCMV, and PMV-TARI. Since all three isolates had been derived from single local lesion transfers on C. amaranticolor, it is unlikely that each would contain all three viruses. Their positive reaction to those antisera was probably due to the close serological relationship of BCMV, BlCMV, and PMV-TARI. Since BCMV involvement is unlikely on the basis of host reaction, it would seem that the three isolates are probably identical or closely related to PMV-TARI and BlCMV. This hypothesis was further supported by ISEM (Table 2), where BlCMV-AS was found to trap 1,280 and 680 virus particles, compared to normal serum, which trapped seven particles on one grid and none on the other. Peanut mottle virus (PMV) antiserum trapped only seven virus particles on each grid, but CAMV antiserum, because of its close serological relationship with this isolate, trapped 62 on one and 44 on the other. The modal particle length in spray preparations of S-PN and S-74 was 733 nm and 797 nm, respectively, which closely corresponds with BlCMV's reported modal length of 760 to 780 nm.

Only serological tests using homologous and heterologous antisera can determine the precise identity of the three isolates. Isolates of PN and 74 have already been purified by cesium chloride gradient centrifugation, and an antisera has been obtained with a titer of >1000.

Conclusions

The symptoms produced on 57 differential host species, the reactions observed in ELISA serological tests, and the observations of particle size and morphology provide strong evidence that 1) the three unidentified virus isolates (S-PN, S-PM, and S-74) are the same or very closely related; 2) that they are either identical to or very closely

related strains of BlCMV and PMV-TARI; and 3) that PMV-TARI is either identical to, or a very closely related strain of BlCMV.

Table 1. Host reactions of three soybean virus isolates: S-PM, S-PN, and S-74.

Host plant	PM	PN	74
Arachis hypogaea			
Tainan-9	nLL/-	N,nLL/M	nLL/-
Tainan-4	nLL/-	N,nLL/M	nLL/-
Cassia occidentalis	1/M	1/M	1/M
Cyamopsis tetragonobola	1/M	1/M	1/M
Dolichos lablab	1/M	1/M	1/M
Glycine max			
Bragg	VN,nLL,M/M	VN,nLL/M/M	VN,nLL,M/M
Davis	VN,nLL/VN,M,W,nLL	VN,nLL/VN,M,nLL	VN,nLL/VN,M,W,nLL
Tainan-4	nLL/M,N	nLL/M,N	nLL/M,N
Toyosuzu	-/-	nLL/M	nLL/M
Phaseolus acutifolius			
PI 200749	1/M	1/M	cLL/M
Phaseolus lathyroides	cLL	nLL,M,N	1/M
Phaseolus vulgaris			
Bountiful	VC/M,MAL	nLL,VC/M,MAL	M,nLL/M,MAL
Kentucky Wonder Wax Pole	nLL/M,N	N,nLL/W,N	nLL/W,N
Kentucky Wonder Wax Runner	nLL/W,N	nLL/W,N	nLL/W,N
Pinto III	nLL/-	nLL/-	nLL/-
Saxa	cLL/M,MAL	cLL/M,MAL	cLL/M,MAL
Top-Crop	nLL/-	nLL/N,W	nLL/-
Black Turtle Soup	nLL/N,W	nLL/N,W	nLL/N,W
Local Variety	nLL/-	nLL/-	nLL/-
Vicia faba	n/LL	nLL/-	-/-
Vigna angularis			
Jen-Sen	-/M	-/M	-/M
Vigna mungo	-/M	-/M	-/M
Acc. 3115	-/M	-/M	-/-
Vigna radiata			
V 2773	1/cLL,M	-/-	-/-
V 1111	-/M	-/M	-/-
Vigna unguiculata			
Blackeye	1/M,MO	1/M,MO	1/M,MO
Blue Goose	1/M,MO	1/M,MO	1/M,MO
Early Ramshorn	-/M,MO	nLL/M,MO	nLL/M,MO
Kaohsiung Green-Pod	-/-	-/MO,MAL	-/-
Local Variety (I)	nLL/MO	nLL/MO	nLL/MO
Local Variety (II)	-/MO	-/-	-/MO
Chenopodium amaranticolor	cLL/-	cLL/-	cLL/-
Chenopodium quinoa	cLL/cLL	cLL/cLL	cLL/cLL
Gomphrena globosa	VN,nLL/-	nLL/N	VN,nLL/VC,cLL
Medicago sativa			
Du Puits	-/-	cLL/M	-/-
Nicotiana benthamiana	-/VB,MO	-/M,VC	-/M,VC
Nicotiana clevelandii	-/CS	-/CS	-/CS
Spinacia oleracea			
Bloomsdale Long-standing	-/-	cLL/cLL	-/-
Tetragonia expansa	1/-	-/-	1/-

Symbols: 1 = latent infection, cLL = chlorotic level lesions, nLL = necrotic local lesions, CS = chlorotic spots, M = mosaic, MAL = malformation, MO = mottle, N = necrotic, W = wilting, VB = vein-banding, VC = vein-clearing, VN = vein-necrosis.

Table 2. Reaction of isolate S-PN in ISEM.

Antiserum	Particles Trapped
BlCMV	1280[z]/680
CAMV	44/62
PMV	7/7
NS	0/7

[z] The two numbers indicate the number of particles trapped on each of two grids(= 50 viewing fields; approximately 500 μ^2).
NS = normal serum

Soybean Mosaic Virus (SMV) and an Unidentified Virus on Soybean in Taiwan

Introduction

Soybean mosaic virus (SMV) is known to occur as seven strains, the most serious of which are necrotic strains G4, G5, G6, and G7. The SMV found in previous surveys of Taiwan's main soybean production areas was strain SMV-1, but the search continues for other strains of SMV which should be used in resistance screening. Work is also being done on PMV-TARI. Although first isolated by TARI scientists from peanut, AVRDC virologists have recently detected it on soybean, where it can cause necrotic symptoms similar to those attributed to the necrotic strains of SMV.

The precise identity of PMV-TARI has yet to be determined, but serological tests suggest that it is identical or very closely related to BlCMV.

Materials and Methods

One hundred and fifteen leaf samples showing typical virus symptoms such as mosaic, mottling, yellowing, vein clearing, vein necrosis, leaf spots, crinkling, blistering, and malformed leaves were collected from central Taiwan (Taichung, Nantou, and Changhua Counties), eastern Taiwan (Hualien County), and southern Taiwan (Pingtung County and AVRDC fields in Tainan County). Virus detection was by ELISA, using a 1:1000 dilution of gamma-globulin and enzyme conjugate for both SMV and PMVTARI antisera. For SMV strain detection, five plants of each of eight differential soybean cultivars (Clark, Rampage, Davis, York, Marshall, Ogden, Buffalo, and Kwanggyo) were inoculated. Plants with no symptoms were tested by ELISA for latent infection.

Results

Of the 115 samples tested, 4 reacted positively with SMV-antiserum and 12 with the PMV-TARI antiserum, indicating that PMV-TARI seems to infect soybean more frequently than SMV, and is present in all three of Taiwan's major soybean production areas (Table 3).

Table 3. Survey for SMV and 'PVM-TARI'.

Location	Total no. of samples collected	No. of samples infected	
		SMV	(PMV-TARI)
Central Taiwan			
Changhua County	7	-	-
Taichung County	22	2	8
Nantou County	5	-	-
Eastern Taiwan			
Hualien County	51	1	3
Southern Taiwan			
Pingtung County	10	-	1
AVRDC (Tainan County)	15	1	-
Total	110	4	12

Inoculation of the eight differential soybean cultivars with three of the four samples shown to be infected with SMV demonstrated that one sample (182) contained SMV-G1. The other two (118 and 121) were found to be infected with SMV strains which matched none of the seven identified by Cho and Goodman on the basis of symptom development in the eight differential cultivars (Table 4). They are now being investigated to determine whether they are new strains of SMV not differentiated by Cho and Goodman's strain classification.

Table 4. Host reactions to SMV isolates.

Differential host		SMV isolate 118	121	182
G. max	Clark	-/M[z] (+)[y]	-/M (+)	-/M (N.T.)
G. max	Rampage	-/M (+)	-/M (+)	-/M (N.T.)
G. max	Davis	-/M (+)	-/M (+)	-/- (N.T.)
G. max	York	-/M (+)	-/M (+)	-/- (N.T.)
G. max	Marshall	-/- (-)	-/- (-)	-/- (N.T.)
G. max	Ogden	-/- (-)	-/- (-)	-/- (N.T.)
G. max	Buffalo	-/- (-)	-/- (-)	-/- (N.T.)
G. max	Kwanggyo	-/- (-)	-/- (-)	-/- (N.T.)

[z] Format of symptoms symbols: symptoms on inoculated leaves/symptoms on non-inoculated leaves; M = mosaic, - = no symptom.

[y] Reaction in ELISA using SMV-AS; (+) = positive reaction; (-) = negative reaction; N.T. = not tested by ELISA.

Conclusions

PMV-TARI, which is believed to be identical or very closely related to BlCMV, appears to occur quite frequently on soybean in Taiwan, and deserves further attention. Because of its wide host range, which includes peanut, soybean, bean, and pea, this virus is a potentially serious threat to commercially grown legumes in Taiwan. Developing resistant lines should thus become an integral part of AVRDC's soybean breeding program.

Screening of AGS Lines for Resistance to Soybean Mosaic Virus (SMV)

Introduction

Since previous surveys in Taiwan have detected only strain one of SMV, it was the only strain which could be utilized for resistance screening.

Materials and Methods

Of the 168 promising breeding lines (AGS 1 to 168) screened in 1981, five lines (AGS 9, 19, 129, 147, and 103) were found to be immune to SMV-1 and five (AGS 112, 114, 115, 116, and 166) were rated resistant. These were rescreened by mechanical inoculation at the primary leaf stage with SMV-1 (one part SMV-infected fresh leaves in three parts 0.1 M phosphate buffer pH 6.5). G. max TN-4 was used as the susceptible check and Shih-shih as the immune check.

In 1982 and 1983, fifty-eight promising new breeding lines (AGS 169-229) were screened for the first time for resistance to SMV-1.

Ratings were based on disease incidence: I (immune) = 0% infection (no virus detected by ELISA), R (resistant) = 0-12.5% infection (0% latent infection; virus detected by ELISA), MR (moderately resistant) = 12.6-50% infection, MS (moderately susceptible) = 51-75% infection, and S (susceptible) = 76-100% infection.

Results

The immunity of five promising breeding lines (AGS 9, 19, 129, 147, and 103) to SMV-1 in a first screening was confirmed in this screening. Of the five lines rated resistant to SMV-1 in a first screening, three were found in this screening to be resistant (AGS 114, 116, and 166) and two immune (AGS 112 and 115).

Of the 58 promising breeding lines (AGS 169-229) screened for the first time this year, three were rated immune (AGS 174, 185, and 209) and seven resistant (AGS 203, 206, 211, 213, 214, 216, and 218). Lines AGS 203 and 218 showed symptomless infection.

Conclusions

Immunity to SMV is durable and meaningful only if it includes immunity to several strains. Since screening at AVRDC can now only be done for resistance to SMV-1, seeds of AGS lines found immune to this strain will be sent to cooperators for further screening in the presence of other strains.

Screening Soybean for Resistance to an Unidentified Virus Isolate (S-PM)

Introduction

Three virus isolates (S-PM, S-74, and S-PN) originally recovered from soybean are believed, on the basis of particle morphology and serological tests, to be blackeye cowpea mosaic virus (BlCMV) or a very closely related strain. The present study was designed to identify sources of resistance to this virus, which appears to be widespread on soybean in Taiwan, and perhaps in other parts of Southeast Asia as well. Isolate S-PM was used for screenings, and was presumed to be representative of all three isolates.

Materials and Methods

Nine local soybean cultivars, five AVRDC-AGS lines, and fifteen foreign cultivars were tested for resistance to the S-PM virus isolate.

Ten to forty plants of each cultivar were inoculated with a homogenate of one part virus-infected fresh soybean leaves in three parts 0.01 M phosphate buffer at a pH of 7.0. The inoculated plants were kept in a greenhouse and observed for four weeks for symptom development. Symptomless plants were back inoculated to C. amaranticolor to detect latent infection. Ratings were based on disease incidence, and were similar to those used in SMV resistance screening.

Results

Immunity to isolate S-PM exists in local and foreign soybean cultivars and also in AVRDC AGS lines (Table 5). AGS 19 and AGS 147 appear to carry immunity to both SMV and the soybean PM virus isolate.

Table 5. Reaction of G. max to infection with SMV-PM virus isolate.

Host (AVRDC acc. no.)	Infected plants/ inoculated plants	% infection	Rating[z]
Local cultivars			
Tainung No. 3 (G7)	32/40	80	S
Tainung No. 4 (G57)	10/18	56	MS
TK-5 (G6)	19/37	51	MS
Shih-shih (G38)	4/41	10	R
Kaohsiung No. 3 (G2043)	14/43	33	MR
Kaohsiung No. 8 (G10381)	18/39	46	MR
Chung Hsing No. 1 (G68)	0/38	0	I (S)[y]
Chung Hsing No. 2 (G69)	12/29	41	MR
Chung Hsing No. 3 (G70)	13/37	35	MR
Foreign cultivars			
Palmetto (G2)	13/31	42	MR
CNS (G2034)	0/45	0	I (MR)
Bragg (G2035)	19/33	58	MS
Lee (G2038)	17/33	52	MS
Davis (G2509)	9/23	39	MR
Bansei (G3018)	9/36	25	MR
Toyosuzu (G2508)	23/37	62	MS
York (G3804)	29/32	91	S
Tokyo (G2759)	4/34	12	R
Virginia (G1356)	0/13	0	I (MR)
Stuart (G3771)	29/34	56	MS
Hill (G2444)	0/38	0	I
Corsoy (G2420)	2/27	7	R
Mukalen (G2586)	6/30	20	MR
Jupiter (G2015)	30/41	74	MS
AVRDC AGS lines			
AGS 9	1/40	3	R (I)
AGS 19	0/42	0	I (I)
AGS 103	1/39	3	R (I)
AGS 129	1/35	3	R (I)
AGS 147	0/42	0	I (I)

[z] Immune plants were checked on C. amaranticolor for symptomless infection.

[y] Rating for resistance to SMV (Data from reports or from previous screenings); S = susceptible; MR = moderately resistant; I = immune; NT = not tested.

Preliminary Survey of Soybean Viruses in Southeast Asia

Introduction

Described below is part of a survey made in the soybean production areas of Java and Sumatra in May of 1983. The results of this and future surveys made in Southeast Asia will help determine which soybean viruses are most widespread in the region, and which should be considered in AVRDC's disease resistance breeding program.

Materials and Methods

Twenty-five soybean leaf samples showing such typical virus symptoms as mosaic, mottle, yellowing, vein clearing, leaf deformation, leaf blistering, and stunt were collected in East Java near Malang and in Sumatra near Padang and Sitiung. All samples were dried over calcium chloride prior to transport. The samples were soaked in ten parts ELISA extraction buffer, homogenized, and tested by ELISA against antisera to the following 14 viruses: bean yellow mosaic virus (BYMV), blackgram mottle virus (BMV), peanut stunt virus (PSV), cowpea mosaic virus (CPMV), soybean mosaic virus (SMV), blackeye cowpea mosaic virus (BlCMV), southern bean mosaic virus (SBMV), bean common mosaic virus (BCMV), peanut mottle virus (PMV), cowpea chlorotic mottle virus (CCMV), soybean stunt virus (SSV), bean golden mosaic virus (BGMV), cowpea mottle virus, and PMV-TARI.

Both the gamma-globulin and the enzyme conjugates of the above antisera were used at a dilution of 1:500.

Results and Discussion

Results are shown in Table 6. Soybean stunt virus (SSV) was the virus most frequently detected on soybean in the areas surveyed, confirming previous reports that SSV is Indonesia's most important soybean virus. Blackeye cowpea mosaic virus (BlCMV), the second most common virus, was detected in 4 of the 25 samples. In serological tests these four samples reacted not only with BlCMV, but also with BCMV and PMV-TARI. The virus present in those samples may indeed be BlCMV. Because of its close serological relationship with bean common mosaic virus, however, blackeye cowpea mosaic virus also reacted with that antiserum. A separate AVRDC study has also shown that PMV-TARI is either identical or very closely related to BlCMV (see the first report in this section).

The other ten viruses for which the samples were tested were not detected.

Conclusions

Any project aimed at developing disease resistant soybean cultivars

for Indonesia should consider breeding for resistance to soybean stunt virus (SSV). Several cultivars from Japan and Taiwan have already been identified as sources of SSV-resistant germplasm.

Blackeye cowpea mosaic virus (BlCMV) was the second most frequently detected virus in Indonesia, and ELISA tests also indicate its presence in Taiwan. If these findings are confirmed by additional surveys in Indonesia and other Southeast Asian countries, resistance to BlCMV should also be incorporated into soybean lines being developed for this region.

Table 6. Occurrence of soybean viruses in Indonesia.

	Total	Sumatra	Java
No. of samples collected	25	7	18
No. of samples virus infected	14	6	8
No. of samples containing BlCMV	4	4	-
No. of samples containing BYMV	2	-	2
No. of samples containing SMV	2	1	1
No. of samples containing SSV	11	6	5

Preliminary Rust Tolerance Trials

Introduction

Since previous studies have shown that soybean cultivars under stress from a rust epidemic vary significantly in their relative yielding ability, preliminary (PRTT), intermediate (IRTT) and advanced rust tolerance trials (ARTT), have been established to select high yielding and early maturing soybean lines with improved levels of rust tolerance. The PRTT is usually a non-replicated experiment with a plot size of 2 to 4 m^2. Data collected include yield, 100 seed weight, and days to maturity. Potentially tolerant lines chosen on the basis of their relative or potential yields under stress from a rust epidemic are advanced to the IRTT.

Materials and Methods

Four of the six PRTTs were conducted in the spring season (PRTTs Ia, Ib, IIa and IIb) and two in the fall (PRTTs I and II). All of the 760 F_5 to F_8, and F_{10} families or lines evaluated in the 1983 PRTTs (Table 7) had been previously evaluated and selected for potential rust resistance and/or tolerance.

The spring PRTTs were planted on March 2 (Ia and Ib) and March 3 (IIa and IIb). The number of test families included in PRTTs Ia, Ib, IIa and IIb were 253, 130, 104, and 93, respectively. Plot size for PRTTs Ia & Ib was 1 x 2m, with two replications, and a plant density equivalent to 400,000 plants/ha. Check cultivars were G 38, KS 535, and G 4919. Plot size for unreplicated PRTTs IIa and IIb was 1 x 2 m, with

a plant density equivalent to 200,000 plants/ha. Check cultivars were G 38, KS 535, G 4919, and Tainan No. 4 (TN #4). All of the spring PRTTs were inoculated with an uredospore suspension of rust on March 31 and April 6. For purposes of comparison, yield data were converted to 13% moisture content before being evaluated. All standard AVRDC cultural practices were followed.

The unreplicated fall PRTTs (I and II) were planted on September 13. PRTT I included 120 families selected from the previous spring's PRTT IIb, and PRTT II included 60 families selected from spring PRTT IIa. Plot size was 1 x 2 m, with a plant density equivalent to 200,000 plants/ha. Check cultivars were G 38 and KS 535. Plots were inoculated with an uredospore suspension of rust on October 7 and 13. Yield data were converted to 13% moisture content before evaluation. All standard AVRDC cultural practices were followed.

Results

Although no single cultivar yielded significantly more than high yielding check G 4919, eight of the 253 F_{10} lines in the PRTT-Ia were significantly higher yielding than G 38 (Shih-shih) under rust stress (Table 8). Ten lines selected for potential rust tolerance were advanced to the fall season IRTT (Table 7).

Although under rust stress, three of the 130 F_8 lines in PRTT Ib were significantly higher yielding than G 38 (Table 9), none of them significantly outyielded high yielding check G 4919. All three were considered potentially rust tolerant, however, and were advanced to the fall season IRTT (Table 7).

In PRTT IIa, the seven highest yielding F_7 families yielded 35 to 54% more than the highest yielding check TN #4, and 68 to 92% more than G 38 (Table 10). Over 56% of the families outyielded the check cultivars (Table 11). Because all high yielding families were segregating for plant type, 107 single plant selections were made in 37 families (Table 7). Sixty of these selections were considered potentially rust tolerant, and in the fall were re-evaluated in PRTT II.

The fifteen highest yielding F_5 families from the spring PRTT IIb yielded from 36 to 57% more than TN #4, and 56 to 81% more than G 38 (Table 12). Over 65% of the families outyielded the check cultivars (Table 13). As in PRTT IIa, all of the high yielding families were still segregating for plant type, and 179 single plant selections were therefore made from 58 families. A total of 120 of these selections were considered potentially tolerant, and were re-evaluated in the fall in PRTT I (Table 7).

In autumn's PRTT I, the 18 highest yielding F_6 families yielded from 32 to 53% more than the highest yielding check and 64 to 89% more than G 38 (Table 14). Over 54% of the families were higher yielding than the check cultivars (Table 15). Only 36 appeared to be segregating for plant type, and from these 36 a total of 141 single plant selections were made, the best of which will be included in the 1984s PRTT. Eighty-four families appeared to be of uniform plant type, and approximately 30 of the highest yielding families will be advanced as lines to 1984's IRTT (Table 7).

In the fall PRTT II the 16 highest yielding F_8 families yielded

from 10 to 28% more than the highest yielding check and 36 to 58% more than G 38 (Table 16). Over 30% of the families were higher yielding than the check cultivars (Table 17). Only three of them appeared to be segregating, and 12 single plant selections made from those families will be included in 1984's PRTT. Fifty-seven families appeared uniform for plant type, and approximately 30 of the highest yielding families will be advanced as lines to 1984's IRTT (Table 7).

Table 7. Number of families tested and number of families and lines selected for potential levels of tolerance in the six PRTTs conducted in 1983.

Season	PRTT	Generation	Cross designation	Families or lines evaluated	No. of families with single plant selection	No. of plants selected	No. of bulk harvested lines advanced
Spring	Ia	F_{10}	GC	253	-	-	10
Spring	Ib	F_8	GC	130	-	-	3
Spring	IIa	F_7	SRE-C	104	37	107	-
Spring	IIb	F_5	SRE-D GC	93	58	179	-
Fall	I	F_6	SRE-D GC	120	36	141	30
Fall	II	F_8	SRE-C	60	3	12	30

Table 8. Performance of high yielding, potentially tolerant lines in the spring Preliminary Rust Tolerance Trials Ia.

Line designation[z]	Days to Maturity	Yield[y] (kg/ha)	100-seed[y] wt. (g)
60082-8-14-6-7-68	92	2,309.5	12.8
60087-7-9-6-12-52	96	2,227.0	15.2
60078-7-9-6-12-46	96	2,161.0	13.9
60087-7-9-6-10-31	96	2,144.3	13.9
60078-7-9-6-11-66	96	2,129.3	15.0
60078-7-9-6-12-31	96	2,111.0	14.6
60078-7-9-6-12-8	96	2,105.0	13.3
60078-7-7-7-6-8-42	92	2,077.0	16.1
60087-7-9-6-11-46	98	2,003.5	18.7
60053-8-3-6-10-50	94	1,973.0	11.8
60082-8-17-6-6-28	92	1,884.8	14.6
50227-6-44-6-10-38	96	1,668.8	13.0
60072-9-8-6-7-18	92	1,651.8	12.5
50265-2-9-6-8-66	97	1,624.3	12.1
50057-2-1-10-6-6-22	94	1,509.0	10.6
60082-8-17-6-6-24	96	1,495.3	11.6
50227-5-22-6-9-48	94	1,436.0	12.0
50260-3-21-6-8-52	96	1,218.3	11.7
50227-3-25-6-10-84	96	1,145.8	10.7
60087-7-9-6-10-43	96	1,115.3	13.8
G 4919 (CK)	101	1,976.3	14.1
KS 535 (CK)	93	1,799.2	10.5
G 38 (CK)	89	1,640.1	10.4
LSD 5%	2.1	412.1	2.5
1%	2.8	560.1	3.4
CV (%)	1.0	10.8	9.1

[z] Number of lines evaluated : 253 F_{10} lines
Planted: March 2, 1983
Replication: 2
Plot size: 1 x 2 m^2

[y] At 13% water content.

Conclusions

A number of the potentially tolerant lines identified are early maturing and have potentially high yields. These lines and families will be re-evaluated in 1984.

Results suggest that by selecting potentially high yielding plants from populations grown under severe rust stress, potentially tolerant, high yielding lines can be initially selected as early as the F_5 generation. This hypothesis will be further tested.

Table 9. Performance of high yielding, potentially tolerant lines in spring Preliminary Rust Tolerance Trials Ib.

Line designation[z]	Days to Maturity	Yield[y] (kg/ha)	100-seed[y] wt. (g)
60031-2-7-6-6	95	2,142.0	10.1
G2120-97RR-1	96	2,051.0	4.3
60020-8-7-7-18	91	1,983.3	15.8
60031-2-7-7-18	95	1,659.0	9.2
60058-10-7-9-9y-40	95	1,495.8	7.9
60058-10-6-6-81g-31	96	1,483.8	6.3
60020-8-7-7-70	91	1,461.8	11.7
60058-10-7-8-6y-38	95	1,457.5	6.8
60058-10-7-9-8y-7	96	1,314.5	7.6
60058-10-7-9-71-68	96	1,187.3	7.2
60031-2-8-6y-45	96	1,173.0	9.8
60058-10-7-9-6y-32	95	1,109.5	6.1
60031-2-8-7-14	94	1,108.0	9.0
60031-2-8--y-43	95	997.5	9.4
G2120-98RR-1	96	943.3	4.9
60031-2-9-6y-43	96	929.8	8.1
G 4919 (CK)	103	1,956.1	14.2
KS 535 (CK)	93	1,693.5	10.5
G 38 (CK)	88	1,600.3	10.6
LSD 5%	2.3	231.3	1.0
1%	3.2	316.9	1.3
CV (%)	1.2	7.5	5.2

[z] Number of lines evaluated: 130 F8 lines
Planted: March 2, 1983
Replication: 2
Plot size: 2 x 2 m^2
[y] At 13% water content.

Table 10. Performance of high yielding, potentially tolerant families in spring Preliminary Rust Tolerance Trials IIa.

Family designation[z]	Yield[y] (t/ha)	100-seed[y] wt. (g)	Days to Maturity
C-61-0-BK-BKe-BK&-1e-2	2.74	11.9	98
C-56-1-BK-BKe-BKi-2e-2	2.68	19.5	102
C-22-0-BK-BKe-BKe-2e-2	2.57	14.5	102
C-56-1-BK-BKe-BK&-1i-1	2.56	19.7	102
C-34-0-BK-BKe-BKi-5e-2	2.53	16.5	98
C-61-0-BK-BKe-BKi-5e-2	2.42	15.4	102
C-36-0-BK-BK&-BK&-4e-1	2.40	15.6	98
TN #4 (CK)	1.78	12.3	102
KS-535 (CK)	1.71	11.1	98
G 4919 (CK)	1.70	16.4	105
G 38 (CK)	1.43	10.3	98

[z] Number of lines evaluated: 104
Planted: March 3, 1983
Plot size: 1 x 2 m^2
[y] At 13% water content.

Table 11. Yield distribution of families entered in spring Preliminary Rust Tolerance Trial IIa.

Yield class (t/ha)	No. of entry	% of total entry
> 2.5	5	4.81
2.0-2.5	53	50.49
1.5-2.0	44	42.31
< 1.5	2	1.92
Total	104	

Planted: March 3, 1983
Plot size: 1 x 2 m^2
Grand mean: 2.02 t/ha
Mean of checks: 1.67 t/ha

Table 12. Performance of high yielding, potentially tolerant families in spring Preliminary Rust Tolerance Trials IIb.

Family designation[z]	Yield[y] (t/ha)	100-seed[y] wt. (g)	Days to Maturity
D-14-0-BKℓ-6e-1	2.80	18.2	105
D-18-0-BKe-2e-2	2.68	15.4	102
D-18-0-BKe-1e-1	2.60	15.7	98
D-20-0-BKe-3i-1	2.59	12.7	102
00031-BK-BKi-11e-2	2.51	16.8	99
D-14-0-BKℓ-3e-2	2.49	17.2	105
D-19-0-BKi-2e-1	2.49	17.4	98
D-11-3-BKe-1e-1	2.45	12.7	105
D-18-0-BKe-4e-1	2.44	16.1	98
D-14-0-BK-6e-4	2.44	17.5	102
000111-BK-BKe-3e-3	2.43	16.4	98
D-14-0-BKℓ-6e-2	2.43	18.2	99
D-14-0-BKℓ-6e-5	2.43	17.2	99
000111-BK-BKe-3e-1	2.42	16.4	98
D-14-0-BKℓ-6e-3	2.42	21.0	102
TN #4 (CK)	1.78	12.6	102
KS 535 (CK)	1.72	12.0	99
G 4919 (CK)	1.67	17.3	109
G 38 (CK)	1.55	10.7	99

[z] Number of lines evaluated: 93
Planted: March 3, 1983
Plot size: 1 x 2 m^2
[y] At 13% water content.

Table 13. Yield distribution of families entered in spring Preliminary Rust Tolerance Trial IIb.

Yield class (t/ha)	No. of entry	% of total entry
> 2.5	5	5.38
2.0-2.5	57	61.29
1.5-2.0	21	22.58
< 1.5	10	10.75
Total	93	

Planted: March 3, 1983
Plot size: 1 x 2 m^2
Grand mean: 2.05 t/ha
Mean of checks: 1.68 t/ha

Table 14. Performance of high yielding, potentially tolerant families in fall Preliminary Rust Tolerance Trials I.

Family designation[z]	Days to R8	Yield[y] (kg/ha)	100-seed[y] wt. (g)
D-14-0-BKℓ-6e-3-1	97	3645.0	25.3
D-14-0-BKℓ-6e-1-2	97	3638.5	27.2
D-14-0-BKℓ-6e-1-3	97	3570.5	24.2
D-11-3-BKe-2e-2-1	97	3509.5	16.6
D-14-0-BKℓ-6e-4-4	97	3438.5	27.7
D-11-3-BKi-7e-2-2	94	3417.0	17.6
00104-BK-BKe-1e-1-1	94	3348.0	17.9
D-18-0-BKi-1e-3-1	94	3340.5	19.3
D-14-0-BKℓ-6e-4-1	97	3322.5	23.4
D-14-0-BKℓ-6e-3-2	94	3313.5	24.3
D-11-3-BKe-1e-9-5	94	3302.0	14.5
D-11-3-BKe-2e-2-1	97	3283.5	16.0
D-11-3-BKe-1e-10-1	97	3250.5	15.9
D-14-0-BKi-1e-1-1	97	3232.0	25.3
D-14-0-BKℓ-6e-3-5	90	3218.0	23.8
D-11-3-BKe-1e-5-3	94	3181.5	15.5
D-11-3-BKe-1e-9-1	97	3172.5	16.6
D-14-0-BKℓ-6e-1-1	97	3148.5	25.8
KS 535 (CK)	83	2380.4	16.5
G 38 (CK)	78	1923.6	14.8

[z] Planted: September 13, 1983
Plot size: 1 x 2 m^2
No. of lines evaluated: 120
[y] At 13% water content.

Table 15. Yield distribution of families entered in fall Preliminary Rust Tolerance Trial I.

Yield class (t/ha)	No. of entry	% of total entry
> 3.5	4	3.33
3.0 - 3.5	25	20.83
2.5 - 3.0	36	30.00
2.0 - 2.5	30	25.00
1.5 - 2.0	13	10.83
< 1.5	12	10.00
Total	120	

Planted: September 13, 1983
Plot size: 1 x 2 m^2
Grand mean: 2.46 t/ha
Mean of checks: 2.15 t/ha

Table 16. High yielding, potentially tolerant families in the fall Preliminary Rust Tolerance Trial II.

Family designation[z]	Days to R8	Yield[y] (kg/ha)	100-seed[y] wt.(g)
C-33-0-BK-BKe-BKi-2e-1-2	90	2914.5	24.0
C-22-0-BK-BKe-BKℓ-5e-1-1	86	2886.0	17.5
C-62-0-BK-BKℓ-BKℓ-1e-2-1	90	2755.0	17.4
C-22-0-BK-BKe-BKe-2e-1-4	83	2664.5	17.1
C-22-0-BK-BKe-BKi-3e-4-1	90	2646.5	18.0
C-36-0-BK-BKe-BKe-5e-1-1	83	2638.0	16.8
C-61-0-BK-BKe-BKe-2e-2-2	83	2604.5	16.7
C-57-0-BK-BKe-BKi-3e-2-3	83	2574.5	18.2
C-22-0-BK-BKℓ-BKℓℓ-3e-1-1	90	2569.5	19.9
C-34-0-BK-BKe-BKi-2e-5-1	83	2561.5	21.2
C-22-0-BK-BKe-BKe-2e-1-2	83	2555.0	16.6
C-22-0-BK-BKe-BKe-2e-2-1	83	2543.0	16.4
C-56-1-BK-BKe-BKi-2e-2-4	90	2542.0	23.3
C-33-0-BK-BKe-BKi-2e-1-3	90	2541.0	24.8
C-22-0-BK-BKℓ-BKℓℓ-9e-1-2	90	2522.0	20.2
C-62-0-BK-BKℓ-BKℓ-1e-2-2	90	2501.5	17.7
KS 535 (CK)	83	2283.5	16.1
G 38 (CK)	78	1841.0	15.3

[z] No. of lines evaluated: 60
Planted: September 13, 1983
Plot size: 1 x 2 m^2
[y] At 13% water content.

Table 17. Yield distribution of families entered in fall Preliminary Rust Tolerance Trial II.

Yield class (t/ha)	No. of entry	% of total entry
> 2.5	16	26.67
2.0-2.5	30	50.00
1.5-2.0	10	16.67
< 1.5	4	6.67
Total	60	

Planted: September 13, 1983
Plot size: 1 x 2 m^2
Grand mean: 2.21 t/ha
Mean of checks: 2.06 t/ha

Intermediate Rust Tolerance Trials

Introduction

Since previous studies have shown that soybean cultivars under stress from a rust epidemic vary significantly in their relative yielding ability, preliminary (PRTT), intermediate (IRTT), and advanced rust tolerance trials (ARTT), have been established to evaluate and select high yielding and early maturing soybean lines with improved levels of rust tolerance. The IRTT is a replicated (usually twice) experiment with a plot size of 4 to 8 m^2 and treatments which are either protected or not protected with fungicide. Data collected include yield, 100-seed weight, days to maturity, plant density, and defoliation and rust severity. Lines higher yielding and more tolerant of rust (as determined by their percentage of yield loss and their total yield in the rust stressed treatment) than the checks are advanced to the ARTT.

Materials and Methods

IRRT-I - Four single plant selections from each of nine lines in the spring IRTT were planted in a 2 x 2 m plot with each selection planted in one 0.5 x 2 m row. Single plants were selected on the basis of high yield potential, and also on the basis of uniform morphology among selected plants within lines. Single plant selections from fungicide protected treatments were separated from selections which were not protected. Plant density was equivalent to 200,000 plants/ha. The check cultivars were moderately tolerant yield check G 38 (Shih-shih) and highly tolerant check AGS 181 (SRE-Z-11A). A split plot design was

used with two replications. Main plots were fungicide protected and non-protected. Subplots were the advanced lines and checks. The experiment was planted September 13, and non-protected plants were inoculated with rust 24 and 29 days later. The protective fungicide was Dithane M-45 sprayed every two weeks. Standard AVRDC cultural practices were followed. For purposes of comparison, yield data were converted to 13% moisture content before being evaluated. Yield losses are expressed in terms of the differences between protected and unprotected treatments.

IRTT-II - Thirteen advanced lines consisting of one mutant of G 2120 and progeny from four cross combinations were planted in 3 x 5 m plots at a plant density equivalent to 200,000 plants/ha. Each line had been previously selected for yielding ability under severe rust stress. The check cultivars were moderately tolerant yield check Shih-shih, moderately tolerant check KS 535, and highly tolerant check AGS-181 (SRE-Z-11A). A split-plot design was used with two replications. Main plots were protected or not protected by fungicide, and subplots were the advanced lines and checks. The experiment was planted on September 13, 1983, and non-protected plants were inoculated with rust 24 and 29 days later. The protective fungicide was Dithane M-45, sprayed every two weeks. Standard AVRDC cultural practices were followed.

For purposes of comparison, yield data were converted to 13% moisture content before being evaluated. Yield losses are expressed as the difference between protected and unprotected treatments. Rust severity and defoliation are expressed as estimated percentages. The rate of rust development is the regression coefficient of the correlation between the logit of total rust affected foliage (rust affected foliage + defoliation) and soybean's relative lifetime (DAP x 100/days to R_8).

Results

IRTT-I - Because some lines were still segregating, each single plant selection was evaluated separately. The 14 highest yielding lines outyielded Shih-shih by 45 to 66 percent in the non-protected treatments (Table 18). Yield losses of all 14 lines were less than those of Shih-shih, and 11 lines had yield losses less than those of highly tolerant check AGS 181.

IRTT-II - Ten of the 13 test lines were higher yielding than Shih-shih in both the protected and unprotected treatments (Table 19). Only five lines (60087-7-9-6-10-31, 60087-7-9-6-12-8, 60087-7-9-6-12-52, 60031-2-7-6-6, and G2120 97RR-1), however, outyielded Shih-shih in the non-protected treatment and showed a yield loss equal to or less than that of highly tolerant check SRE-Z-11A. These lines will be retested to confirm their promising levels of tolerance.

Rust development rates ranged from 0.0496 to 0.1637, and estimates of rust affected foliage 70% of the way through the plant's life cycle ranged from 14.4 to 28.4% (Table 20). As in previous studies, neither figure was correlated with yield loss.

Conclusions

Nineteen lines with promising levels of tolerance have been identified, and their levels of tolerance will be confirmed in the next IRTT or ARTT.

Table 18. Yields of potentially tolerant high yielding advanced lines from the IRTT-I grown at AVRDC under fungicide and non-fungicide protected conditions in the fall of 1983.

Entry no.	Cultivar	Yield (t/ha)[z]		% Yield loss
		Fungicide protected	Non-fungicide protected	
4-4	SRE-B-15-0-3-2-1-BK-2e-BKt-4	4.12	3.16	23.3
5-3	SRE-B-15-0-BK-1-1-BK-1e-BKt-3	3.59	3.26	9.2
6-3	SRE-B-15-0-3-1-3-BK-2i-BKt-3	3.51	3.17	9.7
2-4	SRE-B-15-0-0-0-9-BK-1e-BKt-4	3.47	3.21	7.5
8-1	SRE-B-15-0-BK-BK-BKe-BKi-BKt	3.32	3.21	3.3
2-3	SRE-B-15-0-0-0-9-BK-1e-BKt-3	3.24	3.08	4.9
2-2	SRE-B-15-0-0-0-9-BK-1e-BKt-1	3.23	3.03	6.2
2-1	SRE-B-15-0-0-0-9-BK-1e-BKt-1	3.07	3.09	0.0
	G-38 (Shih-shih)[y]	3.35	2.00	40.3
23-4	SRE-B-15-0-BK-BK-BKe-BKi-1e-BKt-8	3.87	3.20	17.3
19-4	SRE-B-15-0-3-2-1-BK-2e-BKt-8	3.81	3.62	5.0
24-4	SRE-B-15-0-BK-BK-BKi-BKe-1e-BKt-8	3.75	3.22	14.1
23-1	SRE-B-15-0-BK-BK-BKe-BKi-1e-BKt-5	3.37	3.32	1.5
19-1	SRE-B-15-0-3-2-1-BK-2e-BKt-5	3.36	3.28	2.4
24-1	SRE-B-15-0-BK-BK-BKi-BKe-1e-BKt-5	3.30	3.16	4.2
	G-38 (Shih-shih)[x]	2.86	2.18	23.9
	AGS 181 (SRE-Z-11A)[w]	2.69	2.36	12.2

[z] Plot size: 1 m^2
[y] Yield check for entries: 2-1 to 8-1
[x] Yield check for entreis: 19-1 to 24-4
[w] Tolerant check for experiment.

Table 19. Yield and percent yield loss of advanced breeding lines from the IRTT-II grown at AVRDC under fungicide and non-fungicide protected conditions during a soybean rust epidemic in the fall of 1983.

Cultivar	Yield (t/ha)[x]		% Yield loss
	Fungicide protected	Non-fungicide protected	
60082-8-14-6-7-68	2.55 +[y]	2.26 +	11.4
60087-7-7-7-6-8-42	2.05	1.60	22.0
60087-7-9-6-10-31	2.19	2.54 +	0.0
60087-7-9-6-10-43	2.69 +	2.15 +	20.1
60087-7-9-6-11-46	2.56 +	2.32 +	9.4
60087-7-9-6-11-66	2.58 +	2.24 +	13.2
60087-7-9-6-12-8	2.44 +	2.25 +	7.8
60087-7-9-6-12-31	2.69 +	2.05 +	23.8
60087-7-9-6-12-46	2.59 +	1.96 +	24.3
60087-7-9-6-12-52	2.56 +	2.41 +	5.9
60020-8-7-7-18	2.26 +	1.67	26.1
60031-2-7-6-6	2.40 +	2.23 +	7.1
G 2120-97RR-1	2.35 +	2.20 +	6.4
Shih-shih (G 38)[z]	2.07	1.54	25.6
KS 535[z]	2.62 +	1.69	35.5
SRE-Z-11A (AGS 181)[z]	2.00	1.86 +	7.0
LSD .05	0.181		

[z] Check cultivars.
[y] significantly different ($P > 0.05$) from check cultivar; + = greater than check.
[x] Planting plot size for each cultivar is 3m x 5m, and plant density is equivalent to 200,000 plant/ha.

Table 20. Rates of rust development and estimated total rust affected foliage on advanced breeding lines in the IRRTT-II at AVRDC in the fall of 1983.

Cultivar	Rate of rust development	Rust affected foliage (%)
60082-8-14-6-7-68	0.1055	20.3
60087-7-7-7-6-8-42	0.0669	15.5
60087-7-9-6-10-31	0.0545	16.5
60087-7-9-6-10-43	0.0779	16.5
60087-7-9-6-11-46	0.0537	19.1
60087-7-9-6-11-66	0.0807	17.3
60087-7-9-6-12-8	0.0496	17.3
60087-7-9-6-12-31	0.0724	14.4
60078-7-9-6-12-46	0.0642	15.0
60087-7-9-6-12-52	0.0522	15.8
60020-8-7-7-18	0.1149	28.4
60031-2-7-6-6	0.0522	17.9
G 2120-97 RR-1	0.0555	27.6
Shih-shih (G 38)[x]	0.1637	18.5
KS 535	0.1390	28.4
SRE-Z-11A (AGS 181)	0.1574	15.1

[z] Regression coefficient of the correlation between total rust affected foliate (rust affected foliage + defoliation) and relative life time (DAP x 100/Days to R8).

[y] Estimated total rust affected foliage when 70% of soybean life cycle is completed.

[c] Check cultivar.

Biological Controls of Soybean Rust

Introduction

In 1983 several fungi other than Phakopsora pachyrhizi were observed on soybean rust lesions. The hyphae of these fungi were usually found within and around the exuded mass of uredospores above the rust uredia, but they were also observed within old, non-functioning uredia and on necrotic portions of the rust lesion. The presence of these fungi seemed to reduce the reproductive duration of the rust uredia within the lesion, indicating that they may be hyperparasites of P. pachyrhizi. Pothidee has reported a Tuberculina species that is a hyperparasite of soybean rust in Thailand. This study was designed to identify the unknown fungi and determine if they are hyperparasites and/or potential biocontrol agents.

Materials and Methods

Two different fungi were isolated and maintained on potato dextrose agar (PDA). Colonies were grown on PDA at room temperature (25°C, ±5°) for morphologic examination. To evaluate hyperparasitism, spores of P. pachyrhizi and one of the unknown fungi were germinated in distilled water on a microscope slide. Slides were then maintained in moisture chambers and removed periodically to be stained with cotton blue for observation of parasitism under a compound microscope.

Biocontrol potential of each of the fungi were evaluated by inoculating soybean plants with P. pachyrhizi and the unknown fungi in the following combinations and sequences:

1. P. pachyrhizi inoculation alone.
2. P. pachyrhizi and fungus A inoculated simultaneously.
3. P. pachyrhizi and fungus B inoculated simultaneously.
4. Fungus A inoculated alone.
5. Fungus B inoculated alone.
6. Fungus A inoculated approximately 10 days after P. pachyrhizi (after rust lesions and uredia had formed).
7. Fungus B inoculated approximately 10 days after P. pachyrhizi (after rust lesions and uredia had formed).
8. Fungi A and B inoculated simultaneously approximately 10 days after P. Pachyrhizi inoculation (after rust lesions and uredia had formed).

After inoculation all plants were incubated in moist chambers for 24 hours and then transferred to a greenhouse. Ten days after inoculation with the unknown fungi, plants were evaluated for the presence of hyphae and conidiophores within rust lesions and uredia. Reproductive capability of the uredia infested with either fungus was assessed by detaching soybean leaves one day and six through ten days after inoculation, brushing them free of spores, and incubating them in petri dish moisture chambers for 48 hours before evaluation of spore production and uredia morphology.

Results and Discussion

Morphology - Both fungi are easily grown, and both readily produce conidia and conidiophores on PDA.

Fungus A appears to belong to the genus Gliomastix. Colonies grown on PDA are white. Hyphae are hyaline, branched, and septate. Conidiophores are distinct, typically simple, hyaline with unbranched phialides. Conidia, typically aggregated in slimy heads, are hyaline, ovate, and one-celled.

Fungus B appears to be a species of Trichothecium. Colonies grown on PDA are pink colored and concentrically zonate. Hyphae are creeping, septate, hyaline, and branched. Conidiophores are erect, simple, non-septate, and hyaline and bear terminal chains of spores. Conidia are acrogenous, two-celled, and roughly ovate, with a nipple-like

projection at the point of attachment. They form in characteristic basipetal chains.

Hyperparasitism - The white, sparse mycelium of Gliomastix sp. is found on soybean rust lesions only on or in uredia and urediospore masses. Although Conidia and conidiophores are found on and within P. pachyrhizi uredia, and some hyphae are wound around spores of P. pachyrhizi, no evidence has been found of its hyperparasitism of the hyphae or spores of P. pachyrhizi.

The abundant white mycelia and conidiophores of Trichothecuim are not only found on and in uredia and urediospore masses of P. pachyrhizi, but also on the necrotic tissue within the rust lesion. No evidence of hyperparasitism of hyphae or spores of P. pachyrhizi has been found.

Biocontrol Potential - Neither Gliomastix sp. nor Trichothecium sp. produced visible lesions when inoculated on soybeans leaves in the absence of P. pachyrhizi; they are apparently not pathogenic on soybeans. Mycelia, conidiophores, and conidia of Gliomastix sp. and Trichothecium sp. were observed within rust lesions and uredia when inoculated after the appearance of the rust lesions, but were not found in rust lesions or uredia when inoculated simulaneously with P. pachyrhizi. Apparently they need either necrotic soybean tissue or established fungal structures of P Pachyrhizi for their growth and reproduction. Uredia of P. pachyrhizi infested with either fungus deteriorated prematurely, becoming dark brown and devoid of urediospores. Urediospore production ceased within 12 days of inoculation with either fungus, while uninfested rust uredia continued to produce abundant urediospores.

Conclusions

Gliomastix sp. and Trichothecium sp. can reduce the reproductive capacity of P. pachyrhizi by destroying its uredia. Thus they should be able to slow the development of soybean rust epidemics, and reduce rust intensities and yield losses. Regardless of whether they are hyperparasites of P. pachyrhizi, both are potential biocontrol organisms. Observations also indicate that Trichothecium sp. has more potential as a biocontrol agent than does Gliomastix sp.

Physiological Races of Soybean Rust

Introduction

Three infection types produced by isolates of Phakopsora pachyrhizi on differential soybean cultivars have already been described by K. R. Bromfield at the USDA Plant Disease Research Laboratory. The infection types and their definition are 1) TAN - tan colored lesion, 0.4 mm^2, usually with 2 to 5 uredia per lesion 14 days after inoculation; and 2) RB type description 0 - absence of macroscopically visible signs or symptoms. Bromfield used four differential cultivars to identify four races of P. pachyrhizi. Recently, as many as eleven cultivars have been

identified as possessing confirmed or suspected race-specific genes for rust resistance. This study was conducted to determine whether these cultivars could be used as differentials, and also to identify the diversity of physiologic races at AVRDC.

Materials and Methods

Pathogen isolation:

Rust infected leaves of soybean cultivars Taita Kaohsiung No. 5 (TK #5), PI 459025, PI 230970, and a wild cultivar (Glycine wightii) were collected from field experiments at AVRDC. By transferring a few spores of a single uredium to detached leaves of soybean cultivar "Wayne", which were being maintained in a petri dish moist chamber, ten isolates were obtained from each cultivar. Before being inoculated to the differential cultivars each isolate was in the above-described manner serially transferred three times to detached leaves of "Wayne". Those isolates which produced mixed infection types (usually TAN and RB) on the same differential cultivar were re-isolated and designated as different isolates. Each isolate was maintained in a growth room at 20 to 24°C on detached leaves of "Wayne".

Differential Soybean Cultivars - Two wild soybean (Glycine soja) cultivars, PI 239871A and PI 239971B, and nine soybean (G. max) cultivars (PI 230970, PI 230971, Taita Kaohsiung No. 5, Tainung No. 4, Wayne, Ankur, PI 200492, PI 459024, and PI 459025) were used as differentials. All have either known or suspected genes for race-specific resistance to P. pachyrhizi.

Race determination:

Both detached leaves and intact plants were used for race determination of P. pachyrhizi on the basis of symptoms on the differential cultivars. For the detached leaf test, the fully expanded unifoliate leaves of each cultivar were removed and washed, and their petioles were cut and wrapped with cotton. The leaves were then placed on moist filter paper in sterile 14 cm petri dishes, with two leaves per petri dish. By being divided into four quarters, each of which contained one drop of sterile water, every leaf was inoculated with four randomly selected isolates. This allowed the testing of eight isolates under nearly identical conditions. Inoculation was accomplished by transferring on the end of a bamboo needle a few uredospores from a single uredium of each isolate to one of the drops of water on the upper surface of the detached leaf. After inoculation, all petri dishes were placed in a growth room at 20 to 24°C with continuous fluorescent light. Each inoculation was replicated four times. A total of 42 isolates were tested.

Infection type was evaluated on intact plants by individually inoculating to each of the differential soybean cultivars an isolate from each of 13 races tentatively identified in the detached leaf tests. Two replications of each set of 11 differentials were placed in large plastic bags and inoculated with a uredospore suspension of one of the tentative races. The bags were then sealed and placed in a growth room

for 48 hours at 20 to 22°C, after which they were removed and the plants returned to the greenhouse. The differentials were inoculated at the V2 to V3 growth stage. Symptoms were evaluated two weeks after inoculation.

Results and Discussion

On the basis of symptoms shown by detached leaves of the 11 differentials (Table 21), the 42 isolates were tentatively classified into 13 races. Two of them, D-b-2T and D-a-6T, still produced mixed infection types (TAN and RB) on Taita Kaohsiung No. 5 and PI 230971, respectively.

Table 21. Reactions on detached leaves of soybean differentials inoculated with 42 isolates of Phakopsora pachyrhizi AVRDC, 1983.

Isolate code	Infection types[z] on differential hosts										
	PI 339871A	PI 339871B	PI 230970	PI 230971	TK #5	TN #4	Wayne	Ankur	PI 200492	PI 459024	PI 459025
23 isolates	T	T	T	T	T	T	T	T	T	T	RB
A-a-2T, B-d-10T B-e-10RB, C-3-2RB	T	T	T	T	T	T	T	T	T	RB	RB
C-e-5T E-a-10T	T	T	T	T	RB	T	T	T	T	T	RB
A-a-2RB	T	T	T	T	RB	T	T	T	T	RB	RB
D-b-2T	T	T	T	T	RB,T	T	T	T	T	T	RB
E-b-2T, E-b-10T	T	T	T	T	T	RB	T	T	T	T	RB
D-a-6T	T	T	T	T,RB	T	T	T	T	T	T	RB
A-a-4RB	T	T	RB	RB	T	T	T	T	T	T	RB
B-3-8RB, E-a-10RB	T	T	RB	RB	T	T	T	RB	T	T	RB
D-b-8RB, E-a-4RB	T	T	RB	RB	T	RB	T	RB	T	T	RB
E-b-3RB	T	T	RB	RB	T	T	T	RB	RB	T	RB
E-g-4RB	T	T	RB	RB	T	RB	T	RB	RB	T	RB
E-g-8RB	T	T	T	RB	T	T	T	RB	T	T	RB

[z] Infection types; TAN - tan colored lesion with 2-5 uredia per lesion 14 da after inoculation, RB = reddish-brown colored lesion with 0-2 uredia per lesion 14 da after inoculation, 0 = absence of macroscopically visible signs or symptoms.

One isolate of each tentative race was selected for inoculation to intact plants of the differential cultivars. Three days after inoculation, a few leaflets from each of the "race"/differential combinations were detached and maintained in petri dish moisture chambers at 20 to 22°C to test the validity of the detached leaf technique. Significant variations were noted when comparing the data from the detached leaf (Table 22) and the intact plant (Table 23) tests. There were also

considerable variations between the two detached leaf tests (Tables 21 and 22). Until the parameters affecting the expression of infection type are better understood, such variations will preclude the use of the detached leaf technique for race determination.

On the basis of inoculation of intact plants (Table 23), the 13 tentative races were reduced to 9 races. Tentative races 1, 2, 4, and 6 were identical, as were 3 and 5. All of the races were compatible (capable of inducing TAN type lesions) on 4 to 10 of the differential cultivars, with the majority being compatible on more than 7 of them. The distribution of the RB, TAN, and 0 infection types in Table 23 indicates that with the possible exception of PI 200492, which is already known to possess a specific gene for resistance to soybean rust, all eleven are valid differentials.

Table 22. Reactions on detached leaves from inoculated plants of soybean differentials inoculated with 13 tentative races of P. pachyrhizi, AVRDC, 1983.

Tentative races	Infection types[z] on differential hosts								
	PI 230970	PI 230971	TK #5	TN #4	Wayne	Ankur	PI 200492	PI 459024	PI 459025
1	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
2	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB	RB
3	TAN	TAN	RB	TAN	TAN	TAN	TAN	RB	RB
4	RB	TAN	TAN	TAN	TAN	TAN	TAN	RB	RB
5	TAN	TAN	RB	TAN	TAN	TAN	TAN	RB	RB
6	TAN	TAN	RB	TAN	TAN	TAN	TAN	RB	RB
7	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB	RB
8	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB,TAN	RB
9	RB	TAN	TAN	TAN	TAN	RB	TAN	RB	RB
10	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB	RB
11	TAN	TAN	RB	TAN	TAN	TAN	TAN	RB	(RB)
12	RB	TAN	RB	TAN	TAN	RB	TAN	RB	RB
13	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB

[z] Infection types; TAN = tan colored lesion with 2-5 uredia per lesion 14 da after inoculation, RB = reddish-bron colored lesion with 0-2 uredia per lesion 14 da after inoculation, 0 = absence of macroscopically visible signs or symptoms. (RB) - RB type lesion producing many uredospores.

Table 23. Reactions on intact plants of soybean differentials inoculated with 13 tentative races of Phakopsora pachyrhizi in a greenhouse test at AVRDC, 1983.

Tentative races	Infection types[z] on differential hosts										
	PI 339871A	PI 339871B	PI 230970	PI 230971	TK #5	TN #4	Wayne	Ankur	PI 200492	PI 459024	PI 459025
1	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
2	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
3	TAN	TAN	TAN	TAN	RB	TAN	TAN	TAN	TAN	TAN	RB
4	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
5	TAN	TAN	TAN	TAN	RB	TAN	TAN	TAN	TAN	TAN	RB
6	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
7	0	0	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
8	RB	RB	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB
9	TAN	TAN	TAN	RB	TAN	TAN	TAN	RB	TAN	TAN	RB
10	RB	TAN	TAN	TAN	TAN	RB	TAN	TAN	TAN	TAN	RB
11	RB,TAN	TAN	RB	RB	TAN	TAN	TAN	TAN	TAN	TAN	(RB)
12	RB	RB	RB	RB	(RB)	TAN	TAN	RB	TAN	TAN	RB
13	RB	RB	TAN	TAN	TAN	TAN	TAN	TAN	TAN	TAN	RB

[z] Infection types; TAN = tan colored lesion with 2-5 uredia per lesion 14 da after inoculation, RB = reddish-bron colored lesion with 0-2 uredia per lesion 14 da after inoculation, 0 = absence of macroscopically visible signs or symptoms. (RB) - RB type lesion producing many uredospores.

Conclusion

The predominate races of soybean rust at AVRDC are complex, and possess multiple virulence factors which allow compatibility with most known differential soybean cultivars. The only cultivar for which a compatible race has not yet been found is PI 459025.

Effect of Precipitation on Rust Development

Introduction

Previous epidemiological studies have indicated that soybean rust development is affected by precipitation patterns; it was most rapid at sites where precipitation had been evenly distributed throughout the season, and was substantially slower at sites where precipitation had occurred in inconsistent patterns. This study was designed to determine more precisely the effect of precipitation and irrigation on rust development.

Materials and Methods

The experiment consisted of three treatments: Furrow irrigation as needed, no irrigation, and overhead irrigation from 16:30 to 16:40 every day through a pipe perforated with holes less than 1mm in diameter and set about 0.8 m above the ground. The study was conducted at AVRDC during three crop seasons, with plantings on October 1 of 1979 and on March 5 and October 1 of 1980. Cultivar TK #5 was grown in 10 x 10 m plots (9 x 9 m harvested) in three replications, with a plant density equivalent to 4×10^5 plants/ha. Data collection and evaluation procedures were similar to those previously described.

Results

The only precipitation during the fall of 1979 was 28.5 mm during seven days, most of which (24.4 mm) fell in a two-day period 47 and 48 DAP. A total of 99.3 mm of precipitation was spread over 12 days in the spring of 1980, and 58.7 mm over 8 days in the fall of 1980. Precipitation was relatively evenly distributed through the middle of each growing season.

In the spring and fall of 1980, the rates of rust development and the estimated number of days after planting when rust reached one percent severity were not significantly different in any treatment within a season (Table 24). Since neither precipitation nor soil moisture appeared to be a substantial limiting factor in these two seasons, only the fall of 1980 was compared with the fall of 1979.

A comparison of rust development in these two seasons shows that precipitation and irrigation are both important factors in rust development (Fig. 1). In both seasons rust epidemics in the overhead irrigation treatments developed within three weeks of the first major

precipitation, even though the epidemic developed 22 days later in the fall of 1979 than in the fall of 1980.

Table 24. Effect of irrigation methods on the initiation and rate of soybean rust development in the cultivar TK #5 during three seasons at AVRDC.

Season	Treatment	Rate of rust development[z]	Days after planting 1% rust[y]
Fall 1979	Overhead	0.2224 a[x]	58.4 b[w]
	Furrow	0.2245 a	66.3 a
	Non-irrigated	0.0926	72.3
Spring 1980	Overhead	0.2480 r	39.7 r
	Furrow	0.2774 r	43.7 r
	Non-irrigated	0.2494 r	47.1 r
Fall 1980	Overhead	0.2992 w	42.7 w
	Furrow	0.3015 w	45.4 w
	Non-irrigated	0.3285 w	47.0 w

[z] Regression coefficient based on logit of % disease and days after planting, mean of three replications except 1979 non-irrigated.
[y] Estimated from linear regression.
[x] Mean separation within columns in each season by Duncan's multiple range test (5% level).
[w] Data were pooled for the computation of linear regression because of insufficient data points.

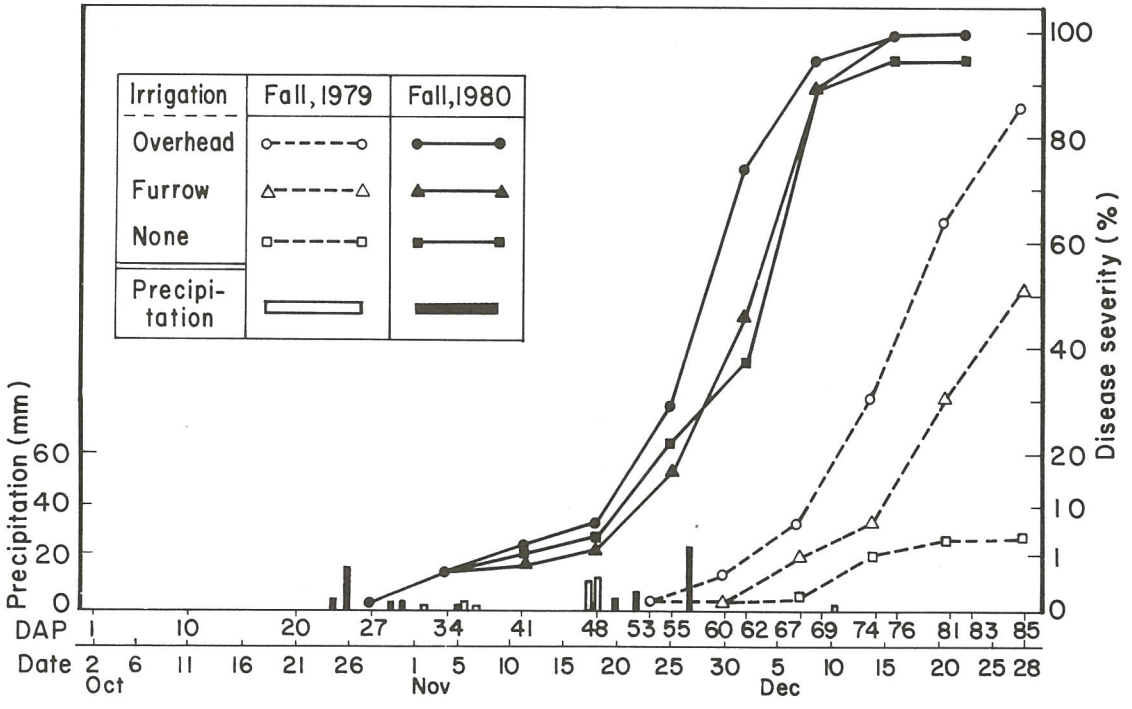

Fig. 1. The influence of precipitation and irrigation systems on soybean rust development during two seasons at AVRDC (cv. TK 5 was planted on October 1, 1979 and 1980).

In 1979, rust reached an estimated 1% severity earliest in the overhead irrigation treatment, and was delayed in the other two treatments, the greatest delay occurring in the non-irrigated treatment (Table 24). The non-irrigated treatment also had the slowest rate of rust development; there was no significant difference in the rates of rust development for the two irrigation treatments. More abundant and more frequent precipitation in the fall of 1980 negated the effects of the irrigation treatments on rust development (Fig. 1).

Conclusions

Precipitation is necessary for the early development of a rust epidemic, even when soybeans are grown with irrigation. Under dry conditions, however, the irrigation method can affect both when the epidemic begins and how rapidly it develops. As can be seen from the delayed rust development in the fall of 1979, overhead irrigation, as applied, did not closely simulate precipitation.

Effect of Temperature on Rust Development

Introduction

Most knowledge of the influence of environmental parameters (primarily temperature and dew period) on rust development had been gained from greenhouse or growth chamber studies. This study, however, was designed to examine such factors under field conditions.

Materials and Method

Determinate soybean cultivar Taita Kaohsiung No.5 and indeterminate cultivar PI 230971 were planted at monthly intervals from December of 1979 to December of 1980. Plot size for each cultivar was 6 x 7 m, and plant population density was equivalent to 6×10^5 plants/ha. Five plants were randomly selected from each plot when the majority of the plants within that plot reached each growth stage. The total number of rust lesions per plant was counted. Data from the previous sampling were used when leaves were missing. Because of its more quantitative nature, number of lesions was chosen as the disease parameter rather than the percentage of affected foliage. Temperature, dew period, precipitation, and aerial spore numbers were also recorded. Temperature data were separated into mean day temperature (mean of the bi-hourly average temperatures from 06:00 to 20:00) and mean night temperatures (mean of the bi-hourly average temperatures from 20:00 to 16:00). Since rust requires free moisture for germination, mean night temperatures, because of their close association with leaf wetness, were presumed to be the more important temperature parameter.

Results

Mean daily night temperatures ranged from 7.1 to 27.1°C, with the lowest temperatures occurring between mid-December and early February, and the highest temperatures occurring from early June to early Sep-

tember. Low temperatures between mid-December and mid-February affected rust development in both the 1979-80 and 1980-81 periods. Mean low night temperatures were 13.9 °C, ±2.59° (X̄±1SD) for December 11, 1979 through February 11, 1980, and 13.1°C, ±2.62° for December 11, 1980 through February 11, 1981. Although aerial rust spores were present, no rust lesions were observed on December 1 plantings of either cultivar between December 11, 1980 and February 4, 1981. Low levels of rust infection were observed when these cultivars were planted on December 4 and December 31, 1979, and the total number of lesions per plant by February 11 was less than 400.

Low temperatures after December 11 also affected rust development in both cultivars when they were planted on October 30. Rust development after December 13, although substantially reduced in this planting, was not prevented completely, as it had been in the December 1, 1980 planting. A more normal pattern of rust development was observed before December 11. Thus, it would appear that under field conditions low mean night temperatures (under 14°C) may be able to either prevent or substantially reduce rust development.

High mean night temperatures from June 5 to September 5 (25.5°C, ±0.86°) alone did not affect rust lesion number; the highest total lesion numbers per plant on either cultivar during this study occurred September 4 on the cultivar TK #5 planted July 1 (7.6×10^4 lesions per plant).

Conclusions

Under field conditions, mean night temperatures of less than 14°C can substantially reduce the rate of rust development once an epidemic has begun, and can prevent a new epidemic from starting. These low temperatures also inhibit soybean growth and development, however. Mean night temperatures of 25.5°C or higher do not alone affect rust development, but the precipitation and dew period associated with such temperatures appear to be principal factors in its regulation.

Reactions of Legume Species to *Phakopsora pachyrhizi*

Introduction

Phakopsora pachyrhizi has a much wider host range than do most rust pathogens. Over 90 legume species of 32 genera have been identified as hosts, and several specific fungal names are considered synonymous with P. pachyrhizi. P. vignae, for example, was originally identified and described on legumes planted in the tropical Americas, whereas P. pachyrhizi was originally identified in Asia. The host range of P. pachyrhizi is also different in the eastern and western hemispheres, and apparent contradictions in reports on which legume species allow symptom development and/or uredia and uredospore production can probably be traced to the varying locations where the research had been conducted. P. pachyrhizi as it is presently described may be two different species,

or at least two distinctly different biotypes, one of which is extant in Asia and the other in the Americas.

This study was designed to explore the possibility that P. pachyrhizi could be separated on the basis of biotype into two distinct biotypes. This was a cooperative project with the National Soybean Research Center (CNP Soja) of Brazil, an institute which operates under the aegis of EMBRAPA.

Materials and Methods

Fifteen known hosts of P. pachyrhizi in Brazil were obtained from CNP Soja (Table 25). Glycine max cultivars Taita Kaohsiung No. 5 (TK #5) and Wayne, and a cultivar of G. wightii (= Neonotonia wightii, G. javanica) were tested at the same time and served as checks. All 18 cultivars were grown in a greenhouse in separate pots. Leaves from one-month old plants were detached and rinsed in sterile distilled water, and the cut petiole was then wrapped in cotton and placed on moist filter paper inside a sterile petri dish.

Table 25. Reactions of legume species to artificial inoculation of Phakopsora pachyrhizi on detached leaves in a growth room test at AVRDC in spring of 1983.

Species or name of legumes	Days after inoculation which lesion produced isolated from		Lesion type[x]	No. of uredia/lesion isolated from	
	TK #5	G. wightii		TK #5	G. wightii
Crotalaria graviana	7	7	TAN	3-5	3-5
C. juncea	7	7	TAN	1-8	1-5
Fava bean (Phaseolus lunatus)	5-7	5-7	RB	1-2	1-2
Feijao de Lima (P. lunatus var. macrocarpus)	5-7	5-7	RB	0-1	0-1
Jacatupe	10-12	10-12	TAN	1-2	1-2
Macroptilium lathyroides	5-7	5-7	RB	0	0
M. atropurpureum (Siratro)	7-10	7-10	RB	0	0
Mayashi bean	5-7	5-7	RB	0-1	0-1
Phaseolus vulgaris[z]	5-7	5-7	RB	0-1	1-3
P. vulgaris[y]	5-7	5-7	RB	0-1	1-4
P. bracteolatus	10-12	10-12	RB	1-2	1-2
Rhynchosia minima	5-7	7-10	TAN	1-3	3-8
Soja perene (G. wightii)	5-7	7-10	TAN	2-5	2-5
Teramnus uncinatus	7	7	RB	0-1	0
Vigna radiata	5-7	5-7	RB	0-1	0-1
Glycine max (TK #5)	5-7	5-7	TAN	1-8	1-8
G. max (Wayne)	5-7	5-7	TAN	3-5	1-8
G. wightii	7	7	RB	0-1	0-1

[z] P. vulgaris Variedode Campineiro Vacional
[y] P. vulgaris Macornal Trepadon
[x] Both of two isolates produced the same reaction
RB = reddish-brown type lesion
TAN = tan type lesion

Two isolates of P. pachyrhizi were obtained from field grown plants, one from the soybean cultivar TK #5 and the other from G. wightii. Each isolate was obtained by transferring uredospores from a single uredium to detached leaves of Wayne and then serially transferring to Wayne until sufficient uredospores could be obtained for inoculation. Inoculation was accomplished by spraying an aqueous suspension of uredospores onto detached leaves in petri dishes. The petri dishes were then covered and placed in a growth room at 22°C, ±2°, with continuous fluorescent light. Lesion type, number of uredia per lesion, and uredospore size were recorded 5 to 12 days after inoculation. Lesion type [TAN or reddish-brown (RB)] was described primarily on the basis of lesion color. The experiment was repeated three times, with three replicates per experiment.

Results

P. pachyrhizi induced TAN lesions on five Brazilian legumes and on soybean cultivars TK #5 and Wayne, and RB lesions on G. wightii and ten Brazilian legumes. Both isolates induced the same lesion type on all hosts. All hosts developed visible lesions 5 to 12 days after inoculation, and 13 of the 18 developed lesions 5 to 7 days after inoculation, regardless of which isolate they had been inoculated with. Two hosts, Phaseolus bracteolatus and Jacatupe, developed lesions 10 to 12 days later than the other hosts. Except for Rhynchosia minima and soja perene, which developed lesions slightly later when inoculated with the isolate from G. wightii, all hosts developed lesions after the same length of time, irregardless of isolate (Table 25).

In some isolate/host combinations [either isolate on Macroptilium lathyroides and M. atropurpureum (Siratro), and the isolate from G. wightii on Teramnus uncinatus] the pathogen was unable to complete its life cycle. Even in these hosts, however, P. pachyrhizi was able to induce lesion development (Table 25).

Although soja perene (from Brazil) and G. wightii (from Taiwan) are members of the same species, differences were observed in lesion type and the number of uredia per lesion. TAN lesions with many uredia were produced on soja perene, and RB lesions with few uredia were produced on G. wightii (Table 25).

More uredia were generally produced within TAN lesions than within RB lesions. One notable exception was the host Jacatupe, where P. Pachyrhizi induced TAN lesions but only produced one or two uredia per lesion (Table 25).

The uredospores produced in various host/isolate combinations varied significantly in size (Table 26). This variation occurred not only among different hosts infected with the same isolate, but also between different isolates on the same host.

Conclusions

Lesion coloration, TAN or RB, is not necessarily related to uredia density, and may be controlled by other factors.

Uredospores of P. pachyrhizi vary significantly in size when

produced on different hosts by different isolates, and thus it cannot be identified by uredospore size alone. Not all of the legumes which are known hosts to P. pachyrhizi in Brazil proved compatible in this test. Although results indicate that American and Asian biotypes of P. pachyrhizi can be distinguished on the basis of host range, further research is necessary.

Table 26. Uredospore size of Phakopsora pachyrhizi grown on detached leaves of 18 legumes in a growth room test at AVRDC in the spring of 1983.

Species or name of legumes	Uredospore size, isolate from (μ)[z]	
	TK #5	G. wightii
Crotalaria graviana	22.37±2.06x30.19±2.79	25.98±1.04x32.44±2.86
C. juncea	24.07±1.34x30.87±2.12	23.80±1.40x32.71±2.52
Fava bean (P. lunatus)	24.11±5.24x30.74±3.17	-
Feijar de Lima (P. lunatus var. macrocarpus)	25.94±2.35x31.01±1.85	27.88±1.11x34.61±1.68
Jacatupe	26.42±1.70x35.09±2.98	23.60±2.09x30.06±2.86
Macroptilium lathyroides	-	-
M. atropurpureum (Siratro)	-	-
Mayashi bean	26.62±1.62x36.41±2.45	-
Phaseolus vulgaris[z]	24.42±1.94x32.47±3.01	28.05±2.24x36.28±2.43
P. vulgaris[y]	21.76±2.45x32.06±3.03	24.84±1.87x34.17±3.16
P. bracteolatus	29.10±3.06x36.52±3.03	27.57±1.96x34.00±2.65
Rhynchosia minima	24.65±1.99x31.11±3.18	24.79±1.73x32.40±2.99
Soja perene (G. wightii)	22.85±3.71x32.71±5.12	23.87± x34.07±
Teramnus uncinatus	24.24±1.82x33.86±5.87	-
Vigna radiata	26.65±1.62x31.86±2.01	24.62±1.68x31.69±2.94
Glycine max (TK #5)	23.46±1.75x32.10±2.89	24.38±1.70x33.97±2.99
G. max (Wayne)	18.84±1.29x29.65±2.91	18.33±1.60x28.22±3.06
G. wightii	24.68±1.80x31.18±4.08	23.60±1.39x29.48±2.14

[z] P. vulgaris Variedode Cornpineiro Vaiconal
[y] P. vulgaris Maconnal Trepadon
[x] Spore size is width x length and the value represents: mean value ± a standard deviation (average from 25 uredospores).

Screening for Resistance to Soybean Bacterial Pustule and Downy Mildew

Introduction

Bacterial pustule caused by Xanthomonas campestris pv. phaseoli (Smith) Dye is often present in AVRDC soybean fields in the summer, and has been reported from all of the world's soybean-growing areas which experience high temperatures and frequent rainfall during the growing season. Early symptoms are minute, pale-green spots with elevated centers, appearing on either or both leaf surfaces. Later, a small raised, light-colored pustule forms in the center. Severe infection often results in premature defoliation, which can cause yield losses by reducing the size and number of seeds.

Downy mildew can also cause some defoliation, and reduces yield by lowering seed quality and reducing seed size. The purpose of this experiment was to screen accessions under field conditions for resistance to both bacterial pustule and downy mildew. The most resistant material will be incorporated into the breeding program, and will also be used in further studies aimed at characterizing resistance to bacterial pustule.

Materials and Methods

The experiment was conducted in the summer of 1983. Thirty-two soybean cultivars previously rated as moderately resistant or highly resistant to bacterial pustule were planted on June 29. Two-meter rows were arranged in an RCB design with three replications. Plant density after thinning was equivalent to 400,000 plants/ha. Pesticides, fertilizers, and irrigation were all applied according to standard AVRDC cultural practices. On August 22, all plots were inoculated with a suspension of X. campestris pv. phaseoli. To prepare this inoculum, soybean leaves severely infected with bacterial pustule were homogenized with distilled water in a commercial blender for about one minute. After being filtered through cheesecloth to remove large particles and fibers, one part of the resulting suspension was diluted with four parts distilled water. Then, with an atomizer attached to a high pressure pump, this inoculum was forcibly sprayed against both sides of the leaf until small water-soaked spots appeared. To ensure successful inoculation, plants were reinoculated by the same method four days later.

Ratings for both diseases were made on September 5, 1983. The following rating system was used for bacterial pustule: 1 = disease severity less than that of G 2034 (cultivar CNS), 2 = disease severity similar to that of G 2034, and 3 = disease severity higher than that of G 2034. Cultivar CNS was used as a reference; although it has been reported as nearly immune to pustule in the USA, and has been used worldwide as a resistant parent, past experience at AVRDC had indicated that it is only moderately resistant and that other accessions are more resistant.

The rating system used to evaluate downy mildew disease severity was similar to the one used for bacterial pustule: 1 = disease severity less than that of G 38 (Shih-shih) or G 57 (Tainung No. 4, TN #4), 2 = disease severity similar to that of G 38 or G 57, 3 = disease severity higher than that of G 38 or G 57. Shih-shih and TN #4 were selected as reference cultivars because previous reports and experience had shown them to possess acceptable levels of resistance to downy mildew.

Results

Four accessions [G 8190 (PI 371611), G 8499 (PI 189402), G 8513 (PI 200454) and G 8823 (PI 374157)] were rated as more resistant to bacterial pustule than G 2034 (CNS), and eight were rated as resistant as G 2034 (Table 27). Thirteen percent of the cultivars were more resistant than G 2034, and 26% were as resistant.

Nineteen of the 32 accessions were more resistant to downy mildew

than either G 38 or G 57 (Tables 27 and 28). Over 93 percent of the accessions were either as resistant or more resistant than the reference cultivars. Because the intensity of the epidemic was low, however, with only 0.5% downy mildew on G 38 and 8% on G 57, cultivars rated as resistant will be retested to confirm their resistance.

Although G 8190, G 8513, and G 8823 were more resistant to bacterial pustule and downy mildew than the reference cultivars, G 8823 was very late maturing, and disease ratings taken at the R_2 stage may have resulted in an overestimation of its resistance. Of all accessions screened, G 8190 and G 8513 ranked 7th and 8th in yield, and had moderate seed size.

The number of days to maturity ranged from 75 to 131, and plant height varied from 43.5 to 217 cm (Table 29). Yields among the accessions ranged from 1.6 to 8.4 t/ha, and 100 seed weight from 8.0 to 21.9 g. Commercial cultivars G 38 (Shih-shih) and G 57 (TN #4) yielded 3.7 and 4.4 t/ha.

Table 27. Evaluation for soybean bacterial pustule and downy mildew resistance. Summer, 1983.

Variety/ acc. no.	Growth[z] stage	Disease rating	
		Bacterial pustule[y]	Downy mildew[x]
G 8096	R6.3	2	1
G 8097	R6-6.3	2	1
G 8098	R6-6.3	3	1
G 8100	R5.8	3	1
G 8101	R5	3	2
G 8190	R5.8-6	1	1
G 8238	R4-5	3	2
G 8239	R5.3-5.5	3	1
G 8244	R5	3	1
G 8255	R5-5.3	3	1
G 8258	R6	3	2
G 8264	R6	2	1
G 8315	R5.8	2	1
G 8492	R5-5.3	3	1
G 8499	V21-R2	1	3
G 8509	R3-4	3	1
G 8513	R4-5	1	1
G 8587	R2-3	2	1
G 8657	R2	2	3
G 8759	R2-3	2	2
G 8763	R23-R2	3	2
G 8823	R2	1	1
G 5422	R6.3	3	2
G 5497	R6.3	3	1
G 5554	R6-6.3	2	1
G 2034	R4-5	-	2
G 38	R6.3	3	-
G 4919	R5.5-5.8	3	1
G 5524	R6.3	3	1
TN-4	R5-5.3	3	-
KS 535	R6-6.3	3	2
C-21	R3-4	3	2

[z] Planted: June 29, 1983
Inoculated: August 22 and 23, 1983
Evaluated: September 6, 1983

[y] Rating system for bacterial pustule resistance:
1 = more resistant than G-2034
2 = resistance similar to G-2034
3 - less resistant than G-2034

[x] Rating system for downy mildew resistance:
1 = more resistant than G-38 and TN #4
2 = resistance similar to G-38 and TN #4
3 = less resistant than G-38 and TN #4

Table 28. Reactions of accessions screened for soybean bacterial pustule and downy mildew resistance. Summer, 1983.

Disease	Reaction	No. of entries	%
Bacterial pustule	1	4*	12.9
	2	8	25.8
	3	19	61.3
	Total	31	
Downy mildew	1	19	63.3
	2	9	30.0
	3	2	6.7
	Total	30	

* G 8190, G 8499, G 8513, and G 8823.

Table 29. Yield components and number of days to maturity of accessions screened for resistance to soybean bacterial pustule in summer, 1983.

Variety/ Acc. no.	Date[z] R8	Days to[y] R8	Plant height (cm)	Mean yield (g/lm^2)	Water content (%)	13% water content Yield (kg/ha)	13% water content 100-seed wt.(g)
G 8096	9/30	93	55.0	302.7	10.5	3,114.0	12.7
G 8097	9/29	92	59.6	158.5	10.4	1,632.4	10.7
G 8098	9/30	93	60.4	271.3	10.1	2,803.4	17.6
G 8100	10/3	96	151.8	242.0	10.0	2,482.8	8.2
G 8101	10/5	98	108.2	327.7	10.5	3,371.2	8.4
G 8190	10/3	96	97.6	499.7	10.1	5,163.6	15.6
G 8238	10/11	104	157.4	241.7	10.5	2,486.5	15.9
G 8239	10/3	96	135.7	351.0	10.6	3,606.8	16.0
G 8244	10/11	104	169.6	261.3	10.4	2,691.1	14.6
G 8255	10/11	104	56.5	350.7	10.6	3,603.7	17.4
G 8258	10/11	104	59.9	390.7	10.3	4,028.3	14.4
G 8264	10/5	98	43.5	277.0	10.6	2,846.4	14.6
G 8315	9/29	92	53.2	187.7	10.6	1,928.8	11.5
G 8492	10/19	112	63.5	332.0	10.1	3,430.7	15.9
G 8499	11/1	125	157.3	484.0	10.4	4,984.6	8.9
G 8509	11/1	125	70.1	387.0	10.5	3,981.2	11.2
G 8513	10/19	112	89.0	472.0	10.0	4,882.8	16.4
G 8587	11/7	131	179.2	811.0	9.8	8,408.3	19.0
G 8657	11/1	125	192.7	774.7	10.3	7,678.1	8.0
G 8759	10/24	117	136.0	642.7	10.1	6,641.2	10.3
G 8763	11/3	127	217.6	654.0	10.4	6,735.4	14.3
G 8823	11/3	125	164.3	637.7	10.1	6,589.6	9.4
G 5422	9/20	83	78.3	402.7	9.9	4,170.5	21.4
G 5497	9/12	75	64.5	210.0	10.2	2,167.6	10.6
G 5554	9/19	82	65.6	220.7	10.0	2,283.1	11.8
G 2034	10/14	107	65.9	275.7	10.1	2,848.9	11.5
G 38	9/24	87	63.9	355.7	9.9	3,683.7	15.5
G 4919	10/19	112	61.4	449.7	9.6	4,672.7	18.3
G 5524	10/19	112	66.6	186.3	9.5	1,937.9	21.9
TN-4	10/11	104	97.6	426.3	10.2	4,400.2	13.9
KS 535	10/3	96	81.7	415.0	10.2	4,283.6	17.4
C-21	11/3	127	116.0	534.3	10.0	5,527.2	12.6

[z] Date R8 means the last day among 3 replications reached R8 stage.
[y] Days to R8 indicates the days of the last replication reached R8 stages.

Conclusions

Accessions G 8190 and G 8513 have been shown to have a high level of resistance to both bacterial pustule and downy mildew. In previous tests, both had been rated as highly resistant to bacterial pustule. Both are also moderately early maturing, and both have a high yield potential. Either cultivar would be a good source of resistance to bacterial pustule and downy mildew.

Vesicular-Arbuscular Mycorrhizal Fungi and Their Relationship to Crop Plants and Cropping Systems

Introduction

The vesicular-arbuscular mycorrhizal (VAM) system involves three components - the plant, the environment, and the fungus. Since interactions between these three influence any patterns of association, a better understanding of such interactions in various cropping systems could help determine the potential beneficial effects of various mycorrhizal fungi, and would be the first step toward developing the technologies needed to manipulate the mycorrhizal system for the farmer's benefit.

This study was designed to examine mycorrhizal associations and the presence or absence of various propagules of VA fungi in association with rice, corn, and soybean in the spring, summer, and fall planting seasons.

Materials and Methods

A study of VA mycorrhizal fungi in a rice-legume cropping system was conducted from October of 1981 to November of 1983. In addition, bioassay tests of VAM association were conducted in the greenhouse from July of 1982 to October of 1983. Two types of inoculum were used in these tests - mycelia in field-grown rice roots and spores from pot cultures of field samples. Rice, corn, and soybean used as bioassay plants were grown in autoclaved sand and nutrient solution. Mycorrhizal spores were extracted for microscopic observation by wet-sieving and decanting. Roots were stained with trypan-blue lactophenol before being examined microscopically for mycorrhizal structures.

Results

Under field conditions mycorrhizae were associated with soybean in all three planting seasons (spring, summer, and fall), but were only observed to be associated with rice in the spring, and then only from 60 DAP until harvest at 120 DAP (Table 30).

Spores were present in the soil surrounding both crops in all three seasons, but the absence of arbuscules and mycelia in the roots of either rice or soybean at the harvest of the summer crop would suggest

that these roots do not serve as a source of inoculum for the fall planting. The presence of mycelia with arbuscules in rice roots at the harvest of the spring crop, and in soybean roots at the harvest of spring and fall crops would suggest, however, that mycelium from these roots could be infective propagules for the succeeding crop.

These results were confirmed by the greenhouse bioassay test; when rice roots from the spring and summer crops were used as a source of inoculum for corn, only roots from the spring rice crop proved to be a source of VA mycorrhizae (Table 31). They contained both Glomus mosseae and Gl. etunicatus, but when the spores were inoculated to rice only Gl. mosseae was able to develop a successful association, and only during the spring planting season. In all three seasons Gl. mosseae, Gl. etunicatus, and Acaulospora. A. srobiculata succesfully formed mycorrhizae with corn and soybean, and all had produced spores by harvest time. Regardless of the VAM species, though, no arbuscules were observed in the roots of corn or soybean harvested at the end of the summer season. No arbusculles of Gl. etunicatus were observed in the roots of corn or soybean harvested in any season. The occurrence of both internal and external vesicules varied with VAM species, planting period, and plant.

Table 30. Associations of VA mycorrhizal fungi with rice and soybean under field conditions in sequential planting seasons from October of 1981 to November of 1983.

Host Crop	Planting season and sampling time	VAM association	Infective propagules of VAM fungi	
			mycelium	spore
Rice	Spring (June 82)	M+[z]	+[x]	+
	Summer (Oct. 82)	M-[y]	-[w]	+
	Spring			
	(May 2, 83, 60 DAP)	M+	+	?[v]
	(May 31, 83, 90 DAP)	M+	+	?
	(June 29, 83, Har.)	M+	+	+
Soybean	Fall (Jan. 82)	M+	+	+
	Spring (June 82)	M+	+	+
	Summer (Oct. 82)	M+	-	+
	Fall (Nov. 83)	M+	+	?

[z] Represent mycorrhizal association.
[y] Represent non-mycorrhizal association.
[x] Represent infected roots with arbuscule.
[w] Represent infected roots without arbuscule.
[u] Spore presence not determined.

Conclusions

The status of vesicules and arbuscules appears to vary with VAM species and planting season. Gl. mosseae is the only VAM species tested which forms mycorrhizae with both rice and soybean under greenhouse conditions, but Gl. etunicatus and Gl. mosseae are present in the roots of spring rice, and both are mycorrhizal on the roots of soybean. The absence of arbuscules in roots of corn or soybean harvested at the end of the summer, however, indicates that these roots are poor sources of infective propagules (mycelia), and that spores are thus the principal inoculum for a fall crop.

Table 31. Bioassay tests on VAM association conducted under greenhouse conditions for July 1982 to October 1983.

Test crop	VA mycorrhizal inocula	Test period (sample time)	VAM association	Status of VAM fungi after the harvest of test crop			
				external arbuscule	external vesicle	internal vesicle	internal spore
Rice	Gigaspora margarita[z]	10/6/82-10/28/82 (22 DAP)	M-				
	Gi. gigantea	and					
	Sclerocystis clavispora	Oct 82-Feb 83 (Har.)	M-				
	Glomus mosseae	10/6/82-10/28/82 (22 DAP)	M-				
		Oct 82-Feb 83 (Har.)	M-				
		Mar 83-July 83 (Har.)	M+	+	-	+	+
	Gl. etunicatus	10/6/82-10/28/82 (22 DAP)	M-				
	and	Oct 82-Feb 83 (Har.)	M-				
	Acaulospora scrobiculata	Mar 83-July 83 (Har.)	M-				
Corn	Gi. margarita	Aug 82-Nov 82 (Har.)	M-				
	Gi. gigantea	Aug 82-Nov 82 (Har.)	M-				
	Gl. mosseae	Aug 82-Nov 82 (Har.)	M+	-	+	+	+
		Oct 82-Feb 83 (Har.)	M+	+	+	-	+
	Gl. etunicatus	Oct 82-Feb 83 (Har.)	M+	-	+	+	+
	A. scrobiculata	Oct 82-Feb 83 (Har.)	M+	+	+	-	+
	S. clavispora	Aug 82-Nov 82 (Har.)	M-				
		Oct 82-Feb 83 (Har.)	M-				
	Spring rice roots	July 82-Oct 82 (Har.)	M+	-	+	+	+[y]
	Summer rice roots	Nov 82-Mar 83 (Har.)	M-				
Soybean	Gi. margarita	Feb 83-June 83 (Har.)	M-				
	Gi. gigantea	Feb 83-June 83 (Har.)	M-				
	Gi. mosseae	3/14/83-3/28/83 (14 DAP)	M+	+	-	-	-
		3/14/83-4/4/83 (21 DAP)	M+	+	-	-	-
		3/14/83-4/11/83 (28 DAP)	M+	+	+	-	-
		3/14/83-4/18/83 (3% DAP)	M+	+	+	-	-
		3/14/83-6/3/83 (Har.)	M+	+	+	-	+
	Gl. mosseae	6/17/83-7/15/83 (28 DAP)	M+	+	+	+	-
		6/17/83-7/22/83 (35 DAP)	M+	+	+	+	?[x]
		6/17/83-8/5/83 (49 DAP)	M+	+	+	+	?
		6/17/83-9-6-83 (Har.)	M+	-	+	+	+
		10/6/83-11/28/83 (53 DAP)	M+	+	+	-	+
	Gl. etunicatus	3/14/83-3/28/83 (14 DAP)	M-				
		3/14/83-4/4/83 (21 DAP)	M+	+	+	+	-
		3/14/83-4/11/83 (28 DAP)	M+	+	+	+	-
		3/14/83-4/18/83 (35 DAP)	M+	+	+	+	-
		3/14/83-6/3/83 (Har.)	M+	-	+	-	+
		6/17/83-7/15/83 (28 DAP)	M+	+	+	-	?
		6/17/83-7/22/83 (35 DAP)	M+	+	+	-	?
		6/17/83-8/5/83 (49 DAP)	M+	+	+	+	+
		6/17/83-9/6/83 (Har.)	M+	-	+	+	+
		10/6/83-11/28-83 (53 DAP)	M+	+	+	-	+
	A. scrobiculata	6/17/83-7/15/83 (28 DAP)	M+	+	?	+	?
		6/17/83-7/22/83 (28 DAP)	M+	+	?	+	?
		6/17/83-8/5/83 (49 DAP)	M+	+	?	+	?
		6/17/83-9/6/83 (Har.)	M+	-	+	+	+
	Spring rice roots	10/6/83-11/28/83 (53 DAP)	M+	+	+	-	+[y]

[z] Spores of VAM species were used as inoculum.
[y] VAM species of Gl mosseae and Gl. etunicatus produced.
[x] Status of VA fungi not determined.

Effect of Inoculum Density on the Colonization Rates of Three Vesicular-Arbuscular Mycorrhizae, and on Resulting Soybean Growth Responses

Introduction

In soils with low levels of available phosphorus, vesicular-arbuscular mycorrhizal association can increase a crop's phosphorus uptake and thereby improve its growth and yield. Because such a growth re-

sponse is closely linked to the rate of mycorrhizal colonization, this study was undertaken to learn more about the relationship between mycorrhizal colonization rates, plant growth, VAM species, and inoculum dosage.

Materials and Methods

The study was conducted in a greenhouse from June 17 through September 6, 1983. Three species of VA mycorrhizal fungi were used: Glomus Mossea, Gl. etunaticus, and Acaulospora scrobiculata. Each of the three was made into four different inoculum treatments: 20, 100, and 500 spores, and 1 g of infected roots per $1/5000^{-a}$ Wagner's pot of steamed sand (4.5kg). Spore and infected root inocula were produced from separate corn pot cultures.

Inoculum, rhizobium, 4.145 mg soluble P, and one gram of insoluble phosphate ($FePO_4$) were added to each pot. No inoculum was added to the control pots. Two plants were grown in each pot. At weekly intervals, the other nutrients (a cumulative total of 1132.6 mg N, 398.4 mg K, 296.1 mg Ca, and 98 mg Mg) were divided equally among the remaining eight or nine pots.

Six plants in three replicates were sampled at 28, 35, 49, and 62 DAP, and were harvested at 82 DAP. Only 20 and 100 spore inoculum treatments were sampled at 62 DAP. Data recorded for samples collected before harvest included plant height, fresh weights of plant tops and roots, ratio of top weight to root weight, percentage of root systems colonized by mycorrhizae, and weight of mycorrhizal roots. Data recorded for plants collected at harvest included total dry weight, stem and seed dry weights, and number of pods and seeds per plant.

Results

With the exception of plant height, all growth parameters at all stages of the plant's life cycle indicated that plants infected with G. mosseae and G. etunicatus were more vigorous than the non-inoculated control or plants infected by A. scrobiculata (Tables 32-36). A. scrobiculata was only weakly mycorrhizal on soybeans, and then only in the treatments inoculated with 100 and 500 spores per pot.

Increased spore inoculum concentrations of either G. mosseae or G. etunicatus had a positive effect on all measured parameters except plant height. G. mossea more efficiently colonized the plants' roots, and had a greater effect on their growth. Root pieces infected with either species were a good inoculum source, but one gram of roots infected with G. mosseae elicited a response equivalent to that produced by 20 spores, and a gram of roots infected with G. etunicatus elicited a response equivalent to that produced by either 100 or 500 spores, depending on the parameter measured.

Top weight to root weight ratios of plants infected with either species increased with time, and at 49 and 62 DAP were two or three times that of the control, whose top weight to root weight ratio had actually decreased with time.

Although at harvest time the total dry matter yields of plants

infected with Gl. mosseae or Gl. etunicatus were only 5.7 to 9.4% higher than those of the control, grain yields were 34 to 55 percent higher. Grain yield made up 46 to 53 percent of the total dry matter of plants infected with either of these two species, but only 9 percent of the control's total dry matter yield.

Conclusions

The concentration of mycorrhizae propagules can have a significant effect on plant growth and grain yield. G. mosseae appears slightly more beneficial to soybean growth than does G. etunicatus, but both are far more effective than A. scrobiculata, which seems to be of little benefit to soybean. Both G. mossea and G. etunicatus caused soybean to partition 47% of its total dry matter into grain yield, versus 9% for the control.

Table 32. The effect of VAM species and inoculum type and concentration on plant growth parameters, percentage of root system colonized, and weight of mycorrhizal root systems of greenhouse grown soybeans at 28 DAP.

Treatment	Height (cm)	Top (cm)	Root (gm)	% of root length colonized	T/R[y]	Mycor. root[x] (gm)
Glomus mosseae						
500	32.6	13.9	10.5	69.91	1.30	7.43
100	30.6	8.6	9.6	48.85	0.90	4.78
20	28.6	6.7	7.9	19.34	0.85	1.64
1 gm root	26.9	6.6	6.2	21.83	1.03	1.38
Glomus etunicatus						
500	30.9	9.5	9.0	17.12	1.05	1.55
100	29.8	7.3	7.5	4.31	0.96	0.38
20	28.5	5.9	6.7	4.41	0.86	0.34
1 gm root	32.0	7.8	6.1	7.00	1.25	0.45
A. scrobiculata						
500	39.8	6.7	7.4	0.34	0.90	0.03
100	28.1	5.7	6.6	0	0.86	0
20	28.3	5.7	7.2	0	0.80	0
1 gm root	28.5	3.5	3.9	0	0.91	0
Check	39.6	4.9	5.1		1.00	

[z] Fresh weight.
[y] Top to root ratio.
[x] Weight mycorrhizal root system = root weight x % root length colonized x 10^{-2}

Table 33. The effect of VAM species and inoculum type and concentration on plant growth parameters, percentage of root system colonized, and weight of mycorrhizal root systems of greenhouse grown soybeans at 35 DAP.

Treatment	Height (cm)	Top (cm)	Root (gm)	% of root length colonized	T/R[y]	Mycor. root[x] (gm)
Glomus mosseae						
500	39.9	21.0	13.8	45.15	1.54	6.22
100	42.5	15.2	11.0	32.34	1.38	3.58
20	35.6	10.5	10.8	18.96	0.99	2.05
1 gm root	35.3	11.2	9.4	31.35	1.20	2.95
Glomus etunicatus						
500	40.5	13.9	11.5	20.05	1.21	2.28
100	41.3	8.8	7.6	9.32	1.13	1.21
20	28.8	4.7	6.4	0.38	0.74	0.03
1 gm root	37.3	12.3	10.1	11.83	1.23	1.24
A. scrobiculata						
500	36.7	10.2	9.7	4.94	1.04	0.54
100	33.2	5.2	7.3	0.05	0.72	0.004
20	35.1	6.3	7.5	0.08	0.84	0.007
1 gm root	26.9	3.3	3.6	0.04	1.00	0.002
Check	42.9	5.5	5.8		0.95	

[z] Fresh weight.
[y] Top to root ratio.
[x] Weight mycorrhizal root system = root weight x % root length colonized x 10^{-2}.

Table 34. The effect of VAM species and inoculum type and concentration on plant growth parameters, percentage of root system colonized, and weight of mycorrhizal root systems of greenhouse grown soybeans at 49 DAP.

Treatment	Height (cm)	Top (cm)	Root (gm)	% of root length colonized	T/R[y]	Mycor. root[x] (gm)
Glomus mosseae						
500	48.2	47.7	19.3	40.09	2.49	7.72
100	50.4	40.0	16.8	39.51	2.41	6.74
20	48.2	28.6	14.5	35.53	2.00	5.23
1 gm root	43.5	27.7	13.7	32.71	1.71	5.17
Glomus etunicatus						
500	56.1	32.6	13.9	31.58	2.34	4.39
100	50.4	26.4	13.8	23.40	1.95	3.27
20	44.9	17.5	10.5	20.68	1.57	2.22
1 gm root	55.6	35.5	16.8	30.82	2.12	5.16
A. scrobiculata						
500	41.9	8.0	9.2	1.92	0.86	0.18
100	42.1	8.4	9.6	0.79	0.88	0.078
20	41.3	7.4	8.8	0.12	0.87	0.010
1 gm root	36.0	5.6	5.8	0.43	0.96	0.028
Check	57.5	5.4	6.9		0.77	

[z] Fresh weight.
[y] Top to root ratio.
[x] Weight mycorrhizal root system = root weight x % root length colonized x 10^{-2}.

Table 35. The effect of VAM species and inoculum type and concentration on plant growth parameters, percentage of root system colonized, and weight of mycorrhizal root systems of greenhouse grown soybeans at 62 DAP.

Treatment	Height (cm)	Top (cm)	Root (gm)	% of root length colonized	T/R[y]	Mycor. root[x] (gm)
Glomus mosseae						
500						
100	48.5	49.2	15.2	37.83	3.27	5.80
20	41.9	28.7	12.2	35.90	2.32	4.43
1 gm root						
Glomus etunicatus						
500						
100	48.1	31.0	12.4	17.67	2.39	2.15
20	41.6	27.2	12.4	19.16	2.17	2.39
1 gm root						
A. scrobiculata						
500						
100	40.3	7.0	6.6	0.64	1.05	0.045
20	46.5	6.1	6.8	0.22	0.90	0.014
1 gm root						
Check	64.9	4.5	5.9		0.78	

[z] Fresh weight.
[y] Top to root ratio.
[x] Weight mycorrhizal root system = root weight x % root length colonized x 10^{-2}.

Table 36. The effect of VAM species and inoculum type and concentration on plant growth parameters of greenhouse grown soybean plants at harvest.

Treatment	Total dry wt. (gm.)	Stem dry wt.(gm.)	Seed dry wt.(gm.)	Pod no.	Seed no.
Glomus mosseae					
500	10.94	2.13	5.46	27.0	48.3
100	9.23	1.80	4.46	25.8	42.8
20	8.00	1.72	3.77	22.5	37.5
1 gm	8.89	1.74	4.39	23.3	37.8
Glomus etunicatus					
500	9.20	1.56	4.90	21.0	38.5
100	8.19	1.44	3.92	23.8	36.5
20	6.64	1.36	3.41	19.3	31.8
1 gm	9.75	2.05	4.44	27.3	40.7
A. scrobiculatus					
500	3.20	0.98	1.19	10.0	15.0
100	1.23	0.73	0.18	4.0	5.0
20	1.11	0.63	0.14	2.0	2.0
1 gm	0.77	0.47	0.14	2.0	2.0
Check	1.16	0.82	0.10	3.0	4.0

Soybean Entomology

Rescreening for Beanfly Resistance in Indonesia

Introduction

In October of 1982, a total of 2,169 soybean accessions were screened at AVRDC for be, beanfly resistance. From this preliminary non-replicated screening, 217 accessions were rated on the basis of their lower levels of beanfly infestation as moderately to highly resistant to beanflies, primarily Melanagromyza sojae. Since the beanfly population pressure is much higher in Indonesia than at AVRDC, in 1983 all 217 accessions were rescreened at the P.T. Patra Tani Soybean Estate, in South Sumatra near Palembang.

Materials and Methods

A 0.2 ha field was rototilled and worked into 0.75 m wide beds. Seeds of each accession were planted in a single 2 m row on the center of the bed. Standard AVRDC cultural practices were followed, but no insecticide was used. Four weeks after germination, the proportion of dead plants in each plot was analyzed by a method based on mean ($\bar{x}$) and standard deviation (SD). The accessions with a mortality rate of less than $\bar{x}$ - 2SD were rated as highly resistant (HR), those between $\bar{x}$ - 2SD and $\bar{x}$ - 1SD as moderately resistant (MR), those between $\bar{x}$ - 1SD and $\bar{x}$ as possessing low resistance (LR), those between $\bar{x}$ and $\bar{x}$ + 2SD as susceptible (S), and those more than $\bar{x}$ + 2SD as highly susceptible (HS).

Results and Conclusions

All accessions were damaged by beanflies. Plant mortality rates varied from 26.7 to 100% (Table 1).

Fourteen accessions were rated as HR, 5 as MR, 17 as LR, and 181 as S. It must be pointed out, however, that while Melanagromyza sojae, a pith feeder, is the major beanfly pest of soybean in Taiwan, in Indonesia Ophiomyia phaseoli, a cortex feeder, is the most destructive. The 14 HR and 5 MR accessions will be rescreened at Palambang in an experiment with larger plots and more replications.

Table 1. Beanfly[z] resistance of selected AVRDC soybean accessions at Palembang, Indonesia.[z]

Resistance rating	% plants killed	Number accessions
Highly resistant (HR)	< 70	14
Moderately resistant (MR)	between 71 to 82	5
Low resistance (LR)	between 83 to 95	17
Susceptible (S)	> 96	181

[z] Mainly Ophiomyia phseoli
Planting date: March 3, 1983.
Observation date: April 4-5, 1983.

Screening Segregating Populations for Beanfly Resistance

Introduction

In 1979, four Glycine soja accessions (G3089, G3091, G3104, and G3122) were identified as highly resistant to beanflies (Melangromyza sojae and Ophiomyia Centrosematic). AVRDC's soybean breeder crossed one of these accessions, G3122, with cultivated accession G215. By using a decapitation technique in the greenhouse, and later field testing through 1982, several lines were selected which had been less damaged in each screening. In 1983, one set of materials was tested at AVRDC and another at the P.T. Patra Tani farm, which is located near Palembang, Indonesia. In the meantime, AVRDC's soybean breeder made further crosses in 1982 and backcrosses in early 1983. In October of 1983, the first backcrossed seeds (BC_1F_2) were screened for beanfly resistance. Described here are the results of those screenings.

Materials and Methods

Seeds of each entry were planted in a single row on a 5 x 0.75 m raised bed. Standard cultural practices were followed, but no insecticide was applied. Six weeks after planting, ten plants (or 50% of the plants when there were less than 20 plants per plot) were sampled. The stems were dissected, and the number of larvae and pupae within was recorded. The number of beanfly damaged plants in each sample was also recorded. Resistance levels of each entry were determined by a statistical formula based on the mean and standard deviation of the number of larvae and pupae found in all entries evaluated in the test.

Results

First test:

This test included 210 F_6 entries and one each of the susceptible and resistant parents. The crop was planted in early May and observed

for beanfly-induced mortality four weeks after germination. The rate of plant mortality in crosses ranged from 84 to 100%, and was 68% in the resistant parent. Beanflies killed 100% of the susceptible parents. Many of the surviving plants died at a later growth stage, and no seeds could be harvested.

Second test:

This test, planted at AVRDC, included 44 F_7 populations selected on the basis of their superior beanfly resistance ratings in previous tests, along with one susceptible and one resistant parent. By six weeks after planting, 70 to 100% of the plants had been damaged by beanflies. One hundred percent of the susceptible parents and 60% of the resistant parents were damaged.

Third test:

This test included four backcross populations and eight straight crosses and parentals. All were planted in late October and evaluated in early November. All entries were infested by beanflies, and the rate of damage ranged from 91 to 100%. One hundred percent of the susceptible parents and 60% of the resistant parents were damaged by beanflies.

M. sojae, the major beanfly species infesting soybean in Taiwan, is a pith feeder. The resistant accessions, all G. soja, have a very thin pith. After they have been crossed with cultivated soybean, however, their progeny have a thicker pith, and with it lower levels of resistance.

In Indonesia, O. phaseoli, a cortex feeder, is the most important soybean pest. This insect is not an important soybean pest in Taiwan, however, and materials selected in Taiwan are resistant only to M. sojae.

Conclusions

Soybean germplasm should be screened for resistance to O. phaseoli in Indonesia. Screening at AVRDC should emphasize tolerance of M. sojae.

Screening for Beanfly Tolerance

Introduction

Since beanfly-resistant soybean accessions have poor agronomic characteristics (i.e. thin stems) which seem to be linked to their resistance, screening was begun in 1981 to identify accessions which instead are tolerant of beanfly damage. (A tolerant cultivar is defined as one whose yield is not reduced by heavy beanfly infestation.) Preliminary screenings in 1980 and 1981 resulted in the identification of some promising accessions. Since subsequent multi-replicate tests

showed them to be less tolerant than they had initially appeared to be, however, an additional 256 entries were screened in 1983.

Materials and Methods

A 1.2 ha field was rototilled and worked into 1 m wide beds. Two parallel rows of each accession were planted on the beds in two adjacent 5 m plots, with 25 cm between beds. Standard AVRDC cultural practices were followed, but only one plot of each entry was sprayed with insecticide. Two insecticides, monocrotophos and omethoate, were sprayed alternatively at 3, 6, 10, 17, 24, and 31 days after germination, at a rate of 0.5 kg a.i./ha.

Four weeks after germination, each plot was sampled by uprooting ten plants and counting the number of beanfly larvae and pupae found within. Also recorded was the percentage of plants with visible beanfly damage.

Starting six weeks after planting, all plots were sprayed periodically with insecticide to protect against other insects. At harvest each plot's seed yield was recorded.

Results and Conclusions

In the control plots, 85 to 100% of the plants were damaged by beanfly, primarily M. sojae. Yield reduction varied from 0 to 50%. Entries whose yields were reduced by 5% or less are shown in Table 2. Many of them are new breeding lines developed at AVRDC for high yield potential, and others are used as parents in the Center's breeding program. The average yield loss of 256 entries was 20.7%. The average yield loss was 11.6% for breeding lines and 22% for accessions, which suggests that lines developed for high yields are relatively tolerant of beanfly infestation. Past studies have shown that beanfly infestation weakens soybean plants, and a vigorously growing cultivar is thus likely to be more tolerant.

Table 2. Beanfly tolerance of selected soybean entries.

Entry No.	% Damaged plants		Yield kg/plot		% yield reduction
	+Insecticide	Check	+Insecticide	Check	
G342	0	100	1.14	1.10	4
G531	0	90	1.26	1.20	5
G553	0	85	1.10	1.05	5
G1992	0	85	1.16	1.16	0
G3517	0	90	1.10	1.10	0
G5422	0	100	1.01	1.01	0
G8586	0	90	1.21	1.26	0
PI459024	0	100	1.04	1.06	0
A-32	0	100	1.30	1.25	4
C-21	0	80	1.31	1.24	5
Z13	0	90	1.16	1.15	1
G2120	0	90	1.00	1.10	0
AGS42	0	100	1.32	1.30	2
AGS229	0	95	1.17	1.13	3
G6	0	95	1.05	1.10	0

Average yield reduction for 256 entries: 20.7%.

It must be pointed out that this was a single-replicate, one-season experiment. Since the sole criterion used to measure tolerance was seed yield, which is affected by many factors other than insect infestation, multi-replicate screenings with larger plots will be made in 1984 to confirm the levels of tolerance observed in this trial.

Effect of Beanfly Infestation Upon Soybean Growth and Yield

Introduction

Previous studies had shown that beanfly (primarily M. sojae) infestation can reduce by 20 to 30% the yields of soybean planted in the fall. This study was designed to more closely examine the plant growth and yield components which lead to reduced seed yields.

Materials and Methods

A 546 m^2 field was rototilled and worked into 1 m wide raised beds. The entire area was then subdivided into ten 3 x 5 m plots, with 2 m separating each plot. Two rows of cultivar KS9 were sown 40 cm apart on each bed, with 10 cm between hills and 4 to 5 seeds per hill. Except for insecticide applications, all standard AVRDC cultural practices were followed.

Five plots were kept beanfly-free by being sprayed with 0.5 kg a.i./ha of omethoate at 3, 7, 10, 14, 21, 28, and 35 days after emergence (DAE).

To prevent infestation by other insects, both treated and untreated plots were sprayed at 42 DAE with fenvalerate 20EC at a rate of 100 g a.i./ha.

The following observations were made of the growth and development of soybeans in each plot.

30 DAE (vegetative stage):

A 20-plant sample was taken at random from each plot, and the number of beanfly larvae and pupae found within each plant was recorded, as was the number of plants with visible beanfly damage.

R1, R2, R4, and R5 stages (vegetative and reproductive stages):

At each of these four stages, ten randomly selected plants from each plot were carefully uprooted to study the following characteristics:

1. Plant height as measured from the root-stem junction to the top of the shoot.

2. Number of folded and unfolded leaves.

3. Leaf area per plant and leaf area per leaflet, as measured with a Li-Cor area meter.

4. Fresh and dry weight of leaflets. (Leaflets were dried at 110° C until their weight remained constant, and moisture content was determined by comparing fresh and dry weights.)

5. Number of branches per plant.

6. Fresh and dry weights of shoots with branches and leaves.

7. Number of Rhizobium nodules on roots, fresh and dry weights of nodules, and color of fresh nodules. (Five to ten large nodules from each entry were cross-sectioned to check for pinkness.)

8. Fresh and dry weight of the remaining portion of the roots.

9. Number of flowers per plant at the R1 and R2 stages. Number of pods per plant at the R4 and R5 stages.

10. Fresh and dry weights of pods.

Yield and yield components:

One hundred plants were randomly selected from each plot, and the number of pods per plant and seeds per pod were counted. Total seed yield per plot and 100-seed weight were also recorded.

Plants were uprooted from three 50 x 100 cm areas randomly selected from each plot, and the fallen leaves in each area were also collected. After the dry weight of each plant (including leaves, stems, pods, seeds, and roots) was measured, the harvest index was determined with the following formula:

$$\text{Harvest Index (HI)} = \frac{\text{seed weight}}{\text{plant dry weight}} \times 100$$

Results

The effects of omethoate application are shown in Table 3. Beanfly population and damage on the untreated plants were lower than for the untreated check plants. This made it possible to observe the effects of beanfly infestation upon the growth characteristics of both healthy and infested plants.

At the R1 and R2 stages there were no significant differences in the number of folded and unfolded leaflets, moisture content, leaf area per plant, number of branches per plant, or color and fresh weight of the nodules (Table 4). Significant differences were noted, however, in plant height, fresh shoot weight, leaflet area, fresh leaflet weight, fresh root weight, number of Rhizobium nodules per plant, and number of flowers. At the R4 and R5 stages, however, all growth parameters of the

beanfly infested plants were significantly affected, with the exception of the number of folded and unfolded leaflets, the number of branches per plant, and the color of nodules.

Beanfly-protected plants accumulated significantly greater amounts of dry matter in shoots, leaflets, roots, nodules, and pods than did unprotected plants (Table 4). Treated plants were also more vigorous than the untreated plants, showing that damage caused by insects feeding on the vascular tissues affected the plant's vigor and dry matter accumulation.

Table 3. Effects of omethoate[z-v] application on beanfly infestation in soybean.

Treatments	No. beanfly maggots + pupae per 20 plant sample	Damaged plants (%)
Insecticide treated	6.20b	27.00b
Untreated	61.80a	100.00a

[z] Cultivar: KS9.
[y] Date Planted: 9/23/83.
[x] Insecticide sprayed: 9/30, 10/4, 10/7, 10/11, 10/18, 10/24, 11/1.
[w] Date sampled: 10/27.
[v] Data shown are means of five replicates. Means followed by the same letter are not significantly different at the 5% level.

Table 4. Effects of beanfly infestation on soybean plant characteristics and dry matter accumulation at selected reproductive growth stages.[z-v]

Plant characteristics	R1 - R2		R4 - R5	
	insecticide	no insecticide	insecticide	no insecticide
Plant height (cm)	43.89a	34.85b	52.07a	45.54b
Shoots (Fresh wt. in g)	19.91a	12.68b	22.33a	15.35b
Shoots (dry wt. in g)	2.69a	2.06b	5.20a	4.15b
Leaf area/plant (cm)	712.30a	623.31a	1224.42a	1033.38b
Leaflet area (cm)	29.73a	25.54b	42.97a	37.22b
Leaflets (fresh wt. in g)	8.29a	7.80b	15.75a	13.62b
Leaflets (dry wt. in g)	1.84a	1.51b	4.41a	3.91b
% moisture of leaflets	77.73a	76.85a	71.93a	68.34b
No. branches/plant	1.00a	0.66a	1.82a	1.14a
Roots (fresh wt. in g)	1.63a	1.06b	1.95a	1.36b
Roots (dry wt. in g)	0.49a	0.33b	0.79a	0.60b
Rhizobium nodules/plant	7.48a	3.24b	12.24a	5.42b
Nodules (fresh wt. in mg)	45.00a	2.00a	360.00a	52.00b
Nodules (dry wt. in mg)	0.09a	0.006a	130.00a	30.00b
Nodules color	pinkish	pinkish	pinkish	pinkish
no. flowers/plant	21.82a	13.84b		

[z] Cultivar: KS9.
[y] Date Planted: 9/23/83.
[x] Insecticide sprayed:9/30, 10/4, 10/7, 10/11, 10/18, 10/24, 11/1.
[w] Date sampled: 10/27.
[v] Data shown are means of five replicates. Means on each line and each pair of columns, if followed by the same letter, have not been shown by Duncan's Multiple Range Test to be significantly different at the 5% level.

The effects of beanfly infestation on soybean yield and yield components are summarized in Table 5. Seed yields of beanfly infested plants were significantly lower than those of treated plants. This yield reduction was primarily due to fewer seeds per pod; no significant differences were observed in 100 seed weight. This could be due to poorer dry matter accumulation caused by lower levels of photosynthesis resulting from reduced leaf area, or else by the impeded translocation of nutrients from the roots to the shoot.

Table 5. Effects of beanfly infestation on soybean yield and yield components.[z-u]

Plant characteristics	Insecticide protected	Control
No. pods/plant	28.39a	24.75b
No. seeds/pod	2.11a	1.91b
1000 seed weight (g)	184.92a	182.72a
Yield (t/ha)	2.986a	2.362b
Harvest index	35.9a	34.9a

[z] Cultivar: KS9.
[y] Date Planted: 9/23.
[x] Insecticide sprayed: 9/30, 10/4, 10/7,10/11, 10/18, 10/24, and 11/1.
[w] Date sampled: 10/27.
[v] Data shown are means of five replicates. Means on each line and each pair of columns, if followed by the same letter, have not been shown by Duncan's Multiple Range Test to be significantly different at the 5% level.

Conclusions

The effects of beanfly infestation were most clearly seen at the later stages of plant development. Plants at the vegetative stage are still small and developing rapidly enough to compensate for beanfly damage. Beanfly infestation reduces soybean yields by decreasing the plant's growth and vigor. Dry matter accumulation is reduced in all plant parts, possibly because beanfly larvae feeding on the pith and associated conducting tissues reduce the transport of nutrients.

Effect of Trichome Density Upon Beanfly Infestation of Soybean

Introduction

Certain published reports indicate that trichomes on soybean leaves are a factor in the resistance of *Glycine soja* to beanfly (primarily *M. sojae*) infestation. Since unifoliate and trifoliate leaves of accession

PI 227687 have a higher than normal trichome density, it and TK5, a popular local cultivar, were used to study the correlation between trichome density and beanfly infestation.

Materials and Methods

Seeds of PI 227687 and TK5 were planted in clay pots. After germination, the plants were thinned to two per pot.

In the first experiment, the potted plants to be infested by beanflies were moved to an open field soon after germination. All plants were dissected four weeks after germination. The number of beanfly larvae and pupae found within the stems was recorded, as was the percentage of plants with visible beanfly damage. Unifoliate and trifoliate leaves were also sampled, and the trichome density was recorded for the upper and lower surfaces of each leaf.

In the second experiment, the potted plants were allowed to grown in a greenhouse until the unfolding of the first trifoliate leaves, at which time the unifoliate leaves of half of the plants of each accession were removed. All of the plants were then moved to an open field. After being exposed to beanfly infestation for one month, they were evaluated for infestation in the manner described earlier. In the third experiment, the trichome density of four beanfly resistant *Glycine soja* accessions (G 3089, G 3091, G 3104, and G 3122) was recorded in an experiment similar to that performed with the two *Glycine max* accessions.

Results

The results of the observation of trichome density and beanfly infestation of PI 227697 and TK5 are summarized in Table 6.

Accession PI 227687 had a significantly greater trichome density, and had significantly fewer beanfly larvae and pupae within its stems than did TK5. There was no difference, however, in the percentage of plants damaged by beanflies.

Table 6. Leaf trichome density and beanfly infestation in two soybean accessions.[z]

Accessions	No. trichomes/cm^2		No. beanfly larvae+pupae /10 plants		Damaged plants %		Yield[y] reduction %
	Up	Lo	+UL	-UL	+UL	-UL	
TK5	34.1a	63.8a	21.5a	51.8a	100a	100	0
PI227687	86.4b	115.3b	6.8b	19.5b	95b	100	37

[z] On unifoliate leaves. Up: Upper surface; Lo: Lower surface; +UL: Unifoliate leaves intact; -UL: Unifoliate leaves removed.

[y] A separate, single replicate field experiment.

Since trichome density is greater on trifoliate than on unifoliate leaves (Table 7), unifoliate leaves were detached in order to force the insect to infest the plants via the trifoliate leaves. The number of insects within the plant, however, was actually greater when unifoliate leaves were removed, and for both accessions the percentage of damaged plants was identical.

In a separate study, beanfly damage was found to cause a much greater yield loss in PI 227687 than in TK5, which suffered almost no yield loss whatsoever.

The trichome density of beanfly resistant G. soja accessions was significantly greater than that of susceptible G. max accession TK5 (Table 7).

Since all four G. soja accessions had already shown resistance to beanflies, they were not exposed to beanflies in this test.

Table 7. Trichome density on unifoliate and trifoliate leaves of selected G. max and G. soja accessions.

Accessions	No. trichomes/25mm^2			
	Unifoliate leaves		Trifoliate leaves	
	Upper surface	Lower surface	Upper surface	Lower surface
TK5[z]	19.23c	37.67c	19.23d	46.63d
PI227687[z]	65.50b	100.00b	150.67a	194.30a
G3089[y]	82.63b	92.97b	117.00b	109.83c
G8091[y]	66.80b	96.83b	78.90c	97.47c
G3104[y]	82.10b	123.10b	132.43ab	143.70b
G3122[y]	116.37a	126.30a	124.47b	121.13bc

[z] Glycine max.
[y] Glycine soja. Data are mean of six replicates. Means in each column, if followed by the same letter, are not significantly different at the 5% level.

Conclusions

Statistical analyses of both G. max accessions showed a significant negative correlation between trichome density and the number of beanfly larvae and pupae in plants (r=-0.7838* for unifoliate and -0.9414** for trifoliate leaves). Even though they were found to be less heavily infested by beanflies, accessions with a higher trichome density were less resistant, and their yields were still reduced by beanfly infestation. Such correlations would thus seem to be of little practical value.

An Investigation of Beanfly Sex Pheremone Activity

Introduction

Beanflies (Melanagromyza sojae (Zehnt.), Ophiomyia phaseoli (Tryon) and O. centrosematis de Meijere (Diptera: Agromyzidae) are the most important pests of legumes in the tropical and subtropical areas of Asia, Africa, Australia, and Oceania. Of the three, M. sojae and O. phaseoli are the most important. Crop losses of up to 100% have reportedly been caused by these pests in some parts of Africa, Aus-

tralia, and Asia.

Pesticides are presently the only effective means of controlling these insects, but their high costs, the chance of insects becoming resistant to them, and the potential they have for damaging the environment all necessitate the development of cheap, safe, and effective alternative control methods. One, the use of pheremones, is being successfully used in monitoring the population levels of some insect pests closely enough so that necessary control measures can be taken in time to avoid economic damage. In this, the first study of its kind, a series of experiments was conducted to study the sex pheremone activities of beanflies.

Materials and Methods

Pupae of M. sojae and O. phaseoli were collected from soybean and snapbean plants, respectively. Their sex was determined by observing their morphological characteristics under a microscope, and two pupae of the same sex of each species were placed in a cylindrical nylon net cage (4 cm long and 2 cm in diameter). After adult emergence, each cage was placed at the center of a trap coated with "Tangle Foot" sticker.

Five traps were prepared for both sexes of each species. Five traps with only an empty cage in the middle were also prepared as controls.

Traps for both species were hung just under the top of the plant stand in a 500 m^2 field planted to soybean and snapbean. Traps were observed daily, and the number of beanflies within was recorded weekly for one month.

All data was analyzed statistically by Duncan's Multiple range test.

Results and Conclusions

There was no difference in the number of beanflies collected in traps baited with female, male, or no beanflies (Table 8). Although the "bait" insects remained alive for several days, no adult flies were trapped in the pheromone traps. It appears, then, that the classical sex pheromone activity present in lepidoptera does not exist in M. sojae or O. phaseoli.

Table 8. Beanflies collected per week in traps with unmated adults of M. sojae and O. phaseoli.[z]

Species		No. adult beanflies collected (per week)			
		1st	2nd	3rd	4th
M. sojae	Female	1.00a	0.00a	0.00a	0.00a
	Male	1.00a	0.20a	0.00a	0.00a
	None	1.40a	0.20a	0.00a	0.00a
O. phaseoli	Female	0.40a	0.00a	0.00a	0.00a
	Male	0.00a	0.20a	0.20a	0.00a
	None	1.00a	0.60a	0.40a	0.00a

[z] Mean of five traps per treatment per week. Means for each species in each column, if followed by the same letter, are not significantly different at the 5% level.

Efficacy of Selected Insecticides in Controlling Beanfly, and the Resultant Yield Responses of Soybean, Mungbean, Snapbean, and Cowpea

Introduction

Soybean, Glycine max (Linn.) Merrill; mungbean, Vigna radiata (Linn.) Wilzeck; cowpea, Vigna unguiculata ssp. unguiculata cv. gr. unguiculata, and snapbean and phaseolus vulgaris Linn, are all important grain legumes in Southeast Asia, and all are affected by Ophiomyia phaseoli, O. centrosematis, and Melanaromyza sojae.

The larvae of these insects feed concealed in plant stems, and the resulting decreases in plant vigor can mean a considerable yield loss.

The study was conducted to determine whether the three selected insecticides, which are effective in controlling beanflies on soybean and mungbean, can also control them on snapbean and cowpea.

Materials and Methods

A 0.05 ha field was rototilled and worked into 1 meter wide raised beds, and was then divided into sixteen 10 x 2 m plots. Each of the four treatments was arranged in an RCB design with four replicates. Soybean (KS-9), mungbean (VC 1628A), snapbean (local cv.) and cowpea (local cv.) were sown on the raised beds in two rows 40 cm apart, with 10 cm between hills and 4 to 5 seeds per hill. With the exception of insecticide application, standard AVRDC cultural practices were followed. Monocrotophos 55EC, dimethoate 44EC, or omethoate 50EC were sprayed in designated plots at a rate of 0.5 kg a.i./ha at 3, 7, 14, 21, 28, and 35 DAE.

At 35 DAE, insecticidal efficacy was evaluated by uprooting 20 plants at random from each plot. Each plant was dissected, and the number of beanfly larvae and pupae found within were recorded, as was the percentage of plants with visible beanfly damage.

After 42 DAE, all plots, including the control, were protected against other pests by occasional applications of fenvalerate. At harvest the seed yield from each plot was recorded and converted to t/ha. All data gathered were analyzed statistically by Duncan's Multiple Range Test.

Results and Conclusions

Monocrotophos and omethoate significantly reduced levels of beanfly infestation, and gave the best protection against beanfly damage (Table 9). Dimethoate reduced the number of beanfly larvae and pupae per plant in mungbean, snapbean, and cowpea, but the number of beanfly damaged mungbean and cowpea plants remained high. Even though it has given good protection in the past against beanfly infection, dimethoate was the least effective chemical in this test. These results showed that while the beanfly population was suppressed, the damage done by

Table 9. Evaluation of selected insecticides upon yield[z-s] and beanfly populations in soybean, mungbean, snapbean, and cowpea.

Insecticides	Rate Kg ai/ha	No. of beanfly maggots+pupae per 20 plant samples				Damaged plants (%)				Yield[h] ton/ha		
		Soybean	Mungbean	Snapbean	Cowpea	Soybean	Mungbean	Snapbean	Cowpea	Soybean	Snapbean	Cowpea
Monocrotophos 55EC	0.5	8.75c	0.00b	0.00b	0.00b	38.75b	10.00c	20.00b	15.00c	1.33a	1.51ab	2.82a
Dimethoate 44EC	0.5	34.25b	3.25ab	1.25b	2.25b	92.50a	40.00b	30.00b	61.25b	1.18ab	1.44ab	2.54a
Omethoate 50EC	0.5	1.25c	0.00b	0.00b	0.00b	17.50c	10.00c	13.75b	16.25c	1.54a	1.82a	2.70a
Control	-	54.50a	8.75a	38.00a	31.50a	100.00a	75.00a	95.00a	95.00a	0.83b	1.19b	1.91b

[z] Cultivar: Soybean (KS9), Mungbean (1628 Sel.A), Snapbean and cowpea (local).
[y] Date planted: 9/27/83.
[x] Insecticides sprayed:10/3, 10/7, 10/14, 10/21, 10/28, 11/4.
[w] Date of sampling: 11/3.
[v] Date harvested: 12/28.
[u] Data shown are means of four replicates. Means in each column, if followed by the same letter, are not significantly different at the 5% level.[t] Plot size: 10 x 2m.
[s] Mungbean was severely damaged root disease complex and low temperatures.

beanflies was greater than in other treatments. The yields of soybean, snapbean, and cowpea treated with omethoate, monocrotophos, or dimethoate did not differ significantly, and all were significantly greater than those of the controls (Table 9).

Soybean yields were greater than the control plot's by 0.71, 0.50, and 0.35 tons/ha in omethoate, monocrotophos, and dimethoate treated plots, respectively. In snapbean, yield increase in omethoate, monocrotophos, and dimethoate treated plots were 0.63, 0.32, and 0.25 t/ha, respectively. The yield increase in cowpea treated with omethoate, monocrotophos, and dimethoate were 0.91, 0.79, and 0.63 t/ha, respectively.

The yield loss due to beanfly damage in soybean, snapbean, and cowpea can be considered as 46%, 35%, and 32%, respectively. These figures, however, will vary among cultivars.

Efficacy of Selected Insecticides in Controlling Beanfly Infestation of Soybean

Introduction

Insecticides are presently the most effective and practical method of controlling beanflies, but it is important to develop and test new insecticides before pests become resistant to those alredy in use. AVRDC maintains an on-going insecticide screening program designed to determine which insecticides are most effective and economical. Described here are the results of one such test conducted in 1983.

Materials and Methods

After being rototilled and worked into 1 m wide raised beds, a 0.05 ha field was divided into forty 3 x 3.3 m plots separated by 1 m strips. Seeds of cultivar KS9 were sown on each bed in rows 40 cm apart, with 10 cm between hills and 4 or 5 seeds per hill. Except for insecticide applications, standard AVRDC cultural practices were followed.

Including the control, there were ten treatments. An RCB design was used with four replications. Pre-determined quantities of insecticide were diluted in water and sprayed on each plot with a 10 liter air pressure sprayer charged to 2.7 kg/cm^2 (40 psi). One-half liter of spray (50% of the designated quantity of the active ingredient per unit area) was applied to each plot during each of the first four applications, and one liter was applied to each plot (1000 l/ha) in the succeeding three applications. So that one extra liter would remain in the sprayer following the spraying of the fourth replicate, 3 liter insecticide solutions were prepared for the first four applications, and five liter solutions were prepared for the three other applications. Each sprayer was individually calibrated with a stopwatch so that specific volumes of spray solution could be accurately and uniformly delivered to each plot.

Plots were sprayed 3, 7, 10, 14, 21, 28, and 35 DAE, and insecticide effectiveness was evaluated at 21 and 35 DAE. Thirty plants

randomly selected from each plot were uprooted, examined, and dissected to count the number of larvae and pupae found within the stems. The number of plants damaged by beanflies was also recorded.

Since plants were also damaged by a leaf folder, Hedylepta indicata (Fabr.) (Lepidoptera: Pyralidae), the number of leaflets/plot damaged by this insect was also recorded.

After 35 DAE, the entire experiment was protected from other pests by an occasional spray of fenvalerate. Seed yields from each plot were recorded at harvest, and all data was statistically analyzed by Duncan's Multiple Range Test.

Results

The efficacy of the insecticides tested is summarized in Table 10. Omethoate at a rate of 0.50 or 0.25 kg a.i./ha and MK936 at 0.018 or 0.009 kg a.i./ha significantly reduced the beanfly population and gave the best protection against beanfly damage. Omethoate and MK936 were significantly less effective when sprayed at lower dosages (0.125 or 0.0045 kg ai/ha, respectively), but even then they provided significantly better control of beanflies than did fenthion 50EC, carbofuran 40.6EC, or cypermethrin 5.0EC.

Although studies conducted elsewhere have shown carbofuran granules applied at sowing to give good control of beanflies, such was not the case at AVRDC. In this study, spray applications also failed to give good protection against beanflies. Plots treated with fenthion, carbofuran, or cypermethrin were less damaged by the leaf folder than were plots treated with omethoate and MK936 (at the rate of 0.0125 and 0.0045 kg a.i./ha, respectively).

Yield data for plants sprayed with MK936 (at 0.018 or 0.009 kg a.i./ha), carbofuran, fenthion, cypermethrin, and omethoate (at 0.50 or 0.25 kg a.i./ha) did not vary significantly, but all yielded significantly better than did those in the control treatment. Reduced dosages of omethoate and MK936 (0.125 and 0.0045 kg a.i./ha, respectively) produced lower yields.

Table 10. Evaluation of insecticides for the control of beanflies and leaf folder on soybean.[z-t]

Insecticides	Rate kg ai/ha	No. of beanfly maggots+pupae per 30 plant samples		Damaged plants (%)		No. leaffolder damaged leaflets	Yield (t/ha)
		10/20	11/3	10/20	11/3		
MK936 0.36SL	0.0045	17.25d	26.00c	56.50c	76.66b	63.50bc	1.765b
MK936 0.36SL	0.009	6.00ef	7.25e	20.50d	29.17e	51.00cd	1.985ab
MK936 0.36SL	0.018	2.25f	1.25e	12.50d	9.99f	20.25ef	2.108ab
carbofuran 40.6EC	0.50	38.50b	47.75b	95.75a	98.33a	22.00ef	2.265a
fenthion 50.0EC	0.50	47.25a	48.75b	97.75a	96.66a	14.75f	1.993ab
cypermethrin 5.0EC	0.05	47.25a	48.75b	97.75a	96.66a	14.75f	1.993ab
omethoate 50.0EC	0.125	12.75de	17.25cd	46.00c	55.83c	75.00ab	1.795bc
omethoate 50.0EC	0.25	5.25ef	10.00de	19.00d	41.66d	70.00abc	2.038ab
omethoate 50.0EC	0.50	1.00f	1.25e	6.00d	7.50f	69.50abc	2.110ab
Control	-	49.25a	68.25a	100.00a	100.00a	87.75a	1.538c

[z] Cultivar: KS9.
[y] Date planted: 9/27/83.
[x] Insecticides sprayed:10/3, 10/7, 10/11, 10/14, 10/21, 10/28, and 11/4.
[w] Sampling: Thirty-plant samples on 10/20 and 11/3.
[v] Date harvested: 12/23.
[u] Data shown are means of 4 replicates. Means ineach column, if followed by the same letter, are not
[t] significantly different at the 5% level.
Plot size: 10 square meters.

Screening for Resistance to a Leaf Folder, *Hedylepta indicata*

Introduction

A lepidopterous leaf folder, Hedylepta indicata, infests soybean every fall at AVRDC. Infestations during the past ten years had never been serious, though, and no research had been done on its control.

In the fall of 1983, however, the insect became a serious problem, and in some instances 100% of the unprotected plants were defoliated. The high population pressure provided an excellent opportunity to screen for leaf folder resistance soybean germplasm that had been planted for other purposes.

Materials and Methods

After basal fertilizers had been applied, a 0.8 ha field was rototilled and worked into 0.75 m wide beds. Seeds of each accession were planted on the beds in a single 5 m row. Standard cultural practices were followed, but no insecticide was applied. Accessions were evaluated for resistance when the leaf folder population was near its peak and several entries had been completely defoliated. The percentage of damaged leaves was then subjected to a statistical analysis based on mean (x) and standard deviation (SD). Those accessions which had a percentage of damaged leaves under x -2SD were rated as highly resistant (HR), those between x - 2SD and x - 1SD as moderately resistant (MR), those between x - 1SD and x as possessing low resistance (LR), those between x and x + 2SD as susceptible (S), and those more than x + 2SD as highly susceptible (HS).

Results and Conclusions

All 995 accessions tested were damaged by leaf folder, but 24 showed moderate levels of resistance (Table 11). These accessions will be rescreened next year in a multi-replicate confirmatory trial.

Table 11. Performance of soybean accessions for resistance to leaf folder.

Resistance rating	Damaged leaves (%)	Number of accessions
Moderately resistant (MR)	0 to 8.60	24
Low resistance (LR)	8.70 to 29.55	507
Susceptible (S)	29.56 to 71.46	390
Highly susceptible (HS)	71.47 to 100	74

Antibiosis of Selected Accessions to Defoliator Insects

Introduction

Spodopdtera exigua, Porthesia taiwana, and Orgyia sp. are common and, at times, serious defoliator pests of legumes in Taiwan. At AVRDC, all three species infest soybean during the spring. In 1982, three soybean accessions (PI 171451, PI 227687 and PI 229358) were found to have varying levels of antibiosis to S. exigua. Since damage caused by P. taiwana and Orgyia sp. is almost identical to that caused by S. exigua, these three accessions were tested for antibiosis against P. taiwana and Orgyia sp.

Materials and Methods

All experiments were done in the laboratory using leaves from field-grown soybean. Entries PI 171451, PI 227687, PI 229358, and TK5 were planted in two rows on four 5 m beds arranged in an RCB design. Except for the use of insecticides, standard cultural practices were followed.

Larvae of P. taiwana and Orgyia sp. were collected in the field and reared in the laboratory on leaves of soybean cultivar TK5.

Leaves of the four accessions were collected from the field, and two were placed in each petri dish. From 16 to 18 petri dishes were used for each soybean accession. Two freshly hatched larvae of each insect species were placed on the leaves, and all insects were maintained at 25°C. The leaves were replaced with freshly collected ones every 2 to 3 days. Insects were observed daily for molting, mortality, and pupation. Soon after pupation, each cocoon was weighed and placed in a cage with potted soybean plants (cv. TK5). The duration of the pupal period and the percentage of adult emergence were recorded.

Observations on oviposition were also recorded. The pupae were placed in cages containing potted plants of cultivar TK5 and a cotton swab dipped in sugar solution was placed in a petri dish. Orgyia females, which are wingless, laid eggs on the cocoon itself, but Porthesia females laid eggs on the soybean leaves. A record was kept of the number of eggs per female and the percentage of eggs that hatched.

Results

Insects fed on the three PI accessions had a longer larval period, more instars, and a higher mortality rate than did those fed on TK5 (Table 12). Porthesia fed on PI 171451 and PI 227687 had a longer pupal period than did those which were maintained on the other two entries. Few adults emerged from pupae fed on the three PI accessions, and those which did emerge laid fewer eggs when fed on three PI accessions than when they were maintained on TK5.

The results of the biological observations of Orgyia are summarized in Table 13. In the case of Orgyia, the differences in biological

Table 12. Selected biological observations of P. taiwana reared on selected soybean accessions.[z]

Soybean	Larval period (days)	Larval instars (no.)	Larval mortality (%)	Pupal weight (mg)	Pupal period (days)	Adult emergenced (%)	Oviposition no. eggs/ insect
PI171451	33.4b	7.3b	32.5a	82.4a	10.3a	82.4ab	56
PI227687	29.3c	6.9b	30.0a	64.8b	9.9ab	69.4bc	37
PI229358	37.5a	8.1a	45.0a	62.5b	9.6bc	56.3c	22
TK5	24.6b	6.1c	7.5b	68.6b	9.2c	97.5a	62

[z] Data are means of 16-18 replicates. Means in each column, if followed by the same letter, are not significantly different at the 5% level by Duncan's multiple range test.

Table 13. Various biological observations on Orgyia sp. reared on selected soybean accessions[z].

Soybean Accessions	Larval period (days)	Pupal weight (mg/pupa)	Pupal period (days)	Pupal mortality (%)	No. eggs /female
PI171451	28.0a	128.5a	5.0d	94.4a	15
PI227687	27.5b	66.1c	7.1b	55.6b	56
PI229358	24.0d	56.9d	8.0a	97.2a	0
TK-5	25.9c	127.8b	6.5c	38.9b	74

[z] Data are means of 16-18 replicates. Means in each column, if followed by the same letter, are not significantly different at the 5% level by Duncan's multiple range test.

parameters of insects fed on various soybean accessions differed for larval and pupal stages. Insects fed on PI 171451 had a significantly longer larval period and shorter pupal period than did those fed on TK5. Larvae fed on PI 227687 and PI 229358 did not differ greatly from those fed on TK5, but their pupal periods were signifcantly longer, and their pupal weights significantly lower than those of the insects fed on TK5. Insects fed on all three PI accessions suffered greater pupal mortality and laid fewer eggs than did those fed on TK5. All three PI accessions were detrimental to population multiplication of Orgyia sp.

Conclusions

Accessions PI 171451, PI 227687, and PI 229358 have shown antibiosis to Porthesia taiwana and Orgyia sp. These results, coupled with similar results obtained in 1982 with Spodoptera exigua, make these accessions promising sources of defoliator resistance.

Antibiosis of Selected Accessions to *Anomala cupripes*

Introduction

Two scarabid beetles, Anomala cupripes and A. expansa, infest

soybean and other crops, primarily legumes, every spring. The adults feed on soybean leaves, and, if uncontrolled, can cause serious defoliation. Three soybean accessions (PI 171451, PI 227687, and PI 229358) which had shown varying levels of antibiosis to three other defoliators (Spodoptera exigua, Porthesia taiwana, and Orgyia sp) were next evaluated for antibiosis to A. cupripes, the most common beetle species infesting soybean.

Materials and Methods

Accessions PI 171451, PI 227687, P 229358, and TK5 were planted in two rows on four 1 x 5 m beds arranged in an RCB design. Standard AVRDC cultural practices were followed, but no insecticide was applied.

Several leaves of each accession were collected from the field, and their total leaf area was measured with a Licor area meter. They were then placed in twelve 9 cm diameter plastic containers (17 cm tall).

Freshly emerged A. cupripes adults were collected with light traps, and four beetles were placed in each container.

Four containers each of each accession were then maintained at 25, 30, and 35°C for one week. At the end of this period, the damaged leaves were removed so that their leaf area could be measured.

Results and Conclusions

At all three temperatures, the insect consumed less foliage of the three PI accessons than of TK5, but the differences in foliage consumption were most striking at higher temperatures (Table 14). The consumption of leaves from the PI accessions decreased dramatically at higher temperatures. Higher temperatures, especially 35°C, did reduce the insect's consumption of TK 5's foilage, but those reductions were slight. It is possible that higher temperatures increase the expression of antibiosis of PI accessions.

Table 14. Foliage consumptions by A. cupripes maintained on four soybean accessions at various temperatures.[z]

Soybean accession	Average leaf area (cm^2) consumption by 4 beetles/day at °C		
	25	30	35
PI171451	33.0ab	29.3b	6.9b
PI227687	35.6ab	31.8b	12.4b
PI229358	24.7b	25.7b	8.6b
TK-5	45.9a	49.7a	34.3a

[z] Data are means of 16-18 replicates. Means in each column, if followed by the same letter, are not significantly different at the 5% level by Duncan's multiple range test.

Soybean Physiology

Comparison of Selected Methods for Assaying Soybean Seed Vigor

Introduction

Soybean seeds deteriorate rapidly when stored under tropical conditions. Because poor seed quality can cause slow or non-uniform emergence, weak seedlings, and, in the end, reduced yields, a method should be developed for predicting the viability of seeds stored under tropical conditions. This study examined the correlations between various vigor tests and actual seed storability.

Materials and Methods

The 100-seed weight, protein and oil content, germinaton rate at 25° C, respiration rate of imbibed seeds, and the OD 280 of leaching of imbibed seeds were recorded for seeds of selections G2120, G8285, G8707, AGS66, AGS78, and H15. Aging was accelerated by storing seeds at 40°C and 100% RH for three days, or at 40° C and 75% RH for three weeks. Stress tests were conducted by soaking moistened seeds for two hours in 20% methanol at room temperature or for two hours in 2% NH_4Cl at 40° C. A cold test was conducted by storing moistened seeds at 10° C for seven days before germination at 25° C. In a natural storability test, seeds were stored for 85 days at 30° C and 80% RH. Each test was replicated three times, with 40 seeds per replicate.

Results

Some seeds of G2120 and G8707 remained viable after 85 days at 30° C and 80% RH (Table 1). Although AGS66 had the highest germination rate before storage, its germination rate after 85 days at 30° C and 80% RH was the lowest of all six entries. AGS78 had the longest half-life, but the lowest germination rate after storage. This was probably due to its low germination rate before storage.

G2120 had the highest respiration rate (0.34 mg CO_2/mg/hr) but some poor-storage lines also had high respiration rates (0.29 mg CO_2/mg/hr). G8707 showed little leaching, but a less storable entry, AGS 66, also had low levels of leaching. Seeds subjected to NH_4Cl stress, cold stress, or aging for three weeks at 40° C and 75% RH, or for three days

at 40° C and 100% RH, all germinated poorly. Varietal differences in germination rate after these stresses, however, were unable to predict the good storability of G8707 and G2120. Only the methanol stress test seemed a good predictor of storablility; the correlation coefficient between germination after methanol stress and germination after storage was 0.77**.

Table 1. Storage half-life, germination rates before and after storage and aging under methanol stress.

Entry	Germination before storage (%)	Germination after storage (%)	Storage half-life (days)	Methanol stress
G-8285	84ab[z]	3b	74.9b	2c
G-8707	88ab	24a	78.8b	9b
G-2120	83b	24a	74.1b	33a
AGS-66	92a	0b	53.5c	0c
AGS-78	73c	2b	91.6a	0c
H-15	72c	0b	51.9c	1c

[z] Mean separation within columns by DMRT, 5% level.

Conclusions

After 85 days of storage at 30° C and 80% RH, seeds of G8707 and G2120 germinated at a rate of 24%. Germination rate after methanol stress seems to be a good indicator of storability.

Investigation of In-Vitro Weathering of Soybean Seeds

Introduction

In the humid tropics, soybean is often grown during the hot season, when its seed maturation is subjected to high temperatures and high humidity. This experiment examined under laboratory conditions varietal differences in the weathering of seeds pods which were still in developing, but physiologically mature.

Materials and Methods

The ten accessions used in this experiment varied in color and size. Pods were examined at the R7 stage when they were still developing, but physiolocially mature. Pods from each replicate were divided into two groups, one for the control and one for weathering. Pods in the control group were air dried at 25°. Pods for the *in vitro* weathering treatment were also air-dried at 25°C, but only after four days at 30°C and 80% RH. After drying, all pods were threshed for seeds, and the seeds were then examined for disease incidence and germination and

emergence rates. Germination rate was measured in rolled paper, and emergence rate was measured in the soil-filled trays.

Results

In vitro weathering reduced the germination and emergence rates of some entries (Table 2). Large seeds tended to be most susceptible to weathering; the correlation coefficient of 100-seed weight and emergence was -0.52**. What is referred to as weathering can probably be attributed more to diseases than to physiological processes. Seeds with small or black seeds had higher germination and emergence rates.

Table 2. Effect of *in vitro* seed weathering on germination rate, emergence rate, and number of diseased seeds after weathering.

Entry	Seed Color	100-seed wt. (g)	Relative[z] germination (%)	Relative[z] emergence (%)	Diseased seeds (%)
G-2120	green	4.9	94a	95ab	5c
G-3473	black	6.1	100a	95ab	3c
G-3818	black	5.2	90a	76abcd	2c
G-4464	yellow	19.5	67b	75bcd	37b
G-4556	green	8.1	95a	80abc	9c
G-4711	yellow	19.9	44c	59d	70a
G-4802	yellow	19.3	60bc	76abcd	43b
G-8285	green	19.5	63bc	75bcd	43b
G-10366	yellow	7.2	96a	90ab	10c
G-10376	black	9.9	100a	96a	0c

[z] Weathering/control x 100%.
[y] Mean separation within columns by DMRT, 5% level.

Conclusions

Although high temperatures and high humidity during maturation can cause seed weathering, there are varietal differences in sensitivity to weathering that can be detected under laboratory conditions. This study confirmed previous results which suggested that small-seeded varieties withstand weathering relatively well. What is referred to as weathering may also be due in part to disease infection.

Morphological and Physiological Responses to Flooding Stress

Introduction

Soybean grown in the humid tropics is often damaged by heavy rainfall. This study was designed to examine some of the varietal

differences in the physiological and morphological responses of soybean to flooding imposed at various growth stages.

Materials and Methods

In the first experiment, G38 and AGS17 were grown in pots with a 15 kg sand and soil mixture, with two plants per pot. Seeds were sown on July 27, 1983. There were four replicates per treatment and four pots per replicate. Plants were subjected to two weeks of flooding at the V4, R2, or R5 stages. Immediately after flooding, the second unrolled leaf from the top of each plant was measured for relative water content, stomatal resistance, and chlorophyll and proline content. Four plants from each replicate were also measured for leaf area, plant height, dry weights (including roots and nodules), and respiration rate. The remaining pots were grown until harvest.

In a second experiment (August 3), ten AVRDC breeding lines were planted in the field, with two plants per hill, 10 cm between hills and 50 cm between rows. There were two rows in each 2 x 3.5 m plot. Plants were flooded from 20 to 40 days after emergence. A split plot design was used; flooding and non-flooding were the main plots and entries were the sub plots. There were four replications per treatment and two plots per replicate. Four hills from each treatment were sampled at 0, 7, 14, and 21 days after flooding. Sampled plants were measured for leaf area and for dry weights of shoots, roots, and nodules. One plot from each replicate was left intact so that its final yield and yield components could be measured.

Results

In the first experiment, flooding at the V4 stage doubled proline levels, but floodings at the R2 and R5 stages had no effect.

Floodings at the R2 and R5 stages did, however, increase stomatal resistance and lowered chlorophyll levels, but flooding at the V4 stage did not. Root respiration of plants flooded at the V5 stage was slightly inhibited. Moisture content was only slightly affected by flooding. Flooding at the V4 and R2 stages substantially reduced nodule dry weight (Table 3). The reduction in total dry weight brought about by flooding at the V4 stage may be attributed to reduced leaf area. Seed yield, however, was most reduced by floodings at the R2 and R5 stages. Both pod number and seed weight were reduced by flooding at the R2 and R5 stages.

In the second experiment, flooding at the vegetative stages substantially reduced yield (Table 4). Flooding tolerant breeding lines AGS 7 and 8 maintained higher levels of leaf area and shoot growth than did other entries. Flooding tolerant entries also tended to have better recovery rates (as expressed by dry weight increases after flooding).

The correlation coefficient of recovery rates and final seed yields was 0.72**. In addition, flooding tolerant entries tended to have more adventitious roots; flooded entries had a correlation between adventitious root number and final yield of 0.48**.

Table 3. Effect of flooding on relative yield, yield components, leaf area, and shoot and nodule dry weights[z].

Flooding stage	Entry	Seed Yield	Pod no. (%)	Seed wt. (%)	Leaf area (%)	Dry wt. (%)	Nodule dry wt.(%)
V-4	AGS 17	61*[y]	68*	79	34*	40*	2*
	G 38	48*	62*	85	45*	52	3*
R-2	AGS 17	39*	49*	75	57**	67*	23**
	G 38	33**	38**	95	79	83	28**
R-5	AGS 17	30**	38**	75	65	60	59
	G 38	40**	64**	68**	49*	71*	91

[z] Expressed as flooded/non-flooded x 100%.
[y] Significant difference at 1%(**), and 5%(*) between flooding and non-flooding.

Table 4. Effect of flooding on soybean yield, yield components, and growth.

Treatment	Yield (t/ha)	Pod no./plant	Leaf area increase (cm^2/day)	Dry weight increase (g/day)
Main-plot (treatment)				
No-flooding	1.97	37	44.0	0.31
Flooding	0.73**[z]	13**	4.6**	0.12**
Sub-plot (flooded entries)				
AGS 1	0.76c[y] (36)[x]	14ab (39)	3.7bc (2)	0.06 (22)
AGS 3	0.99b (42)	15ab (47)	3.0bc (3)	0.07 (23)
AGS 5	0.54d (27)	12bc (32)	2.9bc (1)	0.27 (25)
AGS 7	1.07ab (47)	13bc (45)	6.6b (12)	0.12 (41)
AGS 8	1.18a (58)	18a (54)	10.7a (20)	0.16 (44)
AGS 17	0.70c (31)	14ab (37)	2.9bc (5)	0.10 (43)
G 38	0.44d (24)	7d (22)	2.8bc (9)	0.13 (50)
AGS 62	0.27e (22)	8d (28)	2.2c (2)	0.07 (40)
AGS 66	0.23e (23)	13bc (20)	6.3b (12)	0.10 (32)
AGS 74	0.98b (42)	10cd (29)	5.1bc (9)	0.13 (50)

[z] Significant difference at 1% (**) level, F test.
[y] Mean separation within columns by DMRT, 5% level.
[x] Numbers in the bracket are % of non-flooded treatment.

Conclusions

Under both greenhouse and field conditions flooding slowed plant growth and reduced yields. The greatest yield reductions occurred when plants were flooded at the reproductive stage. Although flooding at the vegetative stage retarded plant growth, plants were able to recover. AGS lines 7 and 8 appeared to have higher recovery rates than did other lines, and consequently had higher yields under flooded conditions.

Nutrition, Environment, and Management

Nutrition Chemistry

Mass Screening Techniques for Sweet Potato Protein Determination

Introduction

High protein content is one of the primary objectives of AVRDC's sweet potato breeding program, and a characteristic which can only be evaluated through chemical analysis. Although officially recommended by the Association of Official Analytical Chemists for the protein determination of food commodities, the Kjeldahl method is both laborious and time-consuming, and is unsuitable for mass screening in the field.

Several mass screening techniques have been developed for various commodities. Among the most popular are the auto-analytical system, the Udy dye binding system, and the NIR spectroscopic system. All are able to make analysis more efficient and economical. The principles and procedures involved in each method are summarized in Table 1. Grinding is an essential part of all methods, and weighing is necessary for most. Neither of these operations can be easily performed in the field. Chopping, drying, and weighing samples comprises over 70% of the total labor involved in analysis.

AVRDC's analytical laboratory presently uses the Udy dye-binding method to screen sweet potato. This works well for evaluating elite sweet potato lines, but it cannot be used for field screening, and thus does not allow breeders to evaluate clones in the field and make selections immediately after harvest. In this study an attempt was made to develop a technique which uses indicator paper to estimate the protein content of roots in the field.

Materials and Methods

The principle of indicator error has long been used by clinical laboratories to test urinary protein. Tetrabromophenol blue, for example, is a common pH indicator which turns a yellow in an acidic solution and blue in an alkaline solution. In the presence of a water soluble protein (albumin), it turns blue even at a low pH. The intensity of the blue color, moreover, is a function of protein concentration. Protein concentrations cause the indicator to turn green at a high pH. (The light absorbtion spectrum of this indicator in high and low pH solutions is shown in Figure 1.) It should be possible,

then, to estimate protein content with an indicator paper whose pH has been fixed by a strong buffer.

After much experimentation, a pH of 3 was found to be optimum for sweet potato screening. Serum albumin was used as a protein standard for color chart reference; a regression equation was used to estimate sweet potato's actual protein content.

Table 1. Analytical and principle procedures of selected protein analysis methods.

	Kjeldahl method	Autoanalyzer	Udy Dye Method	NIR
Principle	Total N. Detn.	Colorimetric	Dye-binding	NIR Ads.
Sample form	Dry powder or fresh sample	Dry powder or fresh sample	Dried powder	Dried powder
Grinding needed?	Yes	Yes	Yes	Yes
Sample weighing needed?	Yes	Yes	Yes	No
Instrument cost	inexpensive	very expensive	inexpensive	expensive
Chemical reagents needed?	Yes	Yes	Yes	No
Efficiency*	40	150	100	100
Accuracy	Standard method	High	High	High
Analytical cost	High	Low	Low	Very low

* Number of samples which can be analyzed in one day by one laboratory technician.

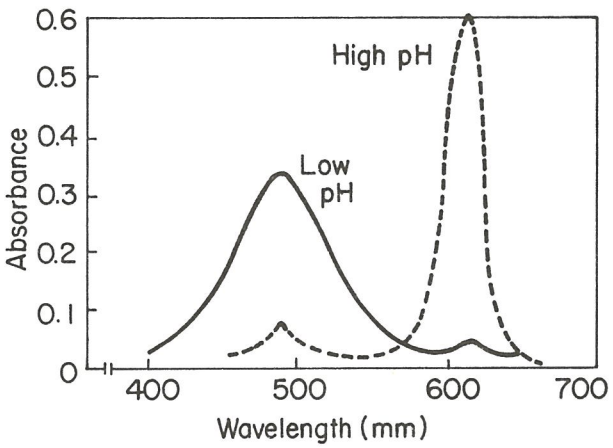

Fig. 1.
Light absorption spectrum of tetra-bromophenol blue in high and low pH solutions.

Results and Conclusions

Ninety-one sweet potato lines were harvested from AVRDC fields. A

sample of roughly 1 cm^3 was taken from the center portion of each root. Several drops of juice were squeezed from the samples onto the indicator paper, and the remainder of the root was used for Kjeldahl protein determination. Preliminary experiments have shown responses to albumin concentrations within the range of 0.2 to 1.5 mg/ml. Correlation coefficients of albumin equivalent concentration and actual protein content as measured by Kjeldahl determination are shown in Table 2.

Although a very low correlation is obtained when comparing all 91 lines, a much higher one can be obtained by examining only the 30 lines with the highest dry matter content (Fig. 2).

Table 2. The correlation coefficients of albumin equivalent concentration and actual protein content.

Treatment	Smaple amount	Correlation coefficient	
		FW basis	DW basis
DM >30%	30	0.7137	0.8375
DM >25%	55	0.6070	0.7240
DM >20%	79	0.6045	0.5230
Total	91	0.6428	0.4925

DM = Dry matter; FW = fresh weight; DW = Dry weight.

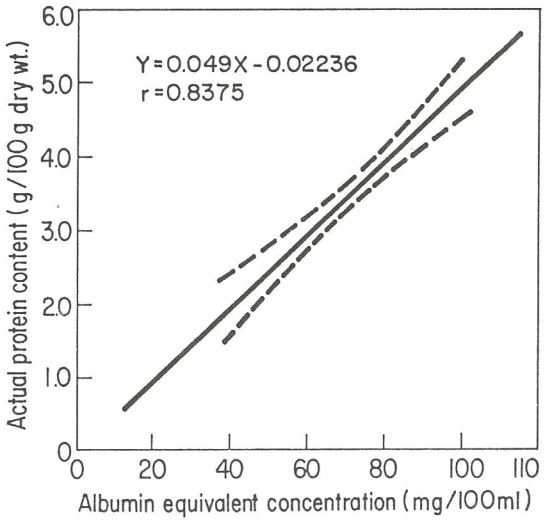

Fig. 2.
Regression between albumin equivalent and actual protein content.

Nitrogen fractionation experiments showed water soluble protein to be the only fracton which could be detected by indicator error; under these experimental conditions free amino acids and globulin fractions did not affect the indicator paper. The percentage of water soluble protein made up of total protein varied from one line to another. This may introduce some of the experimental error found when using indicator error to estimate total protein.

Roots high in dry matter often have a higher protein concentration in their juice than do roots of other lines which have a comparable protein content on a dry weight basis (Table 2). Results closer to those of the Kjeldahl method can be obtained, however, only when high dry matter lines are tested. Since high dry matter content is also a primary goal of AVRDC's breeding program, this variable can be easily managed by first screening for high dry matter content and then screening for protein content.

Previous AVRDC studies have shown that protein content is usually higher in the stem end than in the root end. Since only a few drops of juice are needed for testing, the center portion of the root was assumed to be representative of the whole root. To minimize the error introduced here, however, sampling techniques should be studies further.

Preliminary Testing of Sweet Potato Chips

Introduction

The preparation of sweet potato chips had been studied at several institutions, but the orange-fleshed variety used in those experiments is not commonly available in Asia. The dry textured sweet potatoes found in Asia is more similar to white potato, however, and it was hypothesized that chips made from such cultivars might be similar to those made from white potatoes. The first objective of this study was to develop a processing procedure which would allow the preparation of samples from different varieties under uniform conditions. Only then could they be fairly evaluated in organoleptic tests. The study's second objective was to identify the major factors affecting the quality of sweet potato chips.

Materials and Methods

Medium-sized sweet potato roots of various lines harvested from primary yield trials were washed, peeled, and sliced to various thicknesses. Slices were pan-fried, with actual frying time controlled by a stopwatch. Color and taste were evaluated by panels of three or four randomly selected laboratory technicians. The chemical constituents of fresh and processed products were analyzed according to standard AOAC methods. Phenolic compounds and phenolase activity (darkening) were measured by blending fresh roots with various solutions: a) 1 g thiourea per liter of distilled water, b) 10 g catechol per liter of distilled water, and c) 1 g thiourea + 1 g $FeCl_3$ per liter of distilled water. Color values were determined with a Hunter color difference meter.

Results

Chips made from white or light yellow varieties were found to be the most promising. Several varieties were able to produce chips with

crisp texture, good flavor, and attractive color. Sweet potato's unique flavor was acceptable to many panelists, but was not preferred by those accustomed to chips made from white potato. Color and oily appearance were also found to be major concerns. Preliminary studies of the factors associated with color and oil content may provide criteria for further varietal evaluation.

Darkening of uncooked chips and browning after deep frying were observed. Some varieties darkened after slicing. Visual ratings were a good estimation of the darkening process, and the degree of darkening was correlated with the concentration of phenolic compounds rather than with phenolase activity (Table 3). Varieties with a darkening rating above three were not acceptable for chip preparation. Browning was affected by such variables as frying temperature, frying time, slice thickness, pretreatment of slices, and the smoothness of the surface. Preliminary analysis of the correlation between browning and water soluble nitrogen content suggested that reducing sugar content would probably be the best way to reduce browning. Blanching raw slices with hot water was found an effective method, but, unfortunately, it also made the chips oilier.

Table 3. A comparison of visual ratings of darkening with phenolase activity and concentrations of phenolic compounds.

Sample	Visual rating *	Darkening ΔL	Phenolic compound ΔL	Phenolase ΔL
6371	+	2.3	1.6	12.7
6503	+	5.8	4.7	7.4
P 127	+	7.0	3.8	6.6
P 108	++	5.3	6.2	15.8
P 86	++	8.4	12.6	20.2
6311	++	8.7	7.5	2.2
P 155	+++	8.2	9.0	17.9
P 121	+++	9.2	11.6	1.2
6276	+++	12.3	10.2	13.4
6208	++++	21.7	17.2	9.8

* The more +, the deeper the darkening of slices.

Oiliness was identified as one of the most unfavorable qualities of sweet potato chips. Chips that absorb a great deal of oil are also more expensive to process. Thin slices, low dry matter contents, and blanching before frying are all factors which contribute to oiliness. An oil content of under 35% cannot be achieved with varieties whose dry matter content is under 30% (Fig. 3). The required temperature and frying time depend partially on slice thickness, which means that this variable affects both color and oil content. Whether they have been blanched or not, thicker slices are less oily (Table 4). Regardless of slice thickness, oil content increased with blanching time.

Some varieties developed an unpleasant flavor after processing, but most were acceptable to the laboratory panel. Some panelists preferred the sweetness and flavor of these chips to the flavor of chips made with

white potato. Salt water blanching meant that less salt was required after deep frying; several panelists found that no additional salting was necessary.

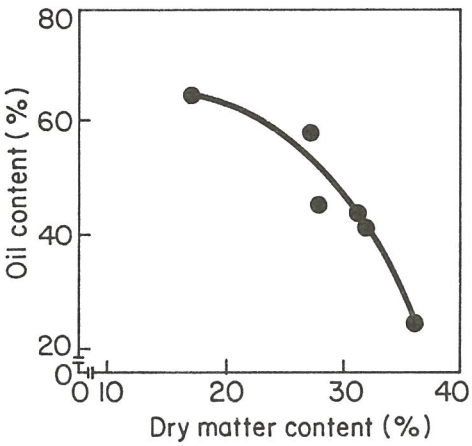

Fig. 3.
Relationship between dry matter and oil content.

Table 4. Relationship between slice thickness, preheating treatment, and oil content.

Thinkness	Blanching time (sec)			
	0	10	30	60
	oil content (%)			
0.8 mm	36.08	-	48.62	-
1.0 mm	36.96	40.85	41.51	45.74
1.2 mm	31.30	31.06	35.37	39.07
1.4 mm	28.93	-	35.56	-

Conclusions

Preliminary trials showed that sweet potato chips made from white and light yellow varieties are the most acceptable. Browning and oiliness were found to be major quality problems. Although blanching with hot water before frying effectively reduces browning, it also makes the chips oilier. A high dry matter content, a low concentration of phenolic compounds, a smoothly sliced surface, and a low sugar content were all important for good chip quality. Of the lines tested, CN 1229-16, CN 1221-1, CN1229-2, and CN 1308-1 seemed to be the most suitable for chip preparation.

Flatulence-Causing Substances in Sweet Potato

Introduction

Legumes have been known to induce flatulence. Extensive studies

have been made of flatulence-causing substances, gas-forming mechanisms, flatulence assay methods, and the physiological effects of flatulence. It is generally agreed that the flatulence causing substances in legumes are α-galactoside oligo-saccharides such as raffinose and stachyose. Legumes high in these compounds produce the most flatulence.

Even though it has frequently been mentioned by Asian consumers, until now sweet potato's ability to induce flatulence had never been studied. The objectives of this study were to confirm that sweet potato does in fact induce flatulence and to identify the compounds responsible.

Materials and Methods

Sugar analysis:

Sweet potato sugars were extracted with 80% EtOH, and extracts were then concentrated and filtered through millipore filters (HA type) and a sep-pak C_{18} cartridge. A 25 ml filtrate was analyzed with an HPLC system with a refraction index detector (Water Associate Model 440). The carbohydrate column (Water Associates, Inc.) was conducted at room temperature using acetonitrile/H_2O (3:1) as solvent at a flow rate of 0.6 ml/minute.

Carbohydrate fractionation:

Sweet potato starch was extracted by water washing and filtered through 132 μ bolting cloth. The edible fiber fraction was collected after the starch had been hydrolyzed with 4.6 N $HClO_4$.

Test diet:

Sweet potato was fractionated into free sugar, starch, and edible fiber. Each fraction was mixed with a basal casein-corn diet in a 2:1 ratio. The flatulence-inducing properties of raw and cooked sweet potato chips were also investigated.

Flatulence evaluation:

Four eight-week-old Long-Evans rats were denied food for 24 hours prior to the test. Each was placed in a metabolic chamber (Figure 4) with 12 g of the test diet. One ml of air was withdrawn from the sampling port after the rat had fed for 16 hours. A gas chromatograph with a thermal conductivity detector was used to detect hydrogen production. A 5 foot by ¼ inch i.d. stainless steel column packed with molecular sieve 5A (30/60 mesh) was conducted at 25° using argon carrier gas at a flow rate of 20 ml/min. Pure hydrogen was used under the same conditions as a reference standard.

Results and Conclusions

Oligosaccarhides in sweet potato roots:

The distribution of sugars extracted from nine sweet potato lines is summarized in Table 5. Total sugar content varied from 13.8 to 28.1%. Sucrose was found to be the dominant free sugar. Raffinose made

up 0.09 to 1.08% of the total dry weight. Stachyose was not detectable, and probably made up less than 0.01% of the total dry weight. α-galactoside oligosaccharides are present at only about one-fifth the level found in soybean, and are thus unlikely to be major flatulence causing substances in sweet potato.

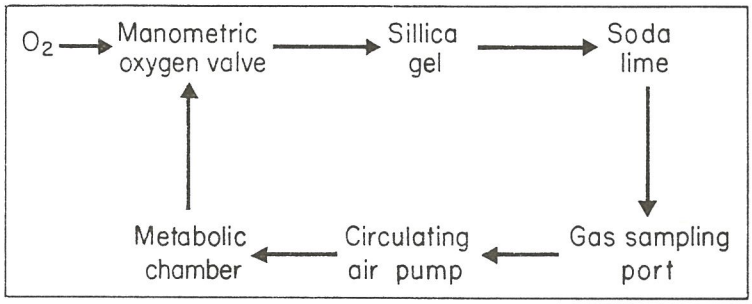

Fig. 4. Life support system for the collection of hydrogen gas.

Table 5. Sugar distribution in sweet potato lines (percentage of total dry matter).

	Total sugar (%)	Arabinose	Mannose	Glucose	Sucrose	Raffinose	Stachyose
Norin 2	14.2	-	-	-	10.12	0.51	0.99
Norin 31	14.7	0.54	0.69	-	11.27	1.08	0.20
Kokei 14	14.2	1.81	2.11	-	9.22	0.56	-
Tainan 18	19.34	3.73	4.89	-	10.52	0.205	-
Tainung 57	21.62	1.32	2.17	-	17.30	0.66	-
New 31	17.99	0.73	1.14	-	15.16	0.19	-
C 63-74	13.84	1.21	-	1.52	10.54	0.095	-
C 64-42	15.29	1.21	-	1.99	11.91	0.17	-
AIS 0122-2	28.16	3.96	4.48	-	14.46	-	-

Hydrogen production induced by various carbohydrate fractions:

The amounts of respiratory hydrogen produced by experimental rats fed with various carbohydrate fractions of sweet potato root are shown in Table 6. Free sugar was found to be an insignificant source of flatulence in sweet potato roots. Sweet potato starch and edible fiber are both able to produce similar amounts of hydrogen. Since starch comprises 50% of sweet potato's total dry weight, 85.07% of all respiratory hydrogen can be presumed to have come from starch. Edible fiber may account for up to 15% of all hydrogen produced.

Since the levels of hydrogen production varied greatly from one animal to another, values observed by this method should probably not be used for quantitative comparison. Nevertheless, differences in the amounts of hydrogen gas produced by similar intakes of sweet potato carbohydrate and a corn diet were great enough so that there was no doubt that sweet potato induces flatulence.

Table 6. Hydrogen produced by rat after ingesting various sweet potato fractions.

	Percentage of dry weight	ml of H_2 produced for each g of sweet potato consumed	Contribution (%)
Free sugar extract	3.99	< 0.0425	< 0.00434
β-starch	50.69	65.4±39.4	85.07
Edible fiber	10.03	59.6±42.0	15.28
α-starch		6.5±4.1	
Basal casein-corn diet		7.7±7.2	

Varietal differences in flatulence production:

Sweet potato samples obtained from AVRDC yield trials were tested for their ability to induce flatulence (Table 7). The volume of hydrogen produced varied from 26 to 71.1 ml/g dry weight, but the high degree of variation found with this assay method made it difficult to conclude that there were distinct varietal differences. Since starch is the major sweet potato constituent that causes flatulence, the varietal differences observed may simply be due to variations in starch content. A statistically significant correlation (r=0.622*) was observed between starch content and hydrogen production. Cooking was found to reduce the amount of hydrogen production sweet potato from 58.0 ml/g dry matter intake to 3.2 ml/g. The reasons for this phenomenon are not clear. Cooking could change certain properties of the starch, or it could reduce levels of flatulence-inducing substances in the non-starch polysaccharide fraction. The phenomenon is presently being investigated.

Table 7. Varietal differences in milliliters of hydrogen produced by each gram of dry matter consumed.

	Starch content(%)	Raw sweet potato	Cooked sweet potato	Starch fraction
CN 941-32	52.14	71.1±31.4	48.6±34.6	-
CN 1028-15	41.14	52.1±52.0	23.1± 9.6	83.3±56.1
CN 1038-16	47.75	60.0±37.0	3.2± 0.2	39.0±18.3
CN 1058-10	33.85	31.2±19.5	-	-
CN1108-13	44.40	34.3±24.2	19.1±10.8	-
CN 1216-10	62.28	54.1±23.6	43.5±24.0	-
CN 1219- 1	49.64	26.4±22.1	-	44.3±40.9
CN 1229- 2	48.45	45.6±26.6	18.5±21.4	59.0±48.5
CN 1229-14	49.84	68.1±44.5	58.0±18.8	86.3±41.9
CN 1232- 9	57.90	63.2±29.4	20.0±15.5	74.1±18.7
AIS0122-2	19.48	26.5±18.3	-	-
TN 57	44.80	55.1±28.4	41.2±29.7	55.2±48.6
TN 65	58.92	56.7±31.1	-	92.8±45.8
Soybean			65.3±47.1	

The hydrogen production induced by sweet potato was found to peak at about ten hours after feeding, and to cease about ten hours later, just as with the hydrogen production induced by soybean (Fig. 5). Such data does not make it possible to determine whether flatulence is caused by starch or by oligosaccharides. The apparently low flatulence inducing properties of CN 1038-16 should be further studied to learn whether they are a genetic characteristic or are simply due to some environmental factor. Either way, it seems hopeful that ways can be found to reduce the flatulence-inducing properties of sweet potato.

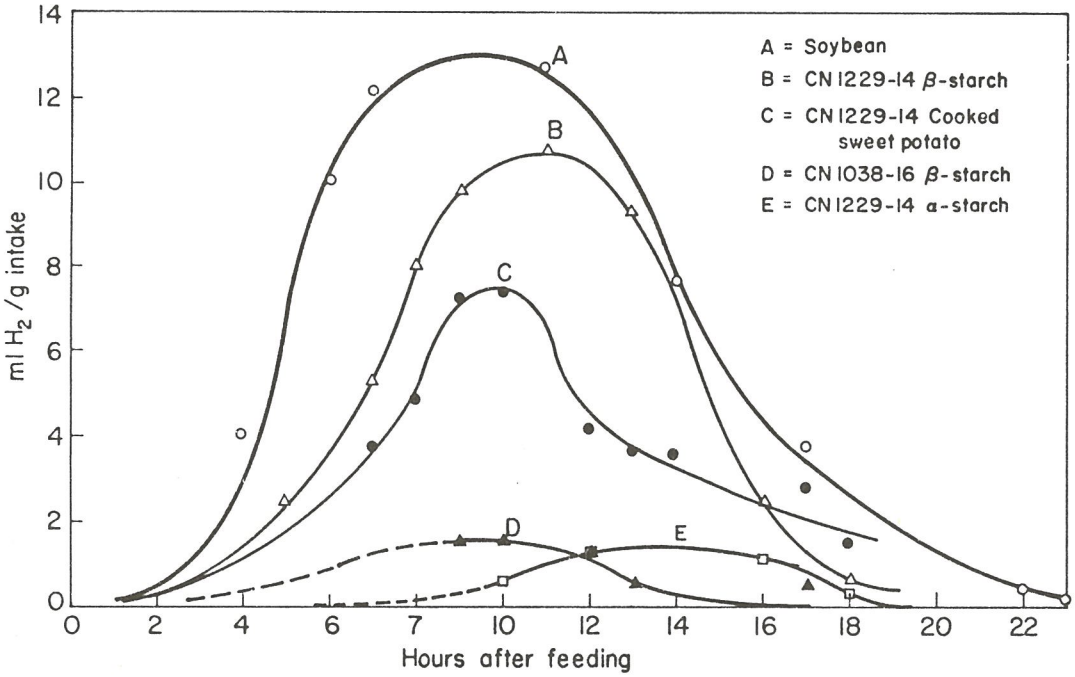

Fig. 5. Hydrogen production of experimental rats introduced by sweet potato starch diets.

The Effect of Sweet Potato Starch on the Digestibility of Sweet Potato Protein

Introduction

Sweet potato has been reported to be lower in feeding efficiency than corn. It has traditionally been cooked before being fed to swine, but this requires a great deal of time, labor, and fuel. Sweet potato seems to have good carbohydrate digestibility, but poor protein digestibility.

Previous studies at AVRDC have demonstrated that the low digestibility of sweet potato protein is due to its starch content. Although isolated sweet potato starch is able to reduce the digestibility of casein, this effect can be overcome by precooking. This year the phenomenon was further studied to learn whether there might be varietal differences which could be used to develop a "feed" cultivar with superior protein digestibility.

Materials and Methods

Starch preparation:

Sweet potato chips were milled and washed, and then filtered through 132 m bolting cloth. The filtrate was sedimented and then air dried.

Test diet:

Sweet potato was the carbohydrate source, and soybean made up 10% of the test diet.

Rat feeding experiment:

Four ten-week-old Long-Evans rats were used for each treatment. Each rat's feces and urine were collected and assayed for protein and carbohydrate content.

Results

Most of the 13 lines evaluated had good agronomic characteristics and high dry matter contents. The digestibility of their starch and its effect on true protein digestibility is shown in Table 8. As reported elsewhere, the carbohydrate digestibility of sweet potato is generally high; it was over 90% for all varieties tested. Under these experimental conditions, most were comparable in digestibility to corn starch. Except for line CN 1219-1, no statistically significant difference was detected in the true protein digestibility of the sweet potato starch diet and the corn starch diet.

Table 8. Varietal differences in protein and carbohydrate digestibility.

	Carbohydrate digestibility	True protein digestibility	Apparent protein digestibility
CN 1028-15	97.22a	77.87ab	70.19bc
CN 1038-16	98.45a	76.48ab	70.23bc
CN 1232- 9	97.74a	79.98ab	73.97abc
CN 1219- 1	94.14b	75.51b	68.40c
CN 1229- 2	96.93a	76.55ab	69.09c
C 63-74	98.98a	76.55ab	69.09c
C 66-73	93.63b	78.27a	78.06a
C 66-73	93.63b	78.24ab	70.01bc
Tainan 14	97.48a	77.63ab	69.48c
Tainan 18	98.46a	78.14ab	69.97bc
Tainung 57	98.33a	78.19ab	70.80abc
Tainung 65	90.11c	77.72ab	68.31c
New 31	91.83bc	79.38ab	73.61abc
Miaonung Sel. 1	97.29a	77.64ab	69.45c
Corn starch	99.01a	84.01a	77.47ab

Data different at over the 5% level of probability show different letters.

More variation was observed, however, in the apparent protein digestility of the various varieties, confirming the results of others who had used pigs as experimental animals. Those experiments, though, examined only apparent digestibility, and not true protein digestibility. Four lines had starch comparable in quality to corn starch: CN1232-9, C63-74, Tainung 57, and New 31. Other properties of these four lines are summarized in Table 9. Tainung 57 is Taiwan's most popular cultivar for human consumption. It has good eating qualities, but a relatively low dry matter content. New 31 is a popular variety for starch extraction, and has a relatively low protein content. New AVRDC breeding line CN 1232-9, whose average yield at ten locations in Taiwan reached 27.0 t/ha with a 27.4% dry matter content, shows great promise as an animal feed line. Another possibility is C63-74, a new breeding line developed by TARI's Chiayi station. It, like CN1232-9, has both a high yield potetial and a high dry matter content. Both lines are currently being evaluated.

Conclusions

It is unclear why sweet potato starch may reduce the apparent digestibility of protein. One possible explanation is that the starch itself is sometimes less digestible. The sweet potato diet and the corn starch diet seemed to produce similar levels of metabolic fecal nitrogen and fecal nitrogen (Table 10). Levels of fecal carbohydrate produced varied, however, from 4.33 to 49.91 mg/hr. Except for New 31, lines with high apparent protein digestibility generally produced less fecal carbohydrate. For reasons not yet fully understood, fecal carbohydrate levels are not significantly correlated with apparent digestibility.

Table 9. Horticultural characteristics of four sweet potato lines.

	Yield (t/ha)	Flesh color	Dry matter %	Protein content %	Starch content %	Sugar content %
CN 1232-9	27.0	Y_3	27.4	4.64	57.90	20.09
C 63-74	23.7*	Y_2O_2	31.6	5.69	64.09	13.84
Tainung 57	28.4	Y_3O_1	23.1	3.79	44.80	21.62
New 31	30.0*	W	31.8	1.85	58.70	17.99

Table 10. Levels of metobalic fecal nitrogen (MFN), fecal nitrogen (FN) and fecal carbohydrate (FCHO) collected from rats after test diet intake.

	MFN mg/hr	FN mg/hr	FCHO mg/ha		MFN mg/hr	FN mg/hr	FCHO mg/ha
CN 1028-15	1.10ab	4.45a	13.06c	Tainan 14	1.22ab	4.48a	11.27c
CN 1038-16	0.93ab	4.51a	7.72c	Tainan 18	1.22ab	3.42a	5.41b
CN 1232- 9	0.84b	4.34a	12.18c	Tainung 57	0.93ab	3.79a	7.44c
CN 1219- 1	0.97ab	4.22a	25.77b	Tainung 65	1.12ab	3.82a	49.91a
CN 1229- 2	1.08ab	4.68a	14.53c	New 31	1.39a	3.95a	33.49b
C 63-74	0.92ab	3.18a	4.33c	Miaonung Sel. 1	1.14ab	4.19a	11.37c
C 66-73	1.04ab	3.79a	27.02c	Corn starch	0.95ab	3.34a	4.19c

Data significantly different at 5% level of probability show different letters.

Trypsin Inhibitors in Sweet Potato: Genotypic and Environmental Effects

Introduction

Yeh (1982) showed that slower growth and a lower protein efficiency ratio (PER) will result if uncooked sweet potato roots exceed 25-30% of a pig's diet. This phenomenon may be related to the trypsin inhibitors found in sweet potato. Reports also indicate that trypsin inhibitor levels are positively correlated with protein concentrations (AVRDC 1976, Lin and Chen 1980).

The present study was conducted to investigate the relationship between trypsin inhibitor activity and protein concentration, and to determine if clones can be identified which have both high protein content and low levels of trypsin inhibitor activity.

Materials and Methods

Samples were obtained from field tests conducted at AVRDC during four seasons in 1981 and 1983. The number of replications varied from two to six (Table 11).

Six randomly selected roots from each experimental unit were washed, shredded, and thoroughly mixed, and an aliquot of 500 g was dried to a constant weight in a forced-air oven at 50°C. The dried sample was weighed and then ground in a cyclone mill to approximately 200 mesh.

Accurately weighed samples of 0.6 g were blended for 1 minute with 35 ml of an aqueous solution of 0.9% NaCl in 10^{-3} N NaOH. After being centrifuged for 10 minutes at 10,000 Xg, 0.5 ml of solution was analyzed according to the procedures of Kakade et al. (1974). A trypsin inhibitor unit was defined as the amount of inhibitor per mg of sweet potato sample which resulted in a decrease of 0.01 absorbance units at 410 nm per 10 ml of reaction mixture. Protein was determined by the dye binding technique of Udy (1956).

Table 11. Field experiments from which simples were obtained.

Season	Number of clones	Number of replications
Winter (10/30-1/28)	26	4
	21	2
Spring (2/25-7/6)	10	6
	11	4
	59	2
Summer (6/1-9/27)	18	4
	31	2
Fall (8/26-12/23)	23	4
	14	3
	33	2

Results and Discussion

Scatter diagrams of each season's cultivar means are presented in Figure 6, and regression equations calculated from these data are presented in Table 12. Both the degree of correlation and the slopes of the regression lines vary among seasons. Although the relationship between protein concentration and trypsin inhibitors is not constant, a statistically significant relationship exists for all seasons studied. This is also apparent from the distribution of the check cultivars grown in each season.

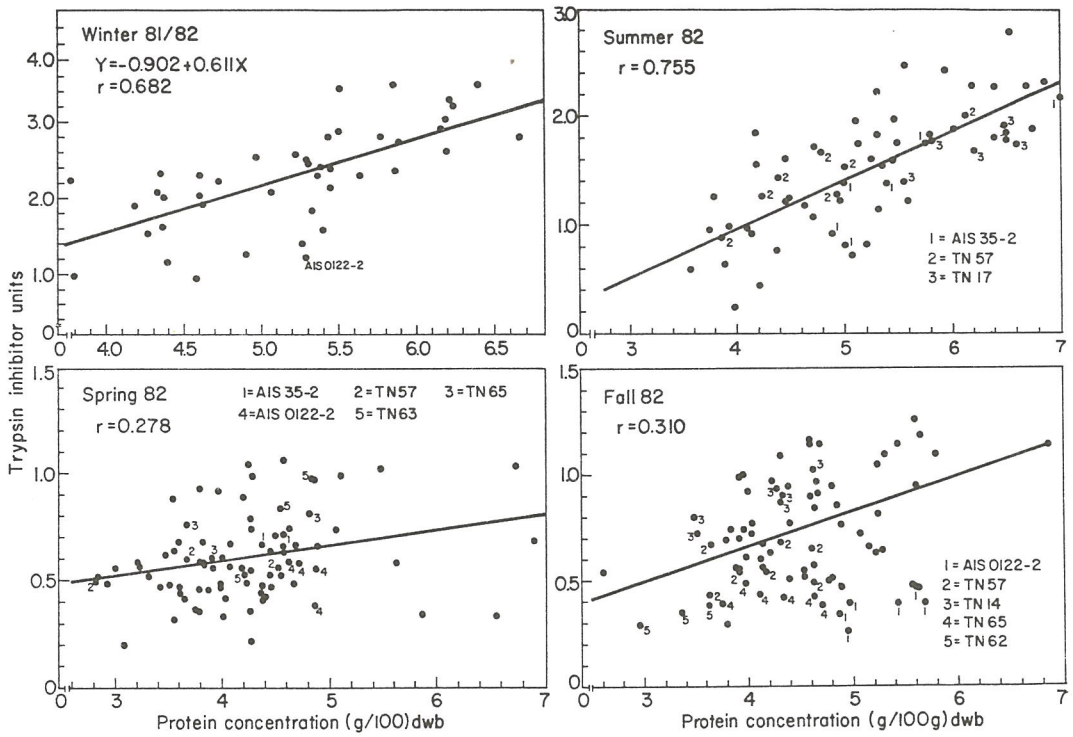

Fig. 6. Distribution of trypsin inhibitor levels and protein content over four seasons.

Table 12. Relationships between trypsin inhibitor units (y) and protein concentration (X_1) over four seasons.

Season	Regression	R	N
Winter 81-82	$y=-0.902 + 0.611X_1$	0.682	43
Spring 82	$y= 0.307 + 0.070X_1$	0.278	86
Summer 82	$y=-0.837 + 0.499X_1$	0.755	64
Fall 82	$y=-0.012 + -.167X_1$	0.310	84

In an attempt to select low trypsin inhibitor from high protein breeding lines in each season, five cultivars were arbitrarily chosen

from those which had the greatest negative residual compared to their predicted TIU value. The residuals of these 20 cultivars were tabulated for all seasons. Breeding lines grown in only one season were ignored. The results are shown in Table 13. High trypsin inhibitor lines similarly identified are shown in Table 14. Even though the relationship changed from season to season, cultivars tended to be consistent in their relationship of TIU activity to protein concentration. This suggests that it is possible to use deviations from expected values to select breeding lines with moderately low TIU levels and moderately high protein contents.

In three of the four seasons, a significant correlation was also observed between dry matter content and TIU. Scatter diagrams and regression equations are presented in Figure 7. Multiple regression equations for each season are presented in Table 15.

Using the method just described, low trypsin inhibitor lines were identified by maximum negative residuals from multiple regression equations, and high trypsin inhibitor lines were identified by maximum positive residuals (Tables 16 and 17).

Table 13. Difference between observed and predicted TIU in selected cultivars.

Cultivar	Winter 81-82 1/30-1/28	Spring 82 2/25-7/6	Summer 82 6/1-9/27	Fall 82 8/26-12/23
CI 1274-4	-0.797*	0.019	-0.608*	-0.222
CI 1275-1	-0.918*	-0.167	-0.396	-0.394*
AIS 0122-2	-1.108*	-0.276*		-0.452*
CI 913-7		-0.027	-0.575*	-0.333*
CI 995-25		0.147	-0.446	-0.429*
CI 1038-16		-0.258*	-0.056	-0.226
CI 1275-3	-0.143		-0.608*	-0.112

* Among the 5 cvs showing the greatest negative residual.

Table 14. Difference between observed and predicted TIU for selected cultivars in each season.

Cultivar	Winter 81-82	Spring 82	Summer 82	Fall 82
CI 1229-2	0.132	0.105	0.523*	0.345
CI 1279		0.356*	0.700*	0.263
CI 1229-14	0.429		0.680*	0.374*
CI 1229-16	-0.033		0.338	0.409*
CI 1272-2			0.804*	0.387*
CI 1221-1			0.279	0.357*
CI 1216-3	0.849*	0.390*	0.056	-0.076
CI 1108-13		0.382*	0.424	0.085
CI 946-13			0.599*	0.202

* Among the 5 cvs showing the greatest positive residual.

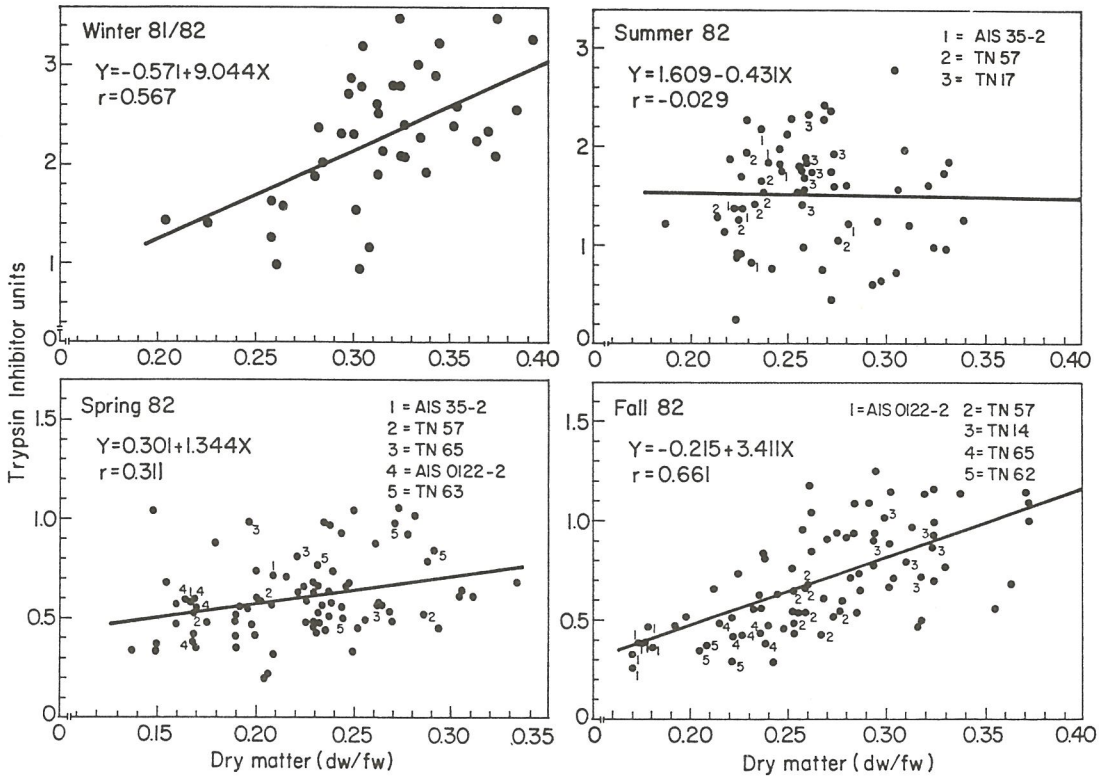

Fig. 7. Distribution of trypsin inhibitor levels and dry matter content over four seasons.

Table 15. Relationships between trypsin inhibitor units (y), protein content (X_1), and dry matter content (X_2) over four seasons.

Season	Regression	R	N
Winter 81-82	$y=-3.381 + 0.581X_1 + 8.324X_2$	0.860	43
Spring 82	$y=-0.347 + 0.115X_1 + 2.506X_2$	0.523	86
Summer 82	$y=-1.948 + 0.499x_1 + 3.378X_2$	0.785	64
Fall 82	$y=-1.048 + 0.160X_1 + 3.832X_2$	0.793	84

Table 16. Differences between observed and predicted TIU values (low trypsin inhibitor lines).

Cultivar	Winter	Spring	Summer	Fall
CI 1275-1	-0.365*	-0.167	-0.385*	-0.339*
CI 1216-3	0.394	0.115	-0.104	-0.377*
CI 1274-4	-0.171	0.180	-0.605*	-0.054
CI 1229-16	-0.336*		0.160	0.227
CI 1234-2	-0.171		-0.327*	-0.268*
CI 1038-16		-0.295*	-0.030	-0.135
CI 1275-3	-0.230		-0.534*	0.060
CI 1274-2		-0.236*		-0.008
CI 1217-4			-0.870*	-0.039

Among the 5 cvs showing the greatest negative residuals.

Table 17. Differences between observed and predicted TIU values (low trypsin inhibitor lines).

Cultivar	Winter	Spring	Summer	Fall
CI 1219-4	0.422*	0.080	0.415	0.322*
CI 1232-9	-0.025	0.264	0.550*	0.060
CI 1280-3	0.609*	0.186	0.609*	0.077
CI 942-47		0.018	0.338	0.291*
CI 946-13		0.269	0.540*	0.277*
CI 1108-13		0.442*	0.530	0.241
CI 1279		0.341*	0.646*	0.250
CI 1229-14	0.580*		0.472	0.277*
CI 1221-1	0.491*		0.049	
CI 1244-5	-0.057			0.265*
CI 1272-2			0.610*	0.021

It seems likely that genotypes can be identified which consistently differ from the population average in their relationship between TIU, protein, and dry matter contents. Such lines are generally higher than the population mean for dry matter, near the mean values for protein, and considerably below the population mean for trypsin inhibitor activity (Table 18).

Although it may be possible to reduce trypsin inhibitor levels, it could be advantageous to simply accept present levels of trypsin inhibitors, amd instead concentrate on increasing protein and dry matter contents. Since trypsin inhibitor levels in sweet potato are only 1/50 to 1/100 those of soybean meal, and are similar to those of steamed soybean meal, it would appear that trypsin inhibitors are not a major factor to be considered in the use of sweet potatoes as a swine feed.

Table 18. Characteristics of selected low trypsin inhibitor lines.

Cultivar	Pedigree	Avergae % of population mean		
		DM	Protein	TIU
CI 1275-1	I361//I122/I117	100	97	67
CI 1274-1	I361//I117/I6	98	100	78
CI 1038-16	I117//I152/I37///I57	101	89	62
CI 1216-3	I307//I3/I136	130	78	89
CI 1234-2	I117/I6//I307	129	82	78
CI 1274-2	I361//I117/I6	120	94	70
CI 1217-4	I307//I117/I6	108	112	92
CI 1275-3	I361//I122/I117	86	86	70
CI 1229-16	I3/I136//I307	117	104	134

Soil Science

Improved Cropping Systems

Introduction

Crop rotation suppresses soil-borne diseases, preserves soil organic matter, increases soil nitrogen, balances soil nutrients, and improves the soil's physical properties.

Crop rotation is even more important in the tropics than in temperate regions, but crop rotation systems developed in the temperate zones cannot be transferred to the tropics without modification. This project, which was begun in 1983 and will continue into successive years, will attempt to develop for AVRDC mandate crops rotation systems specifically tailored to the tropics.

Materials and Methods

Rice crops were planted in the spring and summer of 1983 and experimental cropping sequences were begun in the fall of 1983. Individual crops were planted in 50 m^2 plots. A completely randomized design was used with two replications. Each of the six rotation systems tested included at least two AVRDC mandate crops (Fig. 1). Fertilizer application rates are shown in Table 1. With the exception of Chinese cabbage, all plant parts remaining after harvest were plowed back into the soil.

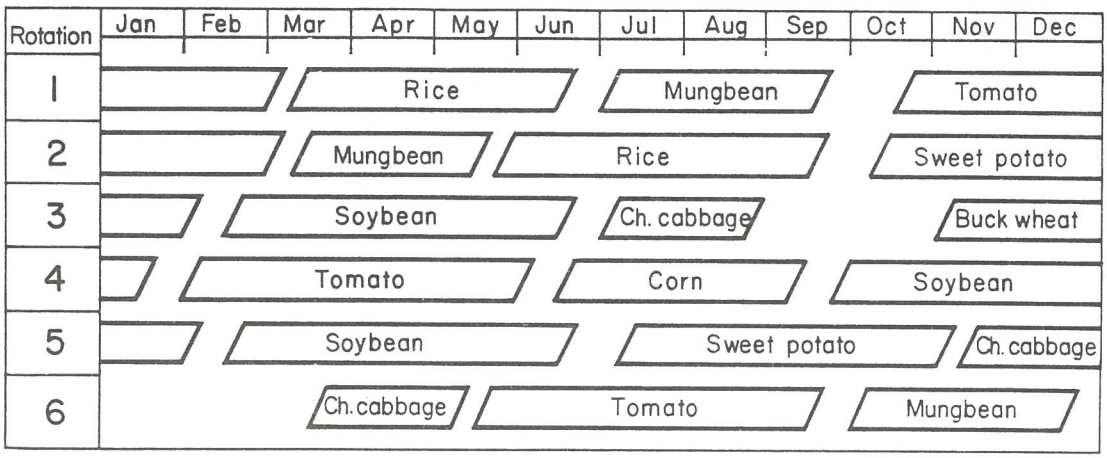

Fig. 1. Rotation systems tested.

Table 1. Applications of fertilizer in each rotation system.

1. Rotation No.: Tomato - Rice - Mungbean

Crop	Basal or top	Fertilizer	Amount applied ($kg/50m^2$)	Kg/ha applied	Constituents (kg/ha) N	P_2O_5	K_2O
Tomato (Tainan 2#)	Basal	4#	3.18	636	70	35	140
	Top	1#	0.75	150	30	7.5	15
Rice	Basal	39#	1.05	210	25	37.8	25
Mungbean (V 1973)	Basal	4#	1.14	227	25	12.5	50
	Total				150	92.8	230

2. Sweet Potato - Mungbean - Rice

Sweet Potato (1108-13)	Basal	4#	1.83	365	40	20	80
	Top	39#	0.84	167	20	30	20
Mungbean (V. 1973)	Basal	39#	1.25+K_2O(100g)	250+K_2O(20kg)	30	45	50
Rice	Basal	1#	1.50	300	60	15	30
	Total				150	110	180

3. Buck Wheat - Soybean - Chinese cabbage

Soybean	Basal	4#	2.27+P_2O_5(225g)	455+P_2O_5(45kg)	50	(25+45)	100
Chinese cabbage (Hong-Luh)	Basal	5#	3.13	625	100	50	75
	Total				150	120	175

4. Soybean - Tomato - Corn

Soybean	Basal	39#	1.68	335	40	60	40
Tomato	Basal	5#	2.20	440	70	35	52.8
	Top	4#	1.83	365	40	20	80
	Total				150	115	172.8

5. Chinese cabbage - soybean - sweet potato

Chinese cabbage (Hong Luh)	Basal	5#	2.20	440	70	35	52.8
Soybean	Basal	39#	1.68	335	40	60	40
Sweet Potato	Basal	4#	1.82	365	40	20	80
	Total				150	115	172.5

6. Mungbean - Chinese cabbage - Tomato

Mungbean (V 1973)	Basal	39#	0.625+K_2O(50g)	125+K_2O(10kg)	15	22.5	25
Chinese cabbage (Ping Luh)	Basal	39#	2.10	420	50	75.6	50
Tomato	Basal	1#	2.13+K_2O(350g)	425+K_2O(70kg)	85	21	(42.5+70)
	Total				150	119.1	187.5

Remark: N P_2O_5 K_2O; 1# 20 5 10; 4# 11 5.5 22; 5# 16 8 12; 12# 5 10 8;39# 12 18 12.

Results

Because the experimental cropping sequence was begun in the fall of 1983, only yield data from the first season are reported here (Table 2).

Even though rice had been cultivated during two previous seasons, mungbean showed typical symptoms of mungbean root disease complex, and tomato was severely damaged by TMV and bacterial wilt.

Because of low levels of nitrogen application (70 kg/ha), Chinese cabbage yields were lower than normal for the fall season.

Table 2. Yields of each rotation system, Autumn 1983.

Rotation No. 1 Tomato yield (per plot)		Tomato (Autumn)	Rice (Spring)	Mungbean (Summer)
Plant harvested[z]		Fruit no.	Average fruit wt. (g/plant)	Yield
Rep I	88	4799	49.8	47.80
II	91	4286	52.5	44.98

[z] Total seedling numbers transplanted were 100 (10 plants/bed x 10 beds/plot = 100 plants/plot). Decrease in plant number at the harvesting time was mainly due to TMV and wilt disease.
Date sowed: September 9, 1983; Transplanted: October 6, 1983; Harvested: January 31, 1984. Cultivar: CL 1561-6-0 (Tainan #2).

Rotation No. 2 Tomato yield (per plot)		Sweet potato		Mungbean		Rice
Plant harvested[y]		Top wt. (kg)	Average top wt. (g/plant)	Marketable tuber Tuber no. (/plot)	Avergae tuber wt. (g/tuber)	Yield (t/ha)
Rep I	179	52.8	295	801	117	18.67
Rep II	177	52.3	295	689	120	16.50

	Not-marketable tuber			Marketable+not-marketable		
	Tuber no. (/plot)	Average tuber wt. (g/tuber)	Yield (t/ha)	Tuber no. (/plot)	Average tuber wt. (g/tuber)	Yield (t/ha)
Rep I	1006	24.4	4.91	1807	65.3	23.58
Rep II	821	27.2	4.47	1510	69.4	20.97

[y] Total seedling no.: 180
(18 plants/bed x 10 beds/plot = 180 plants/-plot, between hill; 30 cm). Date transplanted: October 6, 1983; Harvested: January 20, 1984; Cultivar: 1108-13.

Rotation No. 3	Buck wheat	Soybean	Chinese cabbage

All buck wheat was plowed back into the field after harvest.

(Continued)

Table 2. (Continued) Yields of each rotation system; Autumn 1983.

Rotation No. 4 Soybean Tomato Corn

Soybean yield (per 10 plants)

	Height (cm)	Pod no.	Pod no. /plant	Seed no.	Seed no. /pod	Seed wt. (g)
Rep I	60.9	209	20.9	478	2.28	78.2
Rep II	63.1	194	19.4	392	2.02	78.8

	Nodule no.	Nodule wt. fresh	Nodule wt. dry	100 seed wt. (g)	Yield (ton/ha)
Rep I	322	24.4	6.7	15.76	2.59
Rep II	362	24.0	7.1	15.54	2.58

Plant population: 400, 000/ha.; Date sown: October 7, 1983; Germinated: October 12, 1983; harvested: December 27, 1983; Cultivar: AGS 129.

Rotation no. 5 Chinese cabbage Soybean Sweet potato

Chinese cabbage yield (per plant)

	Outer leaves			Inner leaves			Total		
	Total (kg)	Average wt. per plant (g)	Yield (t/ha)	Total (kg)	Average wt. per plant (g)	Yield (t/ha)	Total (kg)	Average wt. per plant (g)	Yield (t/ha)
Rep I	146	913	29.2	148	928	29.7	294	1840	58.9
Rep II	122	763	24.4	131	820	26.3	253	1583	50.7

Plant population: 32,000/ha (16 plants/bed x 10 beds/plot = 160 plants/plot). Date sowed: September 27, 1983; transplanted: October 12, 1983; harvested: December 6, 1983; Cultivar: Fon Luh.

Rotation no. 6 Mungbean Chinese cabbage Tomato

Mungbean yield (per 10 plants)

	Height (cm)	Pod no.	Seed no.	Seed wt. (g)	Leaf no.
Rep I	64.6	104	785	42.5	56
Rep II	40.0	67	328	21.7	43

	Nodule no.	Nodule wt. Fresh (g)	Nodule wt. Dry (g)	1000 seed wt. (g)	Yield (ton/ha)
Rep I	284	2.54	0.61	60.4	0.86[x]
Rep II	195	1.02	0.58	65.7	0.69

Plant population: 400,000/ha; Date sown: October 7, 1983; germinated: October 12, 1983; harvested: December 27, 1983; cultivar: V 1973A.

[x] Yields were very low due to continuous cropping hazard.

Conclusions

The experiment has seen only the first three of the many rotations which will follow. In future rotations, attempts will be made to: 1) increase the number of rotation systems being used, 2) test continuous cropping of the same crops, 3) evaluate the effects of successive applications of organic materials, and 4) evaluate in improved crop rotation systems the effects of such soil management practices as mulching, irrigation, and deep plowing.

Optimal Soil Management and Fertilizer Applications for Chinese Cabbage

Introduction

Although the amount and timing of nitrogen application are critical for Chinese cabbage, AVRDC's previously recommended practice of applying fertilizer four times a season is both laborious and costly. AVRDC soil scientists recommended in 1982 that a single basal application of 100 to 140 kg/ha be used each season, and this recommendation was further tested in 1983 with a variety of compound fertilizers. Soil management practices were designed to accelerate root growth and thus support higher yields.

Materials and Methods

In the first experiment, seeds of Hybrid No. 62 were planted on July 7, 1983. Seedlings were transplanted on July 28, and the crop was harvested on August 31. Two rows were planted on each 1.5 x 5 m bed, with 50 cm between plants and 50 cm between rows. A split-plot design was used with 2 replications. Treatments can be seen from Table 3.

A second experiment was planted on September 27, transplanted on October 18, and harvested on December 6. Plant spacing was similar to that described above. A split-split plot design was used with two replications (Table 4). Plots were irrigated whenever the water tension at a depth of 15 cm reached pF 1.8 in the first plot and 2.5 in the second.

Results and Discusssion

Deep plowing and compost application had no effect upon Chinese cabbage yields in the summer planting. Compound fertilizer, however, increased the yields experienced with straight fertilizer by 30 to 50% (Table 5).

The last column of Table 5 shows the percentage of plants which had internal rot. Although they appeared healthy, more than 90% were damaged.

In the fall planting, deep plowing did not significantly increase the plant's ratio of dry weight to fresh weight, but improved water

Table 3. Treatment in experiment I.

Main plot	Sub plot
Deep plowing with compost	Fertilization
1. None	1. None[z]
2. Deep plowing with 30 t/ha compost	2. Compound fertilizer 5# 500 kg/ha (basal)
	3. Compound fertilizer 5# 700 kg/ha (basal)
	4. Compound fertilizer 5# 500 kg basal Compound fertilizer 5# 150 kg top
	5. Straight fertilizer N, P_2O_5, K_2O: 100 kg, 80 kg, 100 kg, respectively

[z] The amounts of N, P_2O_5, K_2O in each treatment are as follows:

Treatments	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
1	0	0	0
2	80	40	60
3	112	56	84
4	110	47.5	75
5	110	80	100

Table 4. Treatments in experiment II.

Main plot	Sub plot	Sub-sub plot			
Deep plowing	Moisture status	Fertilization			
		N	P_2O_5	K_2O	Remark
None	pF 1.8	110	80	100	Straight fertilizer (basal)
Deep plowing with 30 t/ha compost	pF 2.5	112	56	84	C.F. 5# 700 kg/ha (basal)
		112	56	84	C.F. 5# 700 kg/ha (basal)
		40	10	20	C.F. 1# 200 kg/ha (top)

Table 5. The results of Duncan's multiple range test for Chinese cabbage yields.

Treatment (fertilization)	Outer leaves fresh weight (g/plant)	Inner leaves fresh weight (g/plant)	Total fresh wt. (g/plant)	Inner wt./ total wt.	Frequency of internal rot (%)
None (NO)	N_2 544.0 A	N_2 501.7 A	N_2 1026.9 A	N_2 48.8 A	N_2 96.3 A
	N_1 542.3 A	N_3 473.8 AB	N_3 976.9 B	N_3 48.6 A	N_4 94.8 A
*C.F. 5# 500 kg (N_1)	N_3 503.2 A	N_1 432.7 B	N_1 975.0 B	N_1 44.1 AB	N_3 94.7 A
C.F. 5# 700 kg (N_2)	N_4 497.9 A	N_4 322.8 C	N_4 820.6 C	N_4 39.0 CB	N_1 91.3 AB
C.F. 5# 500kg 1# 150kg (N_3)	NO 331.5 B	NO 163.5 D	NO 494.9 D	NO 32.7 C	NO 85.2 B
	LSD(.05)=61.2	LSD(.05)=65.3	LSD(.05)=46.2	LSD(.05)=6.4	LSD(.05)=6.9
Straight fertilizer (N_4)					

* Compound fertilizer.

management did (Table 6). Fertilization treatment N_1 also showed increased dry matter production.

Even though deep plowing did not increase yields significantly, it did seem to speed growth (Table 7). Since frequent irrigation increased the total yield by 3%, but also increased soft rot incidence by 7%, marketable yields did not differ greatly between pF 1.8 and pF 2.5 treatments. Top dressing in treatment N_3 increased yields by more than 12%. Cool but clear weather made for ideal growing conditions; although the photosynthetic rate was high, the transpiration rate was not.

Table 6. The results of Duncan's multiple range test for dry weight: fresh weight ratios of some growth components at the head initiation stage.

Treatment	Root Dry/ fresh wt.	Inner leaf Dry/fresh	Outer leaf Dry/fresh
Main plot			
Non (N) Deep plowing (D)	N 9.44 A D 9.38 A LSD(.05)=4.87	N 6.24 A D 5.76 A LSD(.05)=3.49	N 5.76 A D 5.44 A LSD(.05)=1.40
Sub plot			
pF 1.8 pF 2.5	pF 2.5 9.70 A pF 1.8 9.12 B LSD(.05)=0.11	pF 2.5 6.17 A pF 1.8 5.74 A LSD(.05)=0.72	pF 2.5 5.67 A pF 1.8 5.53 A LSD(.05)=0.37
Sub-sub plot			
Straight fertilizer (N_1)	N_1 9.51 A	N_1 6.20 A	N_1 5.73 A
Compound fertilizer (N_2; basal only)	N_2 9.40 A N_3 9.31 A	N_2 5.96 AB N_3 5.70 B	N_2 5.57 A N_3 5.50 A
Compound fertilizer (N_3; basal + top)	LSD(.05)=0.83	LSD(.05)=0.35	LSD(.05)=0.27

Table 7. Duncan's multiple range test for yield components.

Treatments	Marketable yield (t/ha)	Outer leaf yield (t/ha)	Total yield (t/ha)	CGR (g/day/4 plants)
Main plot				
None (N) Deep plowing (D)	D 62.8 A N 58.5 A LSD (.05)=16.6	D 39.3 A N 36.2 A	D 102.1 A N 94.7 A LSD (.05)=73.1	D 49.5 A N 48.9 A LSD (.05)=15.7
Sub plot				
pF 1.8 pF 2.5	pF 1.8 61.9 A pF 2.5 59.5 A LSD (.05) = 2.7	pF 1.8 38.1 A pF 2.5 37.3 A	pF 1.8 100.0 A pF 2.5 96.8 B LSD (.05) = 2.0	pF 2.5 50.8 A pF 1.8 47.6 A LSD (.05) = 9.7
Sub-sub plot				
Straight fertilizer (N_1) Compound fertilizer (basal only)(N_2) Compound fertilizer (basal + top) (N_3)	N_3 64.7 A N_1 59.6 AB N_2 57.6 B LSD (.05) = 5.2	N_3 39.7 A N_1 37.3 AB N_2 36.1 B	N_3 104.5 A N_1 96.9 B N_2 93.7 B LSD (.05) = 7.2	N_1 50.4 A N_2 48.7 A N_3 48.5 A LSD (.05) = 5.9

Average head weight exceeded 2 kg in all treatments, and reached 2.4 kg in the N_3 treatment, which had a total yield over 100 t/ha. For Chinese cabbage to reach a dry matter content of 5%, a nitrogen content of 4% of its dry weight, and a 70% ratio of nitrogen utilization, it must use about 280 to 290 kg N/ha. After rice cultivation AVRDC soils generally have a nitrogen content of less than 0.1%. If the mineralization rate of soil nitrogen during Chinese cabbage cultivation is assumed to be 5%, the supply of soil nitrogen available can be assumed to be roughly 110 kg/ha. (This also presumes 15 cm of top soil and a specific gravity of 1.5).

Without nitrogen fertilizer, Chinese cabbage head weights seldom exceed 1 kg, and the marketable yield is at most 26 to 27 t/ha. This would suggest that soil nitrogen alone can support maximum yields of 120 to 130 kg/ha. To obtain yields of over 100 t/ha, farmers must apply 150-160 kg/ha N.

The interactions between main plot and sub-sub plot were insignificant, as were the interactions between sub plot and sub-sub plot (Table 8). The interactions between main plot and sub plot, however, were significant at the 5% level for marketable yield and outer leaf yield, and at the 1% level for total yield. Thus, deep plowing or irrigation did not help fertilizer to increase yields, but deep plowing and improved water management did.

Changes in water tension after irrigation show that the well-developed soil structure of the deeply plowed plots allowed good drainage of excess water. Without deep plowing, drainage was good after initial irrigations, but soils later dispersed and became muddy, which resulted in poorer soil structure and drainage. This retarded root growth and increased the incidence of soft rot infection.

Table 8. Yield component interactions between treatments.

Components / Interaction	Marketable Yield	Outer leaf Yield	Total Yield	CGR
MP x SSP[z]	0.220[y]	1.52	0.72	0.12
SP x SSP	1.07	1.44	1.15	1.21
MP x SP	26.51*	24.67*	132.82**	0.02

[z] MP: Main plot, SP: Sub plot, SSP: Sub-sub plot.
[y] Numerical values indicate F-value.

Conclusions

In the summer a single basal application of 110 kg/ha N is enough to support high yields. Compound fertilizer can support yields 30 to 50% higher than those achieved with straight fertilizer. The total amount of nitrogen applied, then, is not nearly so important as the rate at which that nitrogen becomes available to the plant. The best treatment is probably a single basal application of 110 kg/ha N, 60 kg/ha P_2O_5, and 90 kg/ha K_2O.

In the fall season, a single basal application of 110 kg/ha N is was sufficent to support relatively high yields, but yields may be in-

creased even further by additional top dressing. Deep plowing cannot increase yields significantly, but does seem to be of some benefit. Deep plowing and good water management together can increase yields significantly. Without deep plowing, frequent irrigation can destroy soil aggregates and damage soil enough so that drainage will be poor, and soft rot incidence may increase. Excessive irrigation should thus be avoided, and soil water tension in the dry season should be maintained at pF 2.3 to 2.5.

Effects of Soil Type on Mungbean Root Disease Complex

Introduction

Mungbean's growth is easily stunted when it is planted continuously on the same piece of land, possibly because of phenomenon known as the mungbean root disease complex. The present study was designed to learn more about how this phenomenon is influenced by variations in soil type.

Materials and Methods

Mungbean was grown in pots filled with six different soils from various parts of Taiwan. All soil samples had been collected from fields recently planted to mungbean. A split plot design was used with three replications.

Main plots consisted of soils from AVRDC, from the Chiayi branch of the Taiwan Agricultural Research Institute, and from the Kaohsiung, Tainan, Yensui, and Fengshan Tropical Horticulture Experimental Stations. Subplots consisted of sterilized soil, unsterilized soil, and soil which had been sterilized and then had added to it a small amount of soil from an AVRDC field where mungbean had shown typical symptoms of the damage which results from continuous cropping. The characteristics of these soils are shown in Figure 2 and Tables 9 and 10.

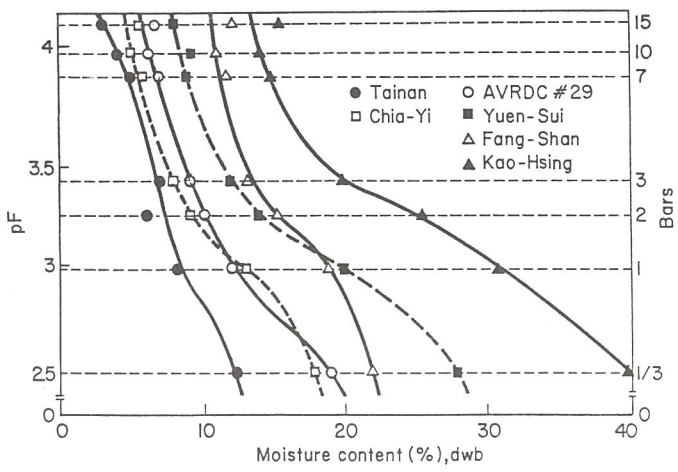

Fig. 2.
The relationship between pF value and moisture content.

Table 9. Relevant properties of the experimental soils.

Soils origin		pH	EC mmhos/cm	T-N %	P_2O_5 ppm	K_2O ppm	CaO ppm	MgO ppm
Kaohsiung	DAIS	5.68	0.48	0.221	64	52	1869	260
Tainan	DAIS	6.01	0.09	0.061	139	156	493	84
Fongshan	THES	4.35	0.19	0.085	26	124	148	51
Chia yi	TARI	5.64	0.12	0.080	46	113	842	132
AVRDC	# 29	7.47	0.64	0.067	72	45	2843	315
Yensue		8.40	0.82	0.112	72	76	4434	764

Table 10. Textures of six experimental soils.

Location	Soil texture (volume %[z])			Origin and classification
	Sand	Silt	Clay	
Kaohsiung	43.9	24.8	31.3	Alluvial, slate origin, clay loam
Tainan	74.4	12.0	13.6	Alluvial, sand stone 4 slate, sandy loam
Fongshan	57.8	22.5	19.7	Hill soil, strong acidic, sandy loam
Chia yi	63.0	22.8	14.2	Latosol, sandy loam
AVRDC	64.4	16.0	19.6	Alluvial, sandy loam
Yensui	49.9	32.4	17.7	Alluvial affected by brackish water, loam

[a] Measured by hydrometer method.

Results

In the unsterilized plot, initial stunting was observed in all soils but the Yensui sample. Stunting was greatly reduced in the sterilized plots, but the addition of even a small amount of soil inoculant negated the effects of sterilization (Table 11). Mungbean did not survive when grown on unsterilized Kaohsiung and AVRDC soils, and did poorly in these soils even when they were sterilized. When planted in other soils mungbean recovered after initial stunting, but grew more poorly in sterilized than in unsterilized soils.

Table 11. Mungbean growth on six different soils, 50 days after germination.

Soil origin	Treatment		
	CK	Sterilized	Sterilized+Inoculated
Fongshan	5	3	3
Tainan	5	4	4
Yensui	5	3	2
Kaohsiung	1	4	4
TARI	5	2	2
AVRDC	1	3	3

5: very good; 4: good; 3: oridinary; 2: poor; 1: very poor.

Conclusions

Although this experiment is still in progress, and the chemical and physical properties of these particular samples have yet to be precisely determined, previous analyses have shown both Kaohsiung and AVRDC soils to have relatively high clay contents, and thus poorer drainage.

Any pathogens present would be absorbed on the surface, and would not easily leach out. This may explain why mungbean grew better on well-drained soils such as those found at Fengshan and Chiayi.

Effects of Selected Mungbean Management Practices

Introduction

Mungbean's growth is easily stunted when it is planted continuously on the same piece of land. Although flooding for one month between plantings has been shown to double the yield of the second planting, yields remain at around 1 t/ha, and never approach the normal 1.8 to 2.0 t/ha. This experiment was designed to find more effective and practical ways to solve this problem, and investigated the effects of submergence, mulching with black vinyl sheeting, plowing in rice straw, and interactions of the three.

Materials and Methods

Soil from a field which had been planted to mungbean during the previous season was placed in 1/5000 Wagner pots. A split-split plot design was used with three replications. Main plots were submergence, no submergence, and submergence with puddling twice a week. Subplots were either covered or not covered with black vinyl sheeting. Sub-sub plots received 0, 2, 10, or 50 g of rice straw per pot. After three weeks one seed of mungbean cultivar A 1973 was sown in each pot.

Results

Results are shown in Table 12. Black vinyl sheeting was able to only slightly increase soil temperatures; they averaged about 40°C during the experiment, with or without sheeting. Temperatures were lowered 2 to 3 degrees by submergence. The initial stunting typical of the mungbean root disease complex was not apparent even in the control plot. Except for height, all differences between treatments in the sub and sub-sub plots were insignificant at the 5% level. Increased applications of rice straw caused chlorosis and reduced yields. Submergence + puddling increased yields by 17%, but submergence alone did not increase yields significantly.

Conclusions

Because of high soil temperatures during the experiment, no initial stunting occurred in any of the test plots. Because the symptoms of

Table 12. The results of Duncan's multiple range test for some relevant growth and yield components.

Treatments	Height (cm)	Total weight (g/pot)	Pod no. (g/pot)	Seed weight (g/pot)
Main plot				
Submergence + puddling (SP)	SP 73.46 A	SP 28.52 A	SP 35.13 A	SP 16.61 A
Submergence (S)	S 67.72 B	N 24.37 B	N 31.71 B	N 14.60 B
None (N)	N 62.63 C	S 24.11 B	S 31.54 B	S 14.25 B
	LSD (.05) = 3.99	LSD (.05) = 2.11	LSD (.05) = 2.15	LSD (.05) = 1.13
Sub plot				
Without Vinyl sheet	N 68.51 A	V 25.73 A	N 33.06 A	V 15.18 A
With vinyl sheet	V 67.36 A	N 25.60 A	V 32.53 A	N 15.13 A
	LSD (.05) = 2.46	LSD (.05) = 2.08	LSD (.05) = 2.31	LSD (.05) = 1.44
Sub-sub plot				
Rice straw 0 g/pot (RO)	RO 71.25 A	RO 26.50 A	RO 33.44 A	RO 15.89 A
Rice straw 2 g	R1 68.37 B	R3 26.06 A	R3 33.22 A	R1 15.13 A
Rice straw 10 g	R2 66.91 BC	R1 25.73 A	R1 32.61 A	R3 14.87 A
Rice straw 50 g	R3 65.22 C	R2 24.37 A	R2 31.89 A	R2 14.74 A
	LSD (.05) = 2.85	LSD (.05) = 2.79	LSD (.05) = 3.76	LSD (.05) = 1.95

mungbean root disease complex apppear to be more serious at temperatures below 25°C, farmers growing autumn mungbean in the tropics would do well to harvest before soil temperatures fall below that level.

Submergence + puddling eliminated the symptoms of mungbean root disease complex, and increased yields by 17%.

Cultivating Tomato on High Beds

Introduction

High temperatures and flooding are both major constraints of tomato production in the tropics. This study was designed to determine whether their effects could be mitigated by cultivating tomato on higher than normal beds.

Materials and Methods

In the first experiment, conducted in the summer of 1983, heat tolerant tomato cultivar 1131-38 was planted on a 20 cm raised bed and on a 50 cm raised bed which had erected over it a clear vinyl roof whose outer edges were 125 cm above the bed's surface (Figure 3).

Each 1 x 10 m bed was planted to 2 rows of tomato, with 50 cm between plants and 50 cm between rows. Seeds were planted on May 25, 1983, seedlings were transplanted to the field on June 15, and fruits

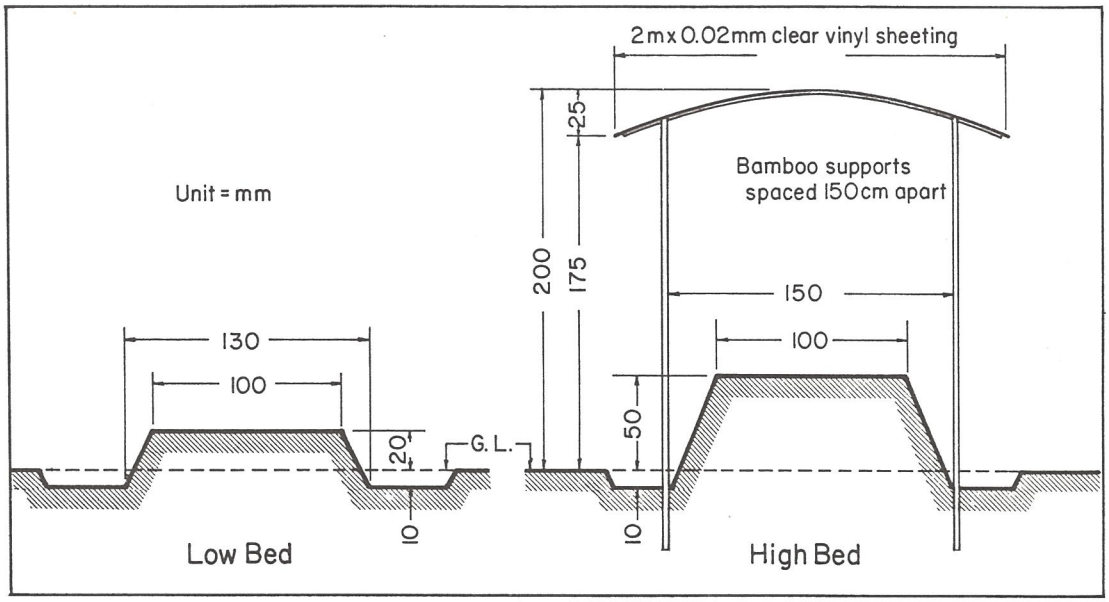

Fig. 3. Schematic description of low and high beds.

were harvested on August 28, September 15, October 7, October 30, and November 30.

Low beds received normal applications of basal fertilizer, but high beds received none. High beds later received 1/20 the normal amount of fertilizer, and 1/30 the normal amount of water.

In a separate experiment conducted in the autumn, cultivars TK 70 and Tainan No. 2 were planted on September 23, transplanted to the field on October 14, and harvested on December 27, January 14, February 24, March 14, and April 2, 1984. Experimental design and planting density were similar to those used for the first experiment, but this time the high bed's height was increased to 1 m, and it received 30 kg/ha N, 20 kg/ha P, and 30 kg/ha K. The low bed received 180 kg/ha N, 100 kg/ha P, and 180 kg/ha K. Water tension at a depth of 20 cm was measured twice a day.

For the first few days after transplanting each seedling on the high bed received approximately 1.5 l of water at the fruit-enlarging stage of the second harvest.

Results and Discussion

Summer trial:

Plants on the low bed were unprotected from the heavy rains which occurred just after transplanting, and nearly all were severely damaged. The most severe damage was not caused by direct contact with the rain drops, but rather by oxygen deficiencies due to the thin layer of clay which covered the surface of the soil after the rain. These rains also washed a great deal of clay from the low beds, leaving behind a bed

which was eroded and sandy. Although plants on the low beds had almost no harvestable yield, those on the high beds yielded roughly 15 t/ha.

Autumn trial:

Plants on the high beds had dark green leaves, but the leaves of those on the low beds, despite the application of top dressing, remained chlorotic. Nevertheless, they seemed to grow well throughout the season. Plants on the high bed were generally shorter, but had more branches and flowers. On the low bed, total water consumption up to the first harvest was roughly 192 l per plant for both cultivars. On the high bed it was about 2.2 l per plant for Tainan No. 2, and 7.1 per plant for TK 70.

Three weeks after transplanting, when the first readings were taken, pF values had already reached 2.4 in the high bed (Table 13). A week later they reached 2.7, and never rose appreciably higher.

Two months after transplanting, when fruit began to enlarge, TK 70 planted on the high bed began to wilt, and some of its fruits showed signs of blossom-end rot. Tainan No. 2 showed no signs of wilting, but did show some blossom-end rot.

Plants on the high bed had more flowers, and had more fruit during the first harvest (Table 14). By the second harvest, though, plants grown on the high bed were producing fewer and smaller fruits. For TK 70 this gap narrowed again by the fourth harvest, and Tainan No. 2 yielded twice as much on the high bed as on the low bed. By the fifth harvest, TK 70's fruit number and weight were 100% higher on the high bed than on the low bed, and Tainan No. 2's fruit number was 100% and its fruit weight 20% higher on the high bed than on the low bed.

Plants grown on the low bed apparently suffered from nitrogen deficiency three months after transplanting, and flowering and fruiting were greatly inhibited.

Although the apparent nitrogen deficiency suffered by plants on the low bed around three months after transplanting severely retarded flowering and fruiting, plants on the high bed, which each received about 1.5 l of water after the third harvest, continued to flower and set fruit.

Plants grown on the high bed had more fruit, but were generally smaller, and produced less total fruit weight than did those grown on the low bed.

In organoleptic tests, tomatoes grown on the high bed were generally found superior to those grown on the low bed (Table 15), and laboratory analysis would suggest that this was due primarily to higher Hunter color ratings and higher levels of soluble solids and titratable acids (Table 16).

Conclusions

Growing tomato on a 100 cm raised bed with a vinyl roof can save a great deal of water and fertilizer, and can improve tomato's growth and yield in both wet and dry seasons. Then, too, by keeping raindrops from striking the soil directly, it can stop them from dispersing clay particles, and thus prevent erosion. further, by preventing the forma-

tion of relatively nonpermeable layer of clay on the soil's surface, this technique can make more oxygen available to the plant. To maintain yields and prevent blossom-end rot, however, plants should be watered at the fruit enlarging stage.

Table 13. Change in pF values during the growth period.

Date	High bed Time measured 8:00	13:00	16:00	Water added/plant	Date	Low bed Time measured 8:00	13:00	16:00	Remarks
Nov 7	2.39	2.48	-		Nov 7	1.65	1.76	-	
Nov 8	2.51	2.45	2.48		Nov 8	1.86	1.94	1.81	
Nov 9	2.6	2.61	2.62		Nov 9	1.81	1.84	1.85	
Nov 10	2.52	2.66	2.61		Nov 10	1.85	1.91	2.14	
Nov 11	2.57	2.58	2.61		Nov 11	1.92	1.85	1.88	
Nov 12	2.59	-	-		Nov 12	1.93	-	-	
Nov 13	2.67	-	-		Nov 13	1.97	-	2.12	
Nov 14	2.68	2.66	2.65		Nov 14	2.07	1.68	1.17	Irrigation
Nov 15	2.69	2.69	2.72		Nov 15	1.82	1.99	2.01	
Nov 16	2.72	2.76	2.74		Nov 16	1.96	2.11	2.13	
Nov 17	2.7	2.7	2.72		Nov 17	2.04	2.1	2.12	
Nov 18	2.73	2.78	2.76		Nov 18	2.05	2.27	2.29	
Nov 19	2.71	2.76	2.76		Nov 19	2.17	2.36	2.37	
Nov 20	2.71	2.72	2.73		Nov 20	2.29	2.35	2.37	
Nov 21	2.74	2.78	2.74		Nov 21	2.26	1.97	1.4	Irrigation
Nov 22	2.73	2.78	2.77		Nov 22	1.49	1.74	1.81	
Nov 23	2.72	2.76	2.76		Nov 23	1.74	2.1	2.13	
Nov 24	2.71	2.7	2.71		Nov 24	1.96	1.96	1.96	
Nov 25	2.7	2.7	2.72		Nov 25	2.16	2.18	2.2	
Nov 26	2.73	2.73	2.73		Nov 26	2.15	2.26	2.28	
Nov 28	2.74	2.77	2.77		Nov 28	2.24	1.3	1.74	Irrigation
Nov 29	2.74	2.73	2.74		Nov 29	1.51	1.8	1.86	
Nov 30	2.75	2.79	2.79		Nov 30	1.8	2.02	2.05	
Dec 1	2.75	2.75	2.76		Dec 1	1.88	1.89	1.93	
Dec 2	2.76	2.77	2.78		Dec 2	1.83	2.21	2.23	
Dec 3	2.75	2.75	2.77		Dec 3	2.13	2.24	2.25	
Dec 4	2.76	2.76	-		Dec 4	2.21	2.29	-	
Dec 5	2.77	2.8	2.8		Dec 5	2.24	2.42	2.41	
Dec 6	2.77	2.77	2.76		Dec 6	2.25	2.53	1.57	Irrigation
Dec 7	2.78	2.78	2.78		Dec 7	-	-	-	
Dec 8	2.78	2.82	2.82		Dec 8	-	1.97	2.0	
Dec 9	2.78	2.77	2.79		Dec 9	1.96	1.96	1.95	
Dec 12	2.79	2.79	2.79		Dec 12	2.03	2.2	2.22	
Dec 13	2.8	2.8	2.82	TK 70 500cc	Dec 13	2.12	2.28	2.45	
Dec 14	2.77	2.88	2.19		Dec 14	2.36	2.49	2.52	Irrigation
Dec 15	2.9	2.85	2.86		Dec 15	-	-	-	
Dec 16	2.82	2.84	2.85		Dec 16	1.24	1.51	1.6	
Dec 18	-	2.8	-		Dec 18	-	1.94	-	
Dec 19	2.81	2.84	2.86		Dec 19	1.94	2.18	2.21	
Dec 20	2.8	2.85	2.86	TK 70 1000cc	Dec 20	2.16	2.27	2.26	
Dec 21	2.77	2.77	2.79	TK 70 1000cc	Dec 21	2.1	2.18	2.19	
Dec 22	2.76	2.83	2.85	TK 70 1000cc	Dec 22	2.08	2.34	2.36	
Dec 23	2.75	2.84	2.85	TK 70 1000cc	Dec 23	2.36	2.45	2.46	Irrigation
Dec 27	2.78	2.85	2.84		Dec 27	2.26	2.27	2.35	Irrigation
Dec 28	2.7	2.76	2.79		Dec 28	1.96	1.96	1.91	
Dec 29	2.75	2.81	2.79		Dec 29	1.83	2.02	1.98	
Dec 30	2.68	2.76	2.77		Dec 30	1.98	1.91	1.92	
Jan 1	2.77	2.76	2.77	TK 600cc	Jan 1	1.88	1.91	-	
Jan 2	2.75	2.73	2.73	TN_2 900cc	Jan 2	1.91	1.91	-	
Jan 3	2.73	2.74	2.72		Jan 3	1.94	1.92	-	
Jan 4	2.73	2.83	2.82	TK 500cc	Jan 4	2.06	2.33	2.35	
Jan 5	2.75	2.84	2.82		Jan 5	2.33	2.37	2.1	Irrigation
Jan 6	2.69	2.72	2.74		Jan 6	2.26	2.3	2.31	
Jan 9	2.76				Jan 7	2.32			

Table 14. Yields of tomato cultivated on high and low beds.

		Fruit no.	High bed Total weight (kg)	Average weight (g/fruit)
TK 70	1st harvesting (Dec 27, 1983)	107	9.90	92.5
	2nd harvesting (Jan 14, 1984)	502	30.30	60.4
	3rd harvesting (Feb 24, 1984)	431	27.55	63.9
	4th harvesting (Mar 14, 1984)	330	20.55	62.3
	5th harvesting (Apr 2, 1984)	582	36.95	63.5
	Total	1952	125.25	64.2
			Low bed	
	1st harvesting	103	12.95	125.7
	2nd harvesting	589	50.80	86.2
	3rd harvesting	573	40.70	71.0
	4th harvesting	323	21.30	65.9
	5th harvesting	336	15.55	46.2
	Total	1924	141.30	73.3
Tainan No. 2			High bed	
	1st harvesting	168	11.40	67.9
	2nd harvesting	460	27.50	59.8
	3rd harvesting	390	22.05	56.5
	4th harvesting	651	26.70	41.0
	5th harvesting	674	22.80	33.8
	Total	2343	110.45	47.1
			Low bed	
	1st harvesting	109	10.90	100.0
	2nd harvesting	676	53.85	79.7
	3rd harvesting	659	40.74	61.8
	4th harvesting	254	13.35	52.6
	5th harvesting	318	18.15	57.1
	Total	2016	136.99	68.0

Table 15. Organoleptic ratings of tomatoes grown on high and low beds.

Color	Excellent		Good	Poor
HB	17		3	
LB	4		16	
Hardness	Hard		Medium	Soft
HB	11		6	3
LB	6		9	5
Taste	Excellent		Good	Fair
HB	8		9	4
LB	2		9	8
Sweetness	Sweet	Fair	Not sweet	Sour
HB	9	10	0	1
LB	3	9	6	2
Texture	Good		Medium	Sponge
HB	9		9	0
LB	3		16	1
Juice	Much		Medium	Little
HB	7		13	0
LB	9		9	2

Table 16. Selected characteristics of fruit from tomatoes grown on high and low beds.

Sample	pH	Soluble Solids (°Brix)	Vit. C mg/100g	Titratable acidity %	Hunter color (a/b)	β-carotene mg/100g
High bed Tainan No. 2	4.22	4.68	13.16	0.362	2.43	0.125
Low bed Tainan No. 2	4.21	4.08	13.49	0.304	2.34	0.121
High bed TK 70	4.19	5.50	16.45	0.533	2.54	
Low bed TK 70	4.15	4.21	16.45	0.394	2.16	

Optimal Soil Management and Fertilizer Applications for Soybean

Introduction

When soybeans are well managed, symbiotic nitrogen fixation can supply up to 100 kg/ha of nitrogen, and can make up over 50% of their total nitrogen uptake. Nevertheless, without additional nitrogen the highest yield it can support is about 2 t/ha. Applying additional nitrogen, however, suppresses nitrogen fixation. This experiment was designed to identify the management practices which can bring both optimum and maximum yields under low input conditions.

Materials and Methods

Two experiments were conducted, one in the spring and the other in the fall. In each case a split-split plot design was used with two replications. Details of each experiment are shown in Tables 17 and 18.

Table 17. Treatments in experiment I.

Main plot Rice straw application (10 ton/ha)	Sub plot Nitrogen level (kg/ha)			Sub-sub plot Phosphorus level (kg/ha)
	Basal	Top[z]	Top[y]	Basal
None	0			0
Mulching	30			80
Plowing	30	30		
	30	30	30	

[z] At flowering stage.
[y] At pod-filling stage.

Table 18. Treatments in experiment II.

Main plot Deep plowing	Sub plot Mulching		Sub-sub plot Fertilization treatment N	P_2O_5	K_2O	Remark[z]
None	None					
Deep plowing with 20 ton/ ha compost	Mulching with 10 ton/ha straw	Basal	30	80	100	Straight fertilizer
		Top	30	-	-	
		Basal	30	45	30	C.F. 39#
		Top	30	15	22.5	C.F. 5#
		Basal	30	15	60	C.F. 4#
		Top	30	45	30	C.F. 39#
		Basal	30	24.5	49	C.F. 2#
		Top	30	7.5	15	C.F. 1#
		Basal	30	15	22.5	C.F. 5#
		Top	30	45	30	C.F. 39#

[z] C.F. indicates compound fertilizer, constituents of CFs are as follows: C.F. 1# 20-5-10 ($N-P_2O_5-K_2O$), C.F. 2# 11-9-18, C.F. 4# 11-5.5-22, C.F. 5# 16-8-12, C.F. 39# 12-18-12.

Results

In the first experiment, fresh and dry weights and leaf area (LAI) of plants at the flowering stage were significantly different in the mulched and unmulched plots in the plowed plot (Table 19). Plowed-in rice straw, which has a high C/N ratio, greatly increased nodule number and weight, but only at the expense of initial plant growth, which was greatly retarded from one week after germination until the flowering stage. Soil nitrogen concentration was inversally proportional to the rate of nodule formation.

Table 19. Results of Duncan's multiple range test for selected growth parameters at the flowering stage.

Treatment	Top dry weight (g/plant)	LAI	Nodule no. (per plant)	Nodule weight (per plant)
Main plot				
None (N)	N 1.56 A	N 1.06 A	P 521 A	P 7.50 A
Mulching (M)	M 1.55 A	M 1.05 A	M 334 B	M 5.71 AB
Plowing (P)	P 1.28 B	P 0.85 B	N 295 B	N 3.82 B
	LSD(.05)=0.15	LSD(.05)=0.13	LSD(.05)=113	LSD(.05)=2.15
Sub-sub-plot				
Phosphorus 0 (PO)	P8 1.65 A	P8 1.15 A	P8 407 A	P8 6.96 A
Phosphorus 80 kg/ha (P8)	PO 1.27 B	PO 0.82 B	PO 360 A	PO 4.41 B
	LSD(.05)=0.15	LSD(.05)=0.09	LSD(.05)=121	LSD(.05)=2.66

Although LAI and leaf dry weight were good indices of plant growth, nodule formation was associated less with initial top growth than with increased root dry weight. Increased nodule formation, then, could perhaps be achieved through more vigorous root growth.

Plowing in rice straw retarded top growth, but significantly increased nodule number (Table 20). Mulching increased both plant growth and nodule formation. Because rice straw mulch affected only a thin layer on the surface of the soil, during the initial growth stages soybean roots were able to take up nitrogen from lower layers of the soil, and were relatively unaffected by the mulch.

Roots near the surface were later found to contain more nodules, confirming that nodule formation is sensitive to nitrogen concentration, soil moisture, and partial oxygen pressure. The optimum concentration of free oxygen in nodule bacteroids is reportedly less than 1 μm; beyond that point nitrogenase activity cannot reach maximum levels.

Initial plant growth was supported primarily by roots in the deeper layers of the soil, but more rapid nodule formation in the roots near the surface meant that nitrogen fixation would later make up a greater percentage of the plant's total nitrogen uptake.

Although at the flowering stage basal applications of nitrogen were far more effective in promoting soybean growth than was a top dressing of nitrogen, in the check plots they were actually detrimental to soybean growth.

Even though the LAI and total dry weight are usually good indices of plant growth, at this point they gave no indication of the lower grain yields which were to be caused by rust and lodging at a later growth stage.

Plowing and mulching of rice straw seemed to favor soybean growth (Table 21). Top dressing at the flowering and pod-filling stages significantly increased plant height, total dry weight, and LAI, and even accelerated nodule formation.

Total dry weight, LAI, and NAR were closely correlated with plant growth and pod number, but yield and yield components, probably because of the rust and lodging mentioned earlier, had either no correlation or a negative correlation with plant growth (Table 22).

Although yield differences between main plots were statistically insignificant, mulching and plowing seemed to slightly favor soybean growth and yield (Table 23). Plowing in rice straw increased 100-seed weight significantly; apparently vigorous nodule formation and the mineralization of the nitrogen immobilized earlier must have supplied sufficient nitrogen during and after the pod-filling stage. This was confirmed by similar increases in 100-seed weight brought about by top dressings of nitrogen.

Seed number, on the other hand, was reduced by plowing in rice straw, and was not increased by top dressings of nitrogen. As a result of induced by initial nitrogen deficiency, this reduction in seed number could lead to reduced yields. Top dressing, although unable to increase seed number, did increase top growth. Unfortunately, it also increased soybean's susceptibility to rust and lodging.

In the second experiment, deep plowing failed to significantly accelerate initial growth, and seemed to suppress nodule formation (Table 23). Mulching with rice straw, however, accelerated both initial growth and nodule formation, just as in the first experiment. Fertil-

Table 20. Results of Duncan's multiple range test for selected growth parameters at the pod filling stage, Spring 1983.

Treatments	Height	Node no.	Root dry wt.	Total dry wt.	Nodule no.	Nodule wt.	LAI
Main plot							
None (C)	C 36.6 A	M 8.8 A	M 7.67 A	M 44.7 A	P 516.3 A	P 10.65 A	M 3.05 A
Mulching (M)	M 35.4 A	C 8.7 A	C 7.21 A	C 43.0 A	M 475.9 A	M 10.62 A	C 2.79 A
Plowing (P)	P 32.7 B	P 8.6 A	P 6.19 A	P 38.3 A	C 402.3 B	C 8.90 A	P 2.68 A
	LSD(.05)=0.7	LSD(.05)=0.5	LSD(.05)=1.61	LSD(.05)=10.2	LSD(.05)=48.0	LSD(.05)=3.18	LSD(.05)=0.51
Sub plot							
Nitrogen 0 kg/ha (NO)	N_3 36.3 A	N_3 8.9 A	N_3 7.72 A	N_3 45.6 A	N_6 445.7 A	N_6 10.79 A	N_3 3.02 A
Nitrogen 30 kg/ha (N_3)	N_6 36.2 A	N_6 8.8 AB	N_6 6.97 AB	N_6 43.5 A	NO 445.7 A	NO 10.1 AB	N_6 2.97 AB
Nitrogen 60 kg/ha (N_6)	NO 32.2 B	NO 8.5 B	NO 6.38 B	NO 36.9 B	N_3 444.3 A	N_3 9.37 B	NO 2.54 B
	LSD(.05)=2.2	LSD(.05)=0.4	LSD(.05)=0.95	LSD(.05)=5.9	LSD(.05)=64.8	LSD(.05)=1.16	LSD(.05)=0.43
Sub-sub plot							
Phosphorus 0 kg/ha (PO)	N_8 35.9 A	P_8 8.9 A	P_8 7.12 A	P_8 43.8 A	P_8 471.9 A	PO 10.12 A	P_8 2.94 A
Phosphorus 80 kg/ha (P_8)	PO 33.9 A	PO 8.6 B	PO 6.92 A	PO 40.1 A	PO 457.8 A	P_8 10.00 A	PO 2.74 A
	LSD(.05)=2.4	LSD(.05)=0.2	LSD(.05)=0.48	LSD(.05)=4.9	LSD(.05)=78.9	LSD(.05)=1.41	LSD(.05)=0.34

Table 21. Results of Duncan's multiple range test for selected growth parameters at harvest, Spring 1983.

Treatments	Height (cm)	Pod no. (per plant)	Nodule no.	Nodule wt.	Total dry wt.	LAI	NAR
Main plot							
None (C)	C 68.0 A	M 31.6 A	M 775 A	M 31.88 A	P 155.0 A	P 4.71 A	P 1.07 A
Mulching (M)	M 67.1 A	M 29.7 A	C 597 A	C 26.34 A	M 154.0 A	M 4.74 A	C 1.00 A
Plowing (P)	P 65.5 A	C 29.0 A	C 580 B	C 26.29 A	C 151.4 A	C 4.42 A	M 0.98 A
	LSD(.05)=3.1	LSD(.05)=6.0	LSD(.05)=190	LSD(.05)=7.09	LSD(.05)=22.7	LSD(.05)=0.32	LSD(.05)=0.27
Sub plot							
Nitrogen 0 kg/ha (NO)	N_9 69.5 A	N_6 30.6 A	N_6 687 A	N_6 30.23 A	N_9 158.5 A	N_6 4.76 A	NO 1.07 A
Nitrogen 30 kg/ha (N_3)	N_6 68.7 A	NO 30.4 A	N_9 647 A	N_9 28.62 A	N_6 158.3 A	N_9 4.67 AB	N_6 1.02 A
Nitrogen 60 kg/ha (N_6)	N_3 66.5 B	N_9 30.0 A	NO 640 A	NO 27.89 A	N_3 153.3 AB	NO 4.37 AB	N_3 0.99 A
Nitrogen 90 kg/ha (N_9)	NO 62.8 C	N_3 29.4 A	N_3 637 A	N_3 25.92 A	NO 143.8 B	N_3 4.33 B	N_9 0.99 A
	LSD(.05)=2.7	LSD(.05)=2.3	LSD(.05)=165	LSD(.05)=4.96	LSD(.05)=9.88	LSD(.05)=0.38	LSD(.05)=0.13
Sub-sub plot							
Phosphorus 0 kg/ha (PO)	N_8 68.6 A	P_8 30.2 A	P_8 671 A	P_8 28.75 A	P_8 155.1 A	PO 4.58 A	PO 1.03 A
Phosphorus 80 kg/ha (P_8)	PO 65.2 B	PO 30.3 A	PO 630 A	PO 27.58 A	PO 151.9 A	P_8 4.48 A	P_8 1.00 A
	LSD(.05)=1.7	LSD(.05)=0.8	LSD(.05)=99	LSD(.05)=2.71	LSD(.05)=5.56	LSD(.05)=0.18	LSD(.05)=0.06

izer treatments F_1 and F_3 showed better initial soybean growth than did treatments F_3 and F_5. This positive response to phosphorus applications in the initial growth stage may have been caused by more rapid root growth. Applying too much phosphorus could result in nitrogen deficiencies, however, if unaccompanied by applications of nitrogen at similarly high rates.

Table 22. The results of Duncan's multiple range test for soybean yield and yield components, Spring 1983.

Treatments	Yield (t/ha)	100 seed wt. (g)	Seed no.
Main plot			
None (C)	M 1.98 A	P 10.99 A	M 800 A
Mulching (M)	P 1.91 A	C 10.78 AB	C 783 A
Plowing (P)	C 1.75 A	M 10.74 B	P 769 A
	LSD(.05)=0.35	LSD(.05)=0.23	LSD(.05)=52
Sub plot			
Nitrogen 0 kg/ha (NO)	N_9 1.95 A	N_9 11.02 A	N_3 798 A
Nitrogen 30 kg/ha (N_3)	N_6 1.95 A	N_6 11.01 A	NO 789 A
Nitrogen 60 kg/ha (N_6)	N_3 1.88 A	N_3 10.72 B	N_4 778 A
Nitrogen 90 kg/ha (N)	NO 1.76 A	NO 10.60 B	N_6 771 A
	LSD(.05)=0.20	LSD(.05)=0.22	LSD(.05)=63
Phosphorus 0 kg/ha (PO)	P_8 1.90 A	PO 10.86 A	PO 793 A
Phosphorous 80 kg/ha (P_8)	PO 1.86 A	P_8 10.82 A	P_8 775 A
	LSD(.05)=0.11	LSD(.05)=0.12	LSD(.05)=53

At the pod-filling stage no significant differences were noted between the deeply plowed and the unplowed treatments (Table 24). Mulching had begun to favor both soybean growth and nodule formation, and plants in fertilizer treatments F_1 and F_2. The more rapid growth of plants in treatments F_3 and F_4 can probably be traced to the nitrogen top dressing they received. Photosynthate fixed during the flowering and pod-filling stages is translocated primarily to the pods, and increases in photosynthetic rate brought about by top dressing at the flowering stage can translate directly into increased yields. At the pod-filling stage LAI was closely correlated with plant growth, but not with pod dry weight. Just the opposite was true with NAR.

At harvest, there were no significant differences between unplowed and deeply plowed treatments, but soybean growth was spurred by rice straw mulching (Table 25). Yield and yield components were not sig-

nificantly increased by deep plowing, but they were increased by mulching, with no significant differences in yield components within mulching treatments (Table 26). Phosphorus applications seemed to increase seed number, and potassium seemed to accelerate the translocation of photosynthate.

Conclusions

Plowing in organic materials such as rice straw, which has a high C/N ratio, can accelerate nodule formation considerably, but only at the expense of initial plant growth. As a result, rice straw, should be applied a basal nitrogen dressing of at least 30 kg/ha. An additional 30 kg/ha top dressing at the flowering stage can increase grain yields even further. Rice straw mulching can accelerate nodule formation without retarding initial plant growth, and is probably a better choice than plowing in rice straw.

Deep plowing not only improves the physical properties of the soil, but also accelerates root growth and nodule formation, which in turn increases the plant's soil nitrogen uptake.

Farmers, therefore, should plow deeply and then apply a rice straw mulch, and with it a basal dressing of 30 kg/ha N, 60 to 80 kg/ha P_2O_5, and 60 to 100 kg/ha K_2O. They should later apply a 30 kg/ha N top dressing at the flowering stage.

(Continued on the next page)

Table 23. The results of Duncan's multiple range test for selected growth parameters at the flowering stage, Autumn 1983.

Treatments	Height (cm)	LAI	Nodule no.	Nodule dry wt.	Root dry wt.	Stem dry wt.	Leaf dry wt.
Main plot							
None (N)	N 40.9 A	D 2.90 A	C 342 A	C 1.36 A	D 2.65 A	D 13.0 A	D 12.9 A
Deep plowing (D)	D 40.7 A	N 2.81 A	D 234 B	D 1.01 A	N 2.55 A	N 12.6 A	N 12.4 A
	LSD(.05)=2.2	LSD(.05)=0.95	LSD(.05)=4	LSD(.05)=1.42	LSD(.05)=2.10	LSD(.05)=5.8	LSD(.05)=5.2
Sub plot							
None (N)	M 41.2 A	M 2.99 A	M 333 A	M 1.23 A	M 2.65 A	M 13.5 A	M 13.0 A
Mulching (M)	N 40.4 B	N 2.72 B	N 244 B	N 1.14 A	N 2.55 A	N 12.1 B	N 12.3 B
	LSD(.05)=0.6	LSD(.05)=0.13	LSD(.05)=78	LSD(.05)=0.17	LSD(.05)=0.16	LSD(.05)=0.1	LSD(.05)=0.3
Sub-sub plot							
Straight F. (F_1)	F_2 41.4 A	F_2 2.96 A	F_2 305 A	F_2 1.23 A	F_2 2.94 A	F_2 13.5 A	F_2 13.2 A
C. F. 39,5# (F_2)	F_4 41.2 A	F_1 2.91 A	F_4 303 A	F_4 1.22 A	F_4 2.58 B	F_4 12.9 A	F_1 12.8 A
C. F. 4,39# (F_3)	F_3 40.7 A	F_4 2.87 A	F_1 298 A	F_1 1.19 A	F_3 2.55 B	F_1 12.9 A	F_4 12.8 A
C. F. 2, 1# (F_4)	F_1 40.7 A	F_5 2.80 A	F_3 282 A	F_3 1.16 A	F_1 2.48 B	F_5 12.4 A	F_5 12.3 A
C. F. 5,39# (F_5)	F_5 39.8 A	F_3 2.75 A	F_5 253 A	F_5 1.13 A	F_5 2.45 B	F_3 12.3 A	F_3 12.3 A
	LSD(.05)=1.5	LSD(.05)=0.24	LSD(.05)=76	LSD(.05)=0.25	LSD(.05)=0.28	LSD(.05)=1.3	LSD(.05)=0.9

Table 24. The results of Duncan's multiple range test for selected growth parameters at the pod filling stage, Autumn 1983.

Treatment	Root dry wt.	Stem dry wt.	Total dry wt.	Nodule no.	Nodule dry wt.	LAI	NAR (g/day)
Main plot							
None (N)	N 6.27 A	D 31.4 A	N 134.3 A	N 342 A	N 1.36 A	D 4.21 A	N 4.36 A
Deep plowing (D)	D 6.14 A	N 30.0 A	D 133.8 A	D 234 B	D 1.01 A	N 4.10 A	D 4.17 A
	LSD(.05)=2.10	LSD(.05)=27.3	LSD(.05)=88.6	LSD(.05)=4	LSD(.05)=1.42	LSD(.05)=3.44	LSD(.05)=0.36
Sub plot							
None (N)	M 6.34 A	M 33.0 A	M 137.0 A	M 333 A	M 1.23 A	M 4.25 A	N 4.34 A
Mulching (M)	N 6.07 A	N 28.4 B	N 131.1 A	N 244 B	N 1.14 A	N 4.05 A	M 4.20 A
	LSD(.05)=0.84	LSD(.05)=1.8	LSD(.05)=9.0	LSD(.05)=78	LSD(.05)=0.17	LSD(.05)=0.41	LSD(.05)=0.47
Sub-sub plot							
Straight F. (F_1)	F_4 6.85 A	F_4 32.2 A	F_4 139.9 A	F_2 305 A	F_2 1.23 A	F_4 4.24 A	F_4 4.47 A
C. F. 39,5# (F_2)	F_5 6.28 A	F_3 31.0 AB	F_5 135.2 A	F_4 303 A	F_4 1.22 B	F_2 4.19 A	F_5 4.38 A
C. F. 4,39# (F_3)	F_3 6.21 A	F_5 31.0 AB	F_3 133.2 A	F_1 298 A	F_2 1.19 B	F_4 4.16 A	F_3 4.37 A
C. F. 2, 1# (F_4)	F_2 6.13 A	F_2 30.7 AB	F_2 132.5 A	F_3 282 A	F_3 2.48 B	F_1 4.11 A	F_1 4.08 A
C. F. 5,39# (F_5)	F_1 5.83 B	F_1 28.5 A	F_1 129.5 A	F_5 253 A	F_5 1.13 A	F_3 4.08 A	F_2 4.04 A
	LSD(.05)=0.55	LSD(.05)=2.9	LSD(.05)=12.5	LSD(.05)=76	LSD(.05)=0.25	LSD(.05)=0.31	LSD(.05)=0.62

Table 25. Results of Duncan's multiple range test for selected growth parameters at harvest, Autumn 1983.

Treatment	Height	Pod no.	Pod dry wt.	Root dry wt.	Stem dry wt.	Leaf dry wt.	Pod/total
Main plot							
None (N)	D 71.9 A	D 204	D 16.8 A	N 7.53 A	D 36.3	D 24.5 A	C 62.6 A
Deep plowing (D)	N 67.9 A	N 200	N 26.3 A	D 7.22 A	D 34.9	C 22.6 A	D 61.7 A
	LSD(.05)=29.8	LSD(.05)=105	LSD(.05)=19.5	LSD(.05)=12.4	LSD(.05)=14.0	LSD(.05)=21.7	LSD(.05)=1.0
Sub plot							
None (N)	M 71.8 A	M 203 A	M 26.9 A	M 7.71 A	M 37.9 A	M 24.5 A	N 63.0 A
Mulching (M)	N 67.9 B	N 201 A	N 26.2 A	N 7.04 A	N 33.3 B	N 22.5 A	M 61.4 B
	LSD(.05)=1.3	LSD(.05)=26	LSD(.05)=5.2	LSD(.05)=1.00	LSD(.05)=2.7	LSD(.05)=3.0	LSD(.05)=1.1
Sub-sub plot							
Straight F. (F_1)	F_2 71.1 A	F_2 207 A	F_1 27.5 A	F_5 7.79 A	F_2 36.9 A	F_2 24.0 A	F_5 62.3 A
C. F. 39,5# (F_2)	F_4 69.9 A	F_1 206 AB	F_2 27.3 A	F_2 7.71 A	F_1 36.2 AB	F_1 24.0 A	F_1 62.3 A
C. F. 4,39# (F_3)	F_3 69.7 A	F_5 205 AB	F_5 26.8 A	F_1 7.23 A	F_5 35.5 AB	F_3 23.4 A	F_2 62.2 A
C. F. 2, 1# (F_4)	F_1 69.7 A	F_3 198 AB	F_3 25.8 A	F_4 7.10 A	F_3 35.1 AB	F_4 23.1 A	F_3 62.1 A
C. F. 5,39# (F_5)	F_5 69.1 A	F_4 193 B	F_4 25.4 A	F_3 7.04 A	F_4 34.4 A	F_5 23.1 A	F_4 62.0 A
	LSD(.05)=1.9	LSD(.05)=13	LSD(.05)=2.2	LSD(.05)=0.89	LSD(.05)=2.3	LSD(.05)=1.3	LSD(.05)=1.1

Table 26. Results of Duncan's multiple range test for yield components, Autumn 1983.

Treatments	100 seed wt.	Seed no./pod	Seed no.	Yield
Main plot				
None (N)	D 16.5 A	D 2.55 A	D 509 A	D 3.44 A
Deep plowing (D)	N 16.4 A	N 2.48 A	N 506 A	C 3.40 A
	LSD(.05)=2.3	LSD(.05)=0.97	LSD(.05)=466	LSD(.05)=2.45
Sub plot				
None (N)	M 16.7 A	M 2.53 A	M 514 A	M 3.45 A
Mulching (M)	N 16.2 A	N 2.49 A	N 501 A	N 3.40 B
	LSD(.05)=0.7	LSD(.05)=0.09	LSD(.05)=64	LSD(.05)=0.04
Sub-sub plot				
Straight F. (F_1)	F_3 16.7 A	F_2 2.54 A	F_2 526 A	F_1 3.50 A
C. F. 39,5# (F_2)	F_1 16.5 A	F_3 2.53 A	F_1 512 A	F_3 3.50 A
C. F. 4,39# (F_3)	F_2 16.4 A	F_4 2.52 A	F_5 511 A	F_2 3.42 AB
C. F. 2, 1# (F_4)	F_4 16.3 A	F_5 2.49 A	F_3 501 A	F_5 3.38 AB
C. F. 5,39# (F_5)	F_5 16.3 A	F_1 2.48 A	F_4 487 A	F_4 3.33 B
	LSD(.05)=0.5	LSD(.05)=0.09	LSD(.05)=35	LSD(.05)=0.11

The Effect of Underground Drainage Ditches and Various Mulches Upon the Yields of Summer Tomato

Introduction

The effects of high temperatures and heavy rains, the major constraints of summer tomato production in the tropics, could possibly be mitigated by appropriate cultural practices. This experiment tested the ability of underground drainage ditches packed with rice husks to smoothly drain away excess water, and also tested the ability of various mulching materials to improve fruit set by reducing soil temperature.

Materials and Methods

Seeds of heat tolerant cultivar 1131-0-0-38-4-0 were planted on August 3, and seedlings were transplanted to the field on August 15. A split-split plot design was used with two replications. Underground ditches or a lack thereof constituted the main plots, mulching material the sub plots, and fertilizer applications the sub-sub plots (Table 27).

In the drainage plot, ditches 25 cm wide and 60 cm deep were dug at 2 m intervals. The bottom 20 cm of each ditch was filled with rice husks, and the ditches were then filled the rest of the way with soil. Beds were made at right angles to the ditches, and all of them were covered with a rice straw mulch. One-fourth of the beds received an additional mulch of a double layer of silver and black vinyl sheeting.

Table 27. Fertilizer applications.

Treatment	N	P_2O_5	K_2O	Remark[z]
				Compound fertilizer (C.F.)
Basal	50.4	75.6	50.4	C. F. 39# 420 kg/ha
Top	16.8	4.2	24.8	C. F. 1# 84 kg + 26 kg KCl
Basal	50.4	75.6	50.4	C. F. 39# 420 kg
Top	48.0	24.0	36.0	C. F. 5# 300 kg
Basal	50.4	75.6	50.4	C. F. 39# 420 kg
Top[y]	39.6	59.4	39.6	C. F. 39# 300 kg
Top[x]	39.6	59.4	39.6	C. F. 39# 300 kg
Basal	60	80	60	Straight fertilizer
Top	60	0	60	Straight fertilizer
Top	60	0	60	Straight fertilizer

Results and Discussion

The total cost of the underground drainage ditches was US $ 100/ha, By using a tractor it was possible to construct the ditches with 90 man-hours/ha. In sandy or silty soils, however, the ditches lost their effectiveness within one month - primarily due to difficulties involved in developing an effective soil structure. In addition, clay particles washed from the bed coated the surface of the furrows, and prevented most of the water from ever reaching the underground drainage ditches. One month after transplanting, the only significant difference between treatments was a substantially greater fresh fruit weight in the drainage treatment. The summer of 1983 was unusually dry, however; except for the 460 mm of rain which fell between August 21 and 26, there was almost no precipitation during the entire period. Although excess water might have been effectively drained from the beds in the underground ditches, rainfall was so slight that the ditches appear to have been superfluous.

At one month after transplanting, flower number and total plant dry weight were good indicators of both yield and initial growth rate (Table 28). Fruit number, though, was a good indicator of initial growth rate, but a poor indicator of yield.

By 70 days after transplanting, the vinyl sheet mulch had significantly increased fresh fruit weight and total dry weight (Tables 29 and 30). Differences between drainage and no-drainage plots had almost disappeared, apparently because of limited rainfall. Correlations of growth parameters measured at this stage indicate that good initial growth favored high yields.

When root structures were examined after harvest it was found that plants in the underground ditch treatments generally had roots which were long, fine, and fibrous. Most of them descended downwards into the soil, and some even reached deeply enough to penetrate the layer of rice

Table 28. Results of Duncan's multiple range test for selected growth parameters measured at 30 days after transplanting.

Treatments		No. of flower (per plant)	No. of fruit (per plant)	Fruit fresh wt. (g/2 plants)	Total dry wt. (g/2 plants)
Main plot					
None	(N)	V 51.0 A	V 44.0 A	V 97.0 A	V 77.7 A
Underground ditch packed with rice husk	(V)	N 45.7 A LSD(.05)=42.1	N 28.1 A LSD(.05)=37.9	N 64.5 B LSD(.05)=18.6	N 60.9 A LSD(.05)=65.2
Sub plot					
Rice straw mulch	(VM)	VM 52.4 A	VM 37.4 A	VM 87.6 A	VM 71.8 A
Double-layer mulch (Rice straw+black and silver colored vinyl sheet)	(VM)	RS 44.3 A LSD(.05)=1.91	RS 34.6 A LSD(.05)=28.7	RS 73.9 A LSD(.05)=32.3	RS 66.8 A LSD(.05)=33.7
Sub-sub plot					
Compound fertilizer (70 kg N/ha)	(N_1)	N_1 50.1 A	N_1 41.8 A	N_1 106.2 A	N_1 72.8 A
Compound fertilizer (100 kg N/ha)	(N_2)	N_4 49.4 A	N_4 41.3 A	N_4 85.8 A	N_4 68.7 A
Compound fertilizer (130 kg N/ha)	(N_3)	N_2 48.1 A	N_3 33.6 AB	N_3 79.0 AB	N_3 68.1 A
Compound fertilizer (180 kg N/ha)	(N_4)	N_3 45.8 A LSD(.05)=7.6	N_2 27.5 B LSD(.05)=11.8	N_2 52.1 B LSD(.05)=34.0	N_2 67.7 A LSD(.05)=14.7

Table 29. Results of Duncan's multiple range test for selected growth parameters measured at 70 days after transplanting.

Plant height (cm)	Branch no. (per 2 plants)	No. of fruit (per 2 plants)	Fruit fresh wt. (g/2 plants)	Total dry wt. (g/2 plants)
U 97.4 A N 93.9 A LSD(.05)=20.6	U 28.8 A N 25.4 A LSD(.05)=69.1	U 87.3 A N 76.4 A LSD(.05)=166.0	U 1732.9 A N 1684.7 A LSD(.05)=1802.7	U 309.3 A N 269.4 A LSD(.05)=480.4
VM 98.6 A RS 92.8 B LSD(.05)=2.8	VM 28.1 A RS 26.1 B LSD(.05)=0.6	VM 91.6 A RS 72.1 A LSD(.05)=32.7	VM 1903.4 A RS 1514.2 B LSD(.05)=219.2	VM 307.9 A RS 270.8 B LSD(.05)=28.8
N_1 97.1 A N_3 96.4 A N_4 95.4 A N_2 93.9 A LSD(.05)=5.9	N_1 28.9 A N_3 27.4 A N_2 26.5 A N_4 25.6 A LSD(.05)=5.7	N_1 89.9 A N_2 84.0 A N_4 79.4 A N_3 74.1 A LSD(.05)=23.5	N_1 1864.4 A N_2 1818.0 A N_4 1585.8 A N_3 1567.1 A	N_1 310.5 A N_2 295.0 A N_3 284.1 A N_4 267.8 A

husks. In the vinyl mulch plot, most roots were larger and were distributed near the surface. Some, however, penetrated deep into the soil, and were fine and tender. The first were most likely responsible for oxygen uptake and the second for the uptake of nutrients and water.

Both underground ditches and vinyl mulching were able to increase yields at the first harvest (Table 31). Fertilizer treatments, however, did not differ in first-harvest yields. Because of low rainfall and poorly developed soil structure, underground ditches lost their effectiveness after the first harvest (Table 31). Vinyl mulch, however, remained effective, and brought significantly greater fruit yields and fruit number at every harvest.

Table 30. Results of Duncan's multiple range test for selected yield components.

Treatments		Total no. fruit	Average fruit wt. (g)	Total yield (t/ha)
Main plot				
None	(N)	N 5470 A	U 24.4 A	N 57.7 A
Under drainage with rice husk	(U)	N 5206 A	N 23.7 A	U 56.0 A
Sub plot				
Rice straw mulch	(RS)	VM 5753 A	VM 24.3 A	VM 62.7 A
Double layer mulch	(VM)	RS 4923 A	RS 24.2 A	RS 51.0 A
Sub-sub plot				
Compound fertilizer (70 kg N/ha)	(N_1)	N_4 6124 A	N_1 24.3	N_4 63.7 A
Compound fertilizer (100 kg N/ha)	(N_2)	N_3 5542 B	N_3 24.2	N_3 59.5 B
Compound fertilizer (130 kg N/ha)	(N_3)	N_2 5055 C	N_2 24.1	N_2 54.2 C
Straight fertilizer (180 kg N/ha)	(N_4)	N_1 4629 D	N_4 23.6	N_1 50.1 D

Table 31. Results of Duncan's multiple range test for selected yield components.

Treatments		Total no. fruit	Average fruit wt. (g)	Total yield (t/ha)
Main plot				
None	(N)	N 5470 A	U 24.4 A	N 57.7 A
Under drainage with rice husk	(U)	N 5206 A	N 23.7 A	U 56.0 A
Sub plot				
Rice straw mulch	(RS)	VM 5735 A	VM 24.3 A	VM 62.7 A
Double layer mulch	(VM)	RS 4923 A	RS 24.2 A	RS 51.0 A
Sub-sub plot				
Compound fertilizer (70 kg N/ha)	(N_1)	N_4 6124 A	N_1 24.3	N_4 63.7 A
Compound fertilizer (100 kg N/ha)	(N_2)	N_3 5542 B	N_3 24.2	N_3 59.5 B
Compound fertilizer (130 kg N/ha)	(N_3)	N_2 5055 C	N_2 24.1	N_2 54.2 C
Straight fertilizer (180 kg N/ha)	(N_4)	N_1 4629 D	N_4 23.6	N_1 50.1 D

Both rice straw and vinyl mulch were able to maintain similar levels of moisture, but soil temperatures in the vinyl mulch treatment were 2 to 3°C higher (Table 32). Nevertheless, moisture in the vinyl mulch treatment remained adequate throughout the season, especially in the layer of soil near the surface.

Since the vertical movement of water varied between mulch treatments, water tension should ideally have been measured at several depths to accurately measure water movement. The total number of fruits, the total yields, and the average fruit weights for each treatment shown in Table 33 are the totals of all seven harvests, and differ in many respects from the results shown in Table 31 for the first three harvests. After the first three harvests, neither drainage nor mulch had a significant effect on either fruit number or total yield.

Fertilizer treatments, however, began to have a significant effect. Increased nitrogen applications, especially when applied as a top dressing, tended to increase yields. The recommended straight fertilizer greatly increased yields, and was followed by an N_3 treatment, 130 kg/ha N as the total nitrogen applied with two top dressings, then N_2 and finally N_1 treatments, totally 100 kg/ha N, 70 kg/ha N, with one top dressing, respectively. In N_1 and N_2 treatments, which received only one top dressing at one month after transplanting, a shortage of nitrogen limited yields at later growth stages.

Conclusions

Although underground drainage ditches packed with rice husks were economical, easy to construct, and initially effective, they quickly lost their effectiveness in sandy or silty soils. Good soil structure could not be easily developed, and particles of clay which washed from the beds quickly reduced the permeability of the soil in the furrow. This erosion was somewhat reduced by mulching, however.

Even though relatively dry weather during this experiment may have rendered the underground drainage ditches superfluous, they do have potential for improving wet-season yields. Such rice-husk drainage systems are not nearly as durable as perforated PVC pipe, the system most commonly used in the AVRDC area, but the materials are much cheaper and are locally available.

Seedlings with good root growth need little irrigation at the early growth stages, and their root development may even be improved by withholding irrigation. Growth is not retarded at moisture levels above pF 2.5, and higher levels of moisture can increase yields only at the fruit enlargement stage.

By maintaining high levels of soil moisture throughout the growth period, vinyl mulching can increase yields significantly. It also encourages the development of roots with differentiated physiological functions, and may have potential for preventing both flooding and drought damage.

Table 32. Results of Duncan's multiple ranges test for selected yield components at the first three harvests.

Treatments	No. of fruit at first harvest (per plot)	Yield at first harvest (t/ha)	No. of fruit at second harvest (per/plot)	Yield at second harvest (t/ha)	No. of fruit at third harvest (per plot)	No. of fruit at third harvest (per plot)	Yield at third harvest (t/ha)	Total[z] Fruit no. (per plot)	Average Fruit wt. (g)	Total[z] Yield (t/ha)
Main plot										
None (N)	U 610.9 A	U 8.76 A	N 232.3 A	N 2.98 A	U 371.1 A	U 371.1 A	U 4.35 A	U 1210.9 A	U 29.3 A	U 16.1 A
Underground ditch (U)	N 505.4 A	N 5.92 B	U 228.9 A	U 2.98 A	N 350.3 A	N 350.3 A	N 4.11 A	N 1087.9 A	N 28.9 A	N 14.1 A
	LSD(.05)=159.6	LSD(.05)=0.72	LSD(.05)=1053.8	LSD(.05)=13.1	LSD(.05)=1090.3	LSD(.05)=1090.3	LSD(.05)=12.1	LSD(.05)=1984.5	LSD(.05)=2.9	LSD(.05)=26.5
Sub plot										
Rice straw mulch (RS)	VM 641.2 A	VM 9.28 A	VM 267.0 A	VM 3.47 A	VM 390.8 A	VM 390.8 A	VM 4.61 A	VM 1299.0 A	VM 29.7 A	VM 17.4 A
Double-layer mulch (VM)	RS 475.1 A	RS 6.40 B	RS 194.2 B	RS 2.49 B	RS 330.5 A	RS 330.5 A	RS 3.85 A	RS 999.8 B	RS 28.6 A	RS 12.7 B
	LSD(.05)=167.2	LSD(.05)=2.20	LSD(.05)=20.4	LSD(.05)=0.33	LSD(.05)=131.3	LSD(.05)=131.3	LSD(.05)=1.82	LSD(.05)=86.3	LSD(.05)=2.5	LSD(.05)=0.3
Sub-sub plot										
Compound fertilizer (70 kg N/ha) (N_1)	N_1 606.8 A	N_1 8.55 A	N_2 250.1 A	N_2 3.18 A	N_1 379.5 A	N_1 379.5 A	N_1 4.49 A	N_1 1215.6 A	N_3 29.8 A	N_1 16.0 A
Compound fertilizer (100 kg/ha) (N_2)	N_4 572.8 A	N_3 7.72 A	N_1 229.4 A	N_3 3.01 A	N_3 376.6 A	N_3 376.6 A	N_3 4.45 A	N_3 1133.5 A	N_1 29.1 A	N_3 15.3 A
Compound fertilizer (130 kg/ha) (N_3)	N_3 529.3 A	N_4 7.66 A	N_3 227.6 A	N_1 2.95 A	N_2 344.3 A	N_2 344.3 A	N_4 4.07 A	N_4 1130.3 A	N_4 28.9 A	N_2 14.5 A
Compound fertilizer (180 kg/ha) (N_4)	N_2 523.9 A	N_2 7.43 A	N_4 215.3 A	N_4 2.78 A	N_4 342.3 A	N_4 342.3 A	N_2 3.92 A	N_2 1118.3 A	N_2 28.8 A	N_4 14.5 A
	LSD(.05)=118.2	LSD(.05)=1.40	LSD(.05)=37.5	LSD(.05)=0.51	LSD(.05)=80.8	LSD(.05)=80.8	LSD(.05)=1.00	LSD(.05)=138.9	LSD(.05)=1.3	LSD(.05)=1.7

[z] Total indicates the sum of 1st, 2nd and 3rd harvests.

Table 33. Changes in soil moisture and temperature during the summer of 1983.

Survey period	Treatment M.P.	S.P.	Soil moisture (PF) (20 cm depth) morning	afternoon	Soil temperature (°C) (10" depth) morning	Afternoon
Aug 17	N	RS	1.92	1.89	27.7	30.8
		VM	1.79	1.73	28.8	31.1
Aug 13	V	RS	1.79	1.83	27.1	30.6
		VM	1.75	1.72	29.6	30.8
Aug 14	N	RS	1.68	1.91	27.9	31.5
		VM	1.56	1.83	29.3	31.5
Aug 20	V	RS	1.67	1.78	27.5	31.6
	V	VM	1.62	1.71	29.1	30.1
Sep 4	N	RS	1.90	2.17	28.5	31.3
		VM	1.92	2.18	29.3	31.0
Sep 10	V	RS	1.73	2.01	27.3	30.0
		VM	1.86	2.21	29.0	31.5
Sep 10	N	RS	2.62	2.67	28.2	31.2
			2.47	2.57	29.4	31.0
Sep 17	V	RS	2.57	2.63	27.4	30.6
		VM	2.67	2.69	29.1	30.9
Oct 2	N	RS	2.49	2.41	28.0	30.5
		VM	2.58	2.56	28.9	31.5
Oct 8	V	RS	2.22	2.16	26.9	30.0
		VM	2.24	2.11	29.0	31.3
Oct 9	N	RS	2.66	2.73	27.8	30.0
		VM	2.64	2.68	28.2	30.5
Oct 15	V	RS	2.63	2.66	26.2	29.5
		VM	2.55	2.58	28.0	30.0
Nov 6	N	RS	2.49	2.61	21.9	26.6
		VM	2.50	2.50	24.5	27.3
Nov 7	V	RS	2.35	2.37	20.5	23.6
		VM	2.39	2.46	23.5	26.2
Nov 13	N	RS	2.26	2.36	20.2	23.5
		VM	2.19	2.28	23.0	24.8
Nov 19	V	RS	2.08	2.19	18.9	21.1
		VM	2.20	2.19	22.2	24.4
Dec 11	N	RS	2.23	2.23	17.3	20.8
		VM	2.35	2.42	19.4	22.0
Dec 17	V	RS	2.28	2.34	16.2	19.6
		VM	2.27	2.32	19.3	22.3
Dec 18	N	RS	2.40	2.45	16.9	20.1
		VM	2.50	2.59	19.3	21.8
Dec 24	V	RS	2.44	2.50	16.7	19.4
		VM	2.44	2.47	18.9	21.4

Remarks: M.P. = main plot. S.P. = sub-plot. N = without drainage ditches. V = with drainage ditches. RS = rice straw mulching. VM = double layer mulching of rice straw and vinyl sheet.

Chinese Cabbage Tipburn

Introduction

Tipburn of Chinese cabbage is generally thought to be caused by calcium deficiencies attributable to a variety of environmental, physiological, or nutritional factors. Such shortages can be traced either to low amounts of available soil calcium or to the plant's inhibited absorption or translocation of calcium.

The present study was designed to clarify the relationship between tipburn (and also internal rot, a related malady which affects leaves inside the head) and the levels of available calcium in the soil, and to confirm that NH_4-N can cause tipburn.

Materials and Methods

After being soaked overnight in 2N HCl, washed repeatedly with tap water, and then washed once more with distilled water, quartz sand was packed into 1/2000 a Wagner's pots. Seedlings of Chinese cabbage cultivar Fong-Luh were grown in a smoked rice hull medium containing a culture solution, and when they were 16 days old transplanted to the sand-filled pots where they received the culture solution described in Table 34. Added to that solution was one of the ten nitrogen treatments shown in Table 35. To avoid the initial growth retardation which is often caused by fertilizer damage, the culture solution was applied at only 0.25 strength for the first four days. Culture solution was stored in a 20 l plastic container which was connected with plastic tubing to two 1 l control bottles, one for each replication (Fig. 4). Each morning these control bottles were filled with the culture solution, which was then allowed to drip onto the pots. The control bottles were usually empty after 16 hours. The water level in each pot was maintained at 5, 7, 8, and 10 cm below the surface of the sand at 7, 11, 13, and 18 days after transplanting, respectively.

Table 34. Constitution of culture solution.

Element	Salts used	Concentration as element (ppm)
N	$NaNO_3$, $(NH_4)_2 \cdot SO_4$	224, 112 and 56
P	K_2HPO_4, $Ca(NO_3)_2 \cdot 4H_2O$	41
K	K_2SO_4, KNO_3, $Mg(NO_3)_2 \cdot 6H_2O$	313
Ca	$CaCl_2 \cdot 2H_2O$, $CaSO_4 \cdot 2H_2O$	320 and 160
Mg	$MgSO_4$ are mixed	49
Fe	EDTA - Fe	3
Mn	$MnSO_4 \cdot H_2O$	0.5
Zn	$ZnSO_4 \cdot 7H_2O$	0.05
Cu	$CuSO_4 \cdot 5H_2O$	0.02
Mo	$Na_2MoO_4 \cdot 2H_2O$	0.01
B	H_3BO_3	0.5

* pH was adjusted to 6.0 using 0.2 N H_2SO_4.

Table 35. Nitrogen treatments (meq/l).

Before head formation		After head formation	
NO_3	16	NO_3	16
NO_3	8	NO_3	16
NO_3	8	NH_4	16
NO_3	8	NH_4	8
NO_3	4	NO_3	16
NO_3	4	NH_4	16
NH_4	16	NO_3	8
NH_4	16	NH_4	8
NH_4	8	NO_3	8
NH_4	8	NH_4	8

* Ca: three levels 0, 8, 16 meq/l.

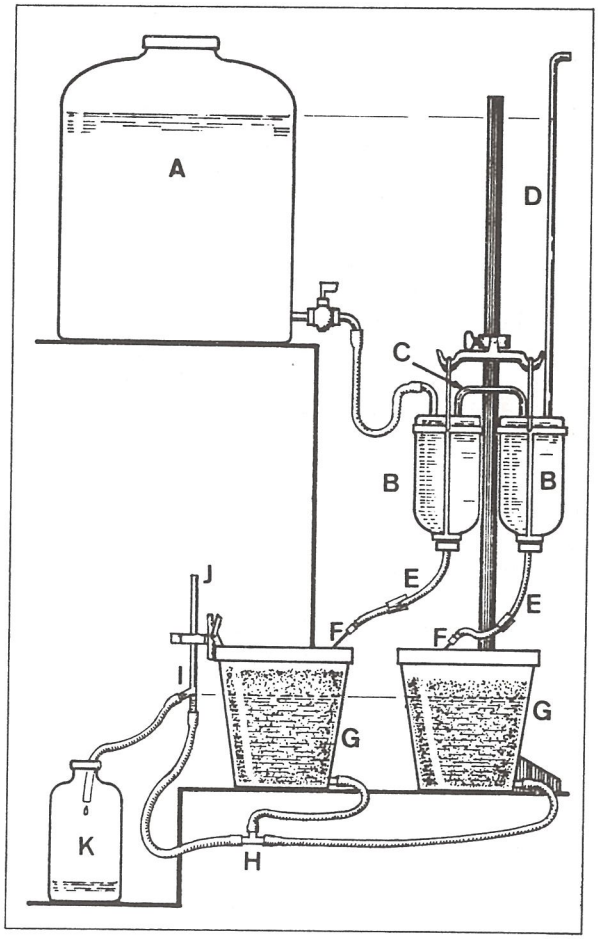

Fig. 4.
Diagram of steady-flow system (A: 20 1 culture solution storage bottle; B: 1 1 control bottle; C: syphon pipe; D: air inlet; E: Ringel injection tube; F: 0.50 x 25 mm needle; G: 1/2000 a pot, H: T-glass tube, I: Y-glass tube; J: air inlet; K: 1 1 leachate collection bottle).

The sand in treatments which received different culture solutions before and after head initiation (27 days after transplanting) was rinsed with distilled water and with several rinses of the new culture solution.

To measure the amounts of various nutrients absorbed at each growth stage, the leachate of the culture solution was collected every three

days and analyzed for NO_3-N, NH_4-N, Ca, and pH. After plants were harvested at 47 DAT, their heads and outer leaves were weighed separately, and were then divided again into blade and midrib for separate analyses of nutrient uptake. After being dried overnight at 80°C, samples were analyzed by the Kjeldahl method for total nitrogen (T-N) content, and an atomic absorption spectrophotometer and a flame photometer were used to measure levels of Ca and K, respectively.

Each plant's roots were examined visually at harvest.

Results and Discussion

The appearance of tipburn symptoms:

Beginning at 7 days after treatment (DATR), all of the plants grown with NH_4-N showed symptoms of tip burn. Leaves turned dark green and wilted; the edges of outer leaves curled upward, and the young leaves were wrinkled and poorly developed. At 11 DATR, the edges of the leaves became scorched and blackened. Symptoms appeared first on the young leaves, and then later on the outer, more fully developed leaves. Symptoms were slightly alleviated by increased applications of calcium.

In the treatment which was grown with NO_3-N up until the head formation stage, and then with NH_4-N after the head formation stage, five days after the change in culture solution the edges of the outer leaves suddenly wilted and became water-soaked, and then later dried up.

Plants grown with NH_4-N before the head formation stage, and with NO_3-N afterwards, however, quickly recovered after the switch in culture solution, and their leaves soon began to grow normally. Plants grown with NH_4-N throughout the growth period developed tip burn symptoms and were unable to form heads.

Root damage caused by ammonia toxicity:

Similar symptoms were found on the roots. Roots of plants grown with NH_4-N were short, darkened, lignified, and easily broken. They were also fewer in number and had fewer hairs. The roots of plants grown with NO_3-N were more numerous and were long, slender, and white, with numerous hairs, confirming the findings of Imai (1977) and Bennet (1964).

There are two possible explanations for the root damage caused by ammonia. The first is that the ammonia damages the roots directly. Ikeda (1977) has shown that it decreases PEP carboxylase activity, and thus impedes the non-photosynthetic CO_2 fixation coupled to the TCA cycle. Similarly, Matsumoto (1974) has shown that it increases respiratory enzyme activity, but without coupling enhanced respiratory processes. Such results would seem to indicate that NH_4-N has a toxic effect upon the respiratory phosphorylation coupled to the TCA cycle in the mitochondria.

The second explanation for the root damage caused by ammonia is the acidity associated with its absorption. In this experiment the pH of the leachate from plants grown with ammonia gradually decreased; levels of nitrogen uptake apparently increased as the plants grew.

Changes in pH values:

By 21 DATR, when tip burn symptoms were becoming severe, the pH value in the Ca 0 treatment was below 5. Regardless of Ca concentration, however, pH values rose when the nitrogen source was changed from NH_4 to NO_3 after the head initiation stage (Fig. 5). By 14 DATR, the pH value of the plants grown with NO_3-N had risen to 7, and did not vary greatly until the nitrogen source was changed to NH_4-N, at which time it fell to nearly 2. The pH values were slightly higher, though, in the Ca 160 and the Ca 320 treatments. The Ca 0 treatment, which had the greatest fluctuations in pH, also had the lowest yields.

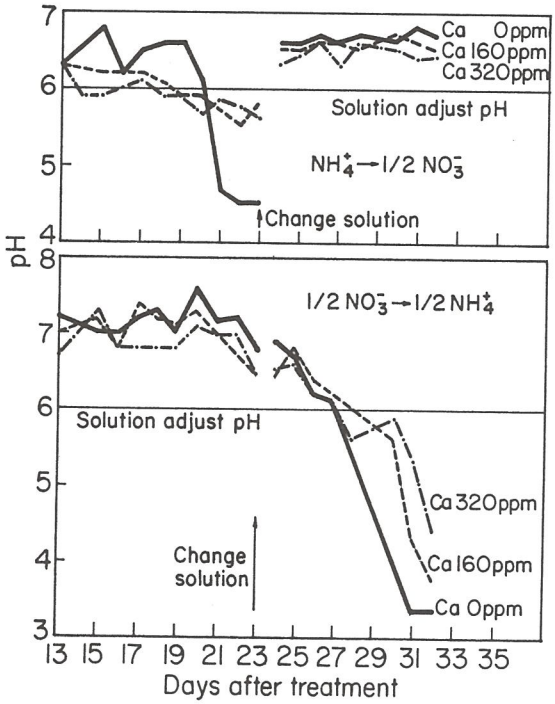

Fig. 5.
pH change in culture solution during growth period.

The mechanism of the pH increase associated with nitrate uptake was first proposed by Kirby et al. (1977), who theorized that nitrate-fed plants excrete the excess OH, and thereby keep their tissue pH neutral during the nitrate assimilation that occurs while H is being excreted in the process of ammonium uptake. This in turn results in a decrease of the medium's pH. Nitrogen assimilation does not require that tissue pH remain neutral, however, and pH values actually vary greatly with time and with growth stage. More important is to keep the culture medium electrically neutral; a great deal of energy is required to separate ion pairs, and no single ion can exist alone. When salts of either NO_3 or NH_4 are added, the nitrogen is absorbed much faster than is the counter ion. The medium thus no longer has a neutral charge, and nitrogen absorption is halted until the medium can be supplied with a co-ion from the plant itself. Simply stated, either NO_3 or NH_4 are absorbed by plants through an exchange of ions between the culture medium and the plant roots. The alleviation of tip burn symptoms by the application of

Ca, then, can be attributed to the competitive inhibition of ammonium uptake by the Ca ions.

Growth and yield parameters:

Plants grown with NO_3-N throughout the growth period showed the highest yields, and those grown with NH_4-N had the lowest yields (Tables 36 and 37). Almost as high were the yields of plants grown with 8 meq of nitrate from transplanting until the head formation stage, and with 16 meq of nitrate from the head formation stage until harvest. Plants which received less nitrate before the head formation stage grew more slowly, and had reduced head yields. Just the opposite was true, however, for plants grown with ammonia; plants in the NO_3 8/NH_4 8, and the NO_3 4/NH_4 16 treatments showed healthy growth until the head formation stage, when the nitrogen source was switched from nitrate to ammonia. A sudden slowing could be then seen in plant growth, and this treatment's yields were greatly reduced from those of the treatment which was grown with nitrate both before and after the head formation stage.

Table 36. The effect of form and concentration of nitrogen and Ca concentration on the head yield of Chinese cabbage.

N form and concentration (meq/l)				Dry weight of the head (g)			Average
before head formation		after head formation		Ca 0 (meq/l)	Ca 8 (meq/l)	Ca 16 (meq/l)	
NO_3	16	NO_3	16	61.8a	57.2a	59.7a	59.5a
NO_3	8	NO_3	16	54.1ab	57.7a	55.0a	55.6a
NO_3	8	NH_4	16	17.0cd	18.0c	20.2b	18.4c
NO_3	8	NH_4	8	21.3cd	34.1b	28.9b	28.1b
NO_3	4	NO_3	16	35.3b	35.6b	27.3b	32.7b
NO_3	4	NH_4	16	9.5cd	10.2c	7.9c	9.2d
NH_4	16	NO_3	8	15.3c	5.6cd	5.9c	8.9d
NH_4	16	NH_4	8	3.1d	1.7cd	1.1c	2.0e
NH_4	8	NO_3	8	13.4cd	14.5c	3.5c	10.4d
NH_4	8	NH_4	8	4.3d	4.6cd	2.9c	3.9de
Average				23.5a	23.9a	21.2c	

Table 37. The effect of form and concentration of nitrogen and Ca concentration on the total dry matter production.

N form and concentration (meq/l)				Dry weight of the head (g)			Average
before head formation		after head formation		Ca 0 (meq/l)	Ca 8 (meq/l)	Ca 16 (meq/l)	
NO_3	16	NO_3	16	145.0a	136.0a	153.4a	144.8a
NO_3	8	NO_3	16	119.1b	128.8a	138.6a	128.8b
NO_3	8	NH_4	16	71.4cd	69.5c	70.0b	70.3d
NO_3	8	NH_4	8	67.6d	80.6b	87.0b	78.4cd
NO_3	4	NO_3	16	91.3c	97.2b	75.8b	88.1c
NO_3	4	NH_4	16	60.1d	70.7c	49.7bc	60.1de
NH_4	16	NO_3	8	51.3d	56.2c	56.5bc	54.7e
NH_4	16	NH_4	8	23.2d	15.0e	18.9d	19.0g
NH_4	8	NO_3	8	45.1de	47.2cd	43.2c	45.1ef
NH_4	8	NH_4	8	24.0f	27.0de	17.8d	22.9g
Average				69.8a	72.8a	71.1a	

Yield losses were greatest for treatments NO_3 4/HN_4 16, NO_3 8/NH_4 16, and NO_3 8/NH_4 8, in that order. This would seem to indicate that at a given level of ammonia application, lower rates of nitrate application result in greater yield loss. Conversely, at a given rate of nitrate application, higher rates of ammonia application resulted in more pronounced yield losses. Treatments NH_4 16/8 and NH_4 8/8 both had very low yields, and there was no significant difference in the yields of the two treatments. Although plants in treatments NH_4 16/NO_3 16 and $NH_4$8/$NO_3$16 recovered dramatically after their culture solution was changed, their yields still fell far short of those in the treatment which was grown with NO_3-N both before and after head formation.

Whether 8 meq or 16 meq of nitrate was applied after head formation did not significantly affect yields; even the root damage caused by 8 meq of NH_4 was too severe to be ameliorated by later applications of NO_3-N.

In most cases, adding 8 meq/l Ca increased yields slightly, but those increases were not statistically significant (Tables 36 and 37). Adding 16 meq/l raised the salt concentration in the nutrient solution so high that yields were actually reduced. No correlation existed, in fact, between the rate of Ca application and the yield losses caused by tip burn. The primary cause of tip burn was not Ca, but rather NH_4-N.

Levels of total nitrogen in plant tissue:

Total nitrogen content was much higher in the leaves of plants grown with NH_4-N both before and after head formation than it was in the leaves of plants grown with NO_3-N both before and after head formation (Table 38). Even though in some cases the nitrogen uptake of plants in the NH_4-N treatments had been slightly accelerated by increased Ca applications, in neither treatment did increased applications of Ca affect the nitrogen content of the inner leaf blade. The head yields shown in Table 37 suggest that increased applications of Ca had aggravated the root damage caused by ammonia toxicity, thus increasing tip burn symptoms and suppressing nutrient uptake.

Table 38. Total nitrogen content (T-N%) of Chinese cabbage leaves.

N form and concentration (meq/l)				Total nitrogen (dry weight basis) (%)			
before head formation		after head formation		head leaf		outer leaf	
				blade	midrib	blade	midrib
NO_3	16	NO_3	16	4.29b	3.31bcd	4.51bc	4.09a
NO_3	8	NO_3	16	4.14b	3.13cd	4.51bc	3.84ab
NO_3	8	NH_4	16	4.94a	4.01a	3.91bcd	2.70e
NO_3	8	NH_4	8	4.26b	3.02d	3.88cd	2.09f
NO_3	4	NO_3	16	4.33b	3.36bcd	4.54b	3.65bc
NO_3	4	NH_4	16	4.33b	3.64ab	3.85d	2.30ef
NH_4	16	NO_3	8	4.12b	3.04d	4.45bcd	3.14d
NH_4	16	NH_4	8	5.28a	3.60b	5.65a	3.33cd
NH_4	8	NO_3	8	4.43b	3.09cd	4.22bcd	3.42bcd
NH_4	8	NH_4	8	5.08a	3.48bc	5.14a	2.64e

Potassium levels in plant tissue:

Potassium levels in the inner leaf blade were greatly affected by the nitrogen source; due to the competition for absorption sites, plants grown with NO_3-N absorbed more K_2O than did those grown with NH_4-N. The rate of Ca application, however, had no effect on potassium uptake into the inner leaf blade; because of its immobility in plant tissue, the Ca concentration in the inner leaf was not high enough to competitively suppress K uptake. Calcium levels reached only one-tenth those of nitrogen or potassium. Because the hydrated ions of NH_4 and K are of similar size, and are both easily translocated into active assimilation sites in the plant tissue, they often competitively inhibit one another's absorption in both the soil and in plant tissue.

Calcium levels in plant tissue:

Calcium levels were also greatly affected by the nitrogen source. Plants grown with NO_3-N before the head formation stage and with NH_4-N after the head formation stage, had much less calcium in their inner leaf blades than did plants grown with NO_3-N both before and after the head formation stage. Plants in the NH_4 16/8 and NH_4 8/8 treatments failed to form heads, however, and their outer leaves were used for nutrient analysis. It must be remembered that in other treatments the outer leaves generally contained more Ca than did the inner leaves (Table 39), so the comparison may not be valid.

Table 39. CaO content of Chinese cabbage leaves.

Treatment No.	(Ca meq/l)	CaO % ILB	ILM	OLB	OLM*	Treatment No.	(Ca meq/l)	CaO % ILB	ILM	OLB	OLM*
	0	0.21	0.52	3.17	1.98		0	0.08	0.18	1.80	0.64
1	8	0.30	1.27	6.00	4.21	6	8	0.09	0.42	2.59	1.73
	16	0.23	1.23	6.42	3.65		16	0.22	0.63	3.16	2.83
	0	0.23	0.55	3.38	2.37		0	0.28	0.58	3.25	2.26
2	8	0.38	1.29	6.65	4.42	7	8	0.13	0.65	3.39	3.01
	16	0.42	1.23	6.47	4.17		16	0.21	0.94	4.55	4.26
	0	0.11	0.36	1.90	0.82		0	0.13	0.45	1.22	0.66
3	8	0.11	0.41	3.32	2.93	8	8	0.42	0.47	2.26	2.04
	16	0.14	0.56	3.68	3.28		16	0.27	0.38	3.08	2.64
	0	0.07	0.21	2.25	0.86		0	0.36	0.72	3.22	2.15
4	8	0.16	0.52	3.70	3.24	9	8	0.41	1.10	4.85	4.16
	16	0.14	0.60	4.03	3.36		16	0.41	0.93	5.51	4.09
	0	0.20	0.57	3.42	2.39		0	0.14	0.38	1.21	0.50
5	8	0.48	1.14	6.36	5.18	10	8	0.38	0.63	2.61	0.98
	16	0.37	1.21	5.85	4.22		16	0.50	0.70	3.17	1.10

ILB = inner leaf blade
ILM = inner leaf midrib
OLB = outer leaf blade
OLM = outer leaf midrib

Increased rates of Ca application brought corresponding increases in the Ca contents of the inner leaf blade. Thus, although Ca uptake and translocation in the tissue is easily suppressed competitively by monovalent cations such as NH_4-N and K, the reverse is not true; because of its immobility in plant tissue, Ca has little effect upon the uptake and translocation of NH_4-N or K.

In plants grown with NO_3-N, both before and after the head formation stage, increase rates of Ca application brought corresponding increases in the Ca content of the inner leaves, but only slight increases in the Ca content of the outer leaves (Table 39). Just the opposite was true, however, for plants grown with NO_3-N before the head formation stage and NH_4-N after the head formation stage. Thus, NH_4-N strongly suppressed Ca translocation into the inner leaves after the head formation stage, but NO_3-N accelerated it.

Regardless of the nitrogen source, calcium levels were much lower in leaves showing tip burn symptoms than in leaves with no symptoms (Table 39). In plants grown with NH_4-N both before and after the head formation stage, increases in the rate of Ca application brought corresponding increases in Ca levels in the healthy leaves (Table 40). In the leaves with tip burn symptoms, though, Ca levels did not increase above 160 ppm. In the leaves of plants grown with NH_4-N before the head formation stage and NO_3-N after the head formation stage, tip burn symptoms were minimized, and were actually nonexistent on newly-developed leaves. Because this recovery was also associated with vigorous rooting, and thus with accelerated water uptake, Ca absorption and translocation were also increased.

Table 40. Effect of Ca solution concentration on leaf Ca content.

Treatment (meq/l)				Outer leaf CaO content (%)					
				Ca 0 ppm		Ca 160 ppm		Ca 320 ppm	
				H*	S	H	S	H	S
NH_4	16	NO_3	8	3.25	2.41	3.75	3.02	4.55	3.63
NH_4	16	NH_4	8	1.22	0.63	2.76	1.76	3.08	1.85
NH_4	8	NO_3	8	3.22	2.03	3.46	2.91	2.76	2.67
NH_4	8	NH_4	8	--	1.20	2.52	2.70	3.16	2.10

H = Healthy leaf
S = Leaf with tipburn symptoms

Upon finding that there is less calcium in damaged plant parts than in healthy plant parts, some have concluded tip burn is caused by a deficiency of calcium (Takahashi, 1981). The results of the present study would suggest, however, that tip burn is not caused by a deficiency of calcium, but rather by ammonia toxicity. Calcium deficiencies are caused by reduced Ca uptake and translocation, which is in turn due to root damage attributable to NH_4-N toxicity. Irrespective of available Ca levels, plants grown with NH_4-N showed severe tip burn symptoms, and those grown with NO_3-N did not.

Roots damaged by ammonia toxicity cannot absorb enough water to compensate for that which is lost from the leaves through transpiration. Leafy vegetables like Chinese cabbage have a large surface area, and

generally transpire a great deal of water. In this experiment each plant needed a minimum of 1.5 l of water per day to prevent wilting after the head formation stage. Calcium is absorbed by plants primarily through the transpiration stream, and both its uptake and its translocation are greatly suppressed by the root damage caused by ammonia toxicity.

It must be remembered, too, that Ca easily forms insoluble compounds with anions such as P and SO_4, but that both NH_4-N and K are usually found in plant tissue either as soluble ion complexes or as free ions. Inner leaf blade Ca levels less than a tenth of N and K levels were thus due primarily to heavy applications of NH_4-N and K.

Internal rot and its relationship to tipburn:

Even when there are no symptoms of tipburn, the edges of inner leaves are often rotten. Similar to tipburn, this phenomenon is referred to as internal rot. In this experiment, such symptoms were noted only in plants to which had been applied high concentrations of NO_3-N both before and after the head formation stage (Table 38). In these treatments the Ca content of the inner leaves correlated well with the rate of Ca application, but there was no correlation between Ca content and internal rot incidence.

Because it causes greater decreases in market value, internal rot is actually a much more serious problem than tipburn of the outer leaves.

High rates of nitrogen fertilizer application have often been implicated as the source of tipburn and internal rot Shafer (1946) and Faust et al. (1968) have suggested that the excessive vegetative growth such fertilizer regimes can cause in leafy vegetables like Chinese cabbage frequently results in tip burn and internal rot due to Ca deficiency. Research at AVRDC has shown, however, that internal rot cannot be prevented by applying additional Ca, and that it is actually due to compact heads caused by the excessive vegetative growth which has been brought about by heavy applications of nitrogen. Thus, avoiding excessively high levels of soil nitrogen can prevent both tip burn and internal rot. Deep plowing, the application of compost or other organic materials, and split applications of nitrogen are all effective ways of accomplishing this goal.

Conclusions

Chinese cabbage tip burn is not caused by calcium deficiency, as is commonly believed, but rather by the water stress resulting from root damage brought about by ammonia toxicity. This root damage also inhibits the uptake of calcium, and thus causes the calcium deficiencies which are associated with tipburn. Increased applications of Ca can ameliorate the symptoms of tip burn, not by eliminating calcium deficiencies, but rather by competitively inhibiting the uptake of NH_4-N. Internal rot is also caused by excess applications of nitrogen, but it is unaffected by calcium levels. Deep plowing, applying organic matter, and administering split applications of nitrogen are all effective ways of minimizing both tip burn and internal rot.

Crop Management

Yield and Yield Components of Soybean Grown Under Drought Stress

Introduction

The amount of water needed by soybean varies according to growth stage, prevailing temperatures, and general atmospheric conditions. This study was conducted to determine the effects of soil water stress on the growth and yield of soybean at various growth stages and to determine which growth stages are most critical for soil water stress.

Materials and Methods

Pot experiment:

Soil from an AVRDC experimental field was air-dried and mixed thoroughly before being fertilized with a mixture of 40 kg/ha N, 200 kg/ha P_2O_5, and 200 kg K_2O/ha. Thirty tapered plastic pots were filled with 20 kg of the mixed soil and placed under a shelter. On March 2, one week after emergence, plants were thinned to four per pot. An RCB design was used with four replications. Water was withheld from 20 to 30 DAP (pre-flowering stage), 32 to 52 DAP (flowering stage), 56 to 66 DAP (pod formation stage), or 66 to 76 DAP (pod filling stage). The check was watered whenever a tensiometer installed at the center of the pot reached a reading of 50 cm, a figure equivalent to a soil moisture content of about 13%. Waterings of 1500 to 2000 cc per pot brought the tensiometer reading back to 0 cm. All plants were harvested on June 10, at 107 DAP.

Field trial:

An RCB design was used with four replications. The treatments included withholding water at 32 DAP (flowering stage), 41 DAP (pod formation stage), 49 DAP (pod filling stage), as well as irrigated and non-irrigated checks. The irrigated check received furrow irrigation 22, 32, 41, and 49 DAP. Cultivar AGS 19 was planted on 2 x 6 m beds, with two seeds per hill, 10 cm between hills, and 25 cm between rows. The crop was planted on September 23 and was harvested on December 20 (89 DAP).

Results

Pot experiment:

Soybean growth was significantly affected by soil water stress occurring after 20 DAP (Table 1). Plant height was significantly reduced during the stress period, but plants recovered quickly after being rewatered; at 76 DAP the plants that had undergone water stress during the pre-flowering and pod filling stages were as tall as the unstressed check. Although stress during the reproductive stages reduced the number of pods that developed, stress during the pre-flowering stage had little effect on pod development (Table 2).

Stress during the reproductive stages significantly reduced the number of pods per plant, the number of seeds per pod, and the total grain yield (Table 3). Only stress imposed during the pod filling stage decreased seed size. This treatment had the lowest yield.

Table 1. The effect upon plant height of soil water stress imposed at different growth stages.[z]

Stress period DAP	Plant height 20 DAP (cm)	30 DAP (cm)	50 DAP (cm)	76 DAP (cm)
20 - 30 (pre-flowering)	12.8a	13.6b	36.1b	52.4ab
32 - 52 (flowering)	13.2a	16.7a	24.3c	41.6c
56 - 66 (pod formation)	13.3a	16.2a	39.1ab	47.2b
66 - 76 (pod filling)	13.4a	16.6a	39.8a	53.0a
None	13.2a	16.4a	40.5a	54.2a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 2. The effect upon pod development[z] of soil moisture stress at various growth stages.

Stress period DAP	Pod Count 66 DAP	76 DAP	107 DAP (harvest)
	----------no./plant----------		
20 - 30 (pre-flowering)	36.0a	40.3a	38.5a
32 - 52 (flowering)	17.6b	27.7c	27.1b
56 - 66 (pod formation)	23.0b	32.5bc	28.2b
66 - 76 (pod filling)	35.2a	36.4ab	27.2b
None	36.7a	40.7a	41.3a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 3. The effects upon yield and yield components of soil moisture stress imposed at various growth stages.[z]

Stress period (DAP)	Yield (gm/plant)	100-seed (gm)	Seeds/pod (no.)	Pod/plant (no.)
20 - 30 (pre-flowering)	13.0a	16.5a	2.4ab	38.5a
32 - 52 (flowering)	8.1b	16.4a	2.0c	27.1b
56 - 66 (pod formation)	9.3b	16.6a	2.3b	28.2b
66 - 76 (pod filling)	5.5c	13.7b	2.1c	27.2b
None	14.8a	17.0a	2.6a	41.3a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Field trials:

Although under field conditions the effects of soil water stress during various reproductive stages could not be easily differentiated (Table 4), withholding water throughout the entire growing period reduced plant height at 60 DAP to 47.4 cm, compared with the check's 60.8 cm. Seed and pod development were similarly affected (Table 5). The number of seeds per pod was not affected by water stress, but the number of pods was significantly reduced when irrigation was withheld for the entire growing season (Table 6). Water stress during the pod filling stage slightly reduced seed size and lowered yields to 2.41 t/ha.

Conclusions

Soil water stress imposed at various growth stages significantly reduced soybean height. The effect was more pronounced in the pot experiment than under field conditions. Both experiments showed that the pod filling stage is the most sensitive to soil water stress. Yield reductions under field conditions were due primarily to smaller seed size, and those in the pot experiment were due to smaller seed size and a lower number of pods per plant.

Table 4. Plant height of soil water stress imposed at various growth stages.[z]

Stress period (DAP)	Height	
	43 DAP (cm)	60 DAP (cm)
Entire season	38.1b	47.4b
None	48.9a	60.8a
32 - 40 (flowering)	47.0a	58.6a
41 - 48 (pod formation)	47.4a	57.8a
49 - 60 (pod filling)	47.5a	59.8a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 5. The effects of water stress imposed at various growth stages upon seed development and number of pods.[z]

Stress period (DAP)	Seed weight		Pod number	
	65 DAP (gm/pl)	78 DAP (gm/pl)	65 DAP (gm/pl)	78 DAP (gm/pl)
Entire season	9.4a	12.0b	20.6a	17.1b
None	10.6a	16.2a	22.8a	21.4a
32 - 40 (flowering)	10.4a	16.0a	24.0a	21.4a
41 - 48 (pod formation)	11.2a	16.1a	22.2a	20.1a
49 - 60 (pod filling)	10.4a	16.4a	23.2a	21.5a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 6. The effects of soil water stress imposed at various growth stages upon soybean yield and yield components.[z]

Stress period (DAP)	Yield (t/ha)	100-seed weight (gm)	Seeds no/pod	Pods no/plant
Entire	1.83c	14.9b	2.3a	15.8b
None	2.69a	15.7a	2.4a	22.2a
32 - 40 (flowering)	2.57ab	15.5ab	2.4a	20.0a
41 - 48 (pod formation)	2.47ab	16.0a	2.5a	19.7a
49 - 60 (pod filling)	2.41b	15.4ab	2.3a	20.6a

[z] Means within a colum followed by the same letter are not significantly different at the 5% level by DMRT.

Soybean Herbicide Evaluation

Introduction

Alachlor, the standard herbicide used on soybean, is a good grass killer, and has been used extensively for weed control in soybean. Under heavy weed infestation, however, it performs poorly. Trials conducted in 1982 had shown metolachlor to be superior to alachlor, and these results were re-evaluated in 1983. So that it could control broadleaf weeds more effectively, metolachlor was combined with oxyfluorfen.

Materials and Methods

Field studies were conducted in the spring, summer, and fall of 1983. Twenty kg N/ha, 100 kg P_2O_5/ha, and 100 kg K_2O/ha were broadcast

and incorporated before planting. At flowering, an additional 20 kg/ha N was side-dressed. AVRDC breeding line AGS 19 was planted in 2 x 6 m plots with 10 cm between plants and 25 cm between rows. The herbicides tested were metolachlor, pendimethalin, alachlor + oxyfluorfen, and metolachlor + oxyfluorfen, all of which were applied pre-emergence. An RCB design was used with four replications.

Results

Results of the spring trials are shown in Table 7. Levels of weed infestation were low; yield losses due to weed interference were 27%. Both grasses and broadleaf weeds were effectively controlled by all herbicide treatments. At 1.5 kg/ha, metolachlor alone was less effective in controlling broadleaf weeds. Plots treated with 0.23 kg/ha oxyfluorfen, regardless of what other herbicides it was combined with, yielded significantly less than the weed-free check. This was due to crop injury in early growth stages. Oxyfluorfen did not appear to be phytotoxic when applied at a rate of 115 g/ha.

Table 7. Effects of selected herbicides on weed density and soybean seed yield, spring 1983.[z]

Herbicide rate (kg ai/ha)	Yield (t/ha)	Weed count 50 DAP	
		Grass (no/m^2)	Broadleaf (no/m^2)
Weedy check	2.33c	132a	103a
Weed-free check	3.20a	0b	0c
Ala. + Oxy.			
2 + 0.115	3.17a	14b	0c
2 + 0.23	2.86b	8b	0c
Metolachlor			
1.5	3.21a	0b	62b
2.0	3.16a	1b	13c
Metol. + Oxy.			
1.5 + 0.115	3.18a	0b	0c
1.5 + 0.23	2.42c	10b	0c
2.0 + 0.115	3.23a	0b	0c
2.0 + 0.23	2.79b	2b	0c
Pendimethalin			
1.0	3.19a	12b	6c
1.5	2.92ab	31b	1c

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Results of the summer trials are shown in Table 8. The major weeds this instance were grasses. Yield losses of 62% resulted when weeds were left unchecked for the entire season. Grasses and broadleaf weeds were effectively controlled by all herbicides. Pendimethalin was less effective than the others, however, in controlling grasses. Although some of the young plants in plots treated with 0.23 kg/ha oxyfluorfen were injured, the effects disappeared at later growth stages and did not reduce yields below those of the weed-free check. All herbicide treatments yielded as well as the weed-free check. Metolachlor alone provided the highest yields.

Table 8. Effects of selected herbicides on weed density and soybean seed yield, summer 1983.[z]

Herbicide rate (kg ai/ha)	Yield (t/ha)	Weed count 50 DAP	
		Grass (no/m^2)	Broadleaf (no/m^2)
Weedy check	1.29b	109a	33a
Weed-free check	3.40a	0d	0b
Ala. + Oxy.			
2 + 0.115	3.25a	17cd	2b
2 + 0.23	3.30a	14cd	1b
Metolachlor			
1.5	3.52a	6d	3b
2.0	3.46a	13cd	3b
Metol. + Oxy.			
1.5 + 0.115	3.26a	13cd	2b
1.5 + 0.23	3.40a	9d	1b
2.0 + 0.115	3.15a	3d	0b
2.0 + 0.23	3.40a	3d	1b
Pendimethalin			
1.0	3.26a	31c	4b
1.5	3.07a	53b	1b

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

In the fall trial, jungle rice, goosegrass, and portulaca were the dominant weeds. Weed interference caused yield losses of about 23% (Table 9). Metolachlor alone gave good control of grasses, but provided only moderate control of broadleaf weeds. Pendimethalin provided only moderate control of grasses. Yields in all herbicide treatments were as good as those of the weed-free check, and there were no phytotoxic reactions in any oxyfluorfen treated plots. Comparing the treated plots and the weedy check showed that in all three seasons better weed control resulted in a higher number of pods per plant (Table 10). One hundred-

seed weight was higher in the weedy check than in most of the treated plots.

Table 9. Effects of selected herbicides on weed density and soybean seed yield, fall 1983.[z]

Herbicide rate (kg ai/ha)	Yield (t/ha)	Weed count 50 DAP	
		Grass (no/m^2)	Broadleaf (no/m^2)
Weedy check	1.99b	128a	75a
Weed-free check	2.58a	0c	0c
Ala. + Oxy.			
2 + 0.115	2.59a	2c	3c
2 + 0.23	2.77a	1c	0c
Metolachlor			
1.5	2.55a	3c	23b
2.0	2.57a	4c	24b
Metol. + Oxy.			
1.5 + 0.115	2.49a	7c	1c
1.5 + 0.23	2.78a	16bc	2c
2.0 + 0.115	2.56a	8c	3c
2.0 + 0.23	2.61a	5c	0c
Pendimethalin			
1.0	2.62a	8c	4c
1.5	2.60a	23b	2c

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 10. Effects of selected herbicides on soybean yield components, 1983.[z]

Herbicide rate (kg ai/ha)	Spring		Summer		Fall	
	Pod (no/plant)	100-seed wt. (g)	Pod (no/plant)	100-seed wt. (g)	Pod (no/plant)	100-seed wt. (g)
Weedy check	17.1d	15.8a	18.1c	17.3a	20.6c	16.2a
Weed-free check	28.2bc	14.5b	42.2a	16.1ab	26.7ab	15.0b
Ala. + Oxy.						
2 + 0.115	29.2abc	13.8bcd	37.9ab	16.0ab	24.7abc	15.6ab
2 + 0.23	28.6abc	12.9de	30.6b	15.4b	25.2abc	15.3b
Metolachlor						
1.5	27.8bc	14.1bc	39.0ab	15.8ab	26.3abc	15.6ab
2.0	29.5abc	13.9bcd	33.6ab	15.7ab	27.0ab	15.7ab
Metol. + Oxy.						
1.5 + 0.115	28.2bc	13.2cde	34.8ab	16.4ab	25.4abc	15.3b
1.5 + 0.23	34.2a	12.4e	32.7ab	16.0ab	26.2abc	15.1b
2.0 + 0.115	25.0c	13.3cde	33.6ab	16.0ab	30.0a	15.1b
2.0 + 0.23	32.2ab	12.5e	39.0ab	16.5ab	30.8a	15.1b
Pendimethalin						
1.0	28.1bc	14.3bc	38.5ab	16.7ab	28.0ab	15.4b
1.5	30.7abc	13.8bcd	36.2ab	16.5ab	22.9bc	15.5b

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Conclusions

Oxyfluorfen is known to be more phytotoxic to shoots than roots. This may explain why 0.23 kg/ha of oxyfluorfen caused crop injuries in the spring, when continuous rain during the early growth stages would have splashed the herbicide-contaminated soil particles up onto the shoot, and also in the summer trial when sprinkler irrigation would have done the same thing. No sprinker irrigation was applied during the fall (dry season) trial, and no crop injury was observed.

Metolachlor alone gave the best weed control during the summer planting, but pendimethalin or metolachlor + 115 g/ha of oxyfluorfen gave the best control in the spring and fall. Yield differences could be traced to differences in 100-seed weight and the number of pods per plant.

Effect of Weed Competition on Soybean Growth and Yield

Introduction

So that weeding can be carried out more efficiently and economically, attempts have been made to determine the most critical time for weed competition with soybean. Trials conducted in 1982 showed that when plants are spaced 10 cm apart with 25 cm between rows, the most critical time is 30 DAP. To determine whether the critical period for weed competition might be altered by wider row spacings, the same test was conducted in 1983, but with the addition of plots whose rows were spaced 50 cm apart.

Materials and Methods

Field trials were conducted in the spring, summer, and fall of 1983. A split-plot design was used with four replications. Main plots were row spacing, and subplots were either kept weed-free or allowed to be infested with weeds for varying lengths of time after planting. Plants were harvested at 117 DAP in the spring, 105 DAP in the summer, and 91 DAP in the fall.

Results

Grain yields were significantly affected by the duration of weed interference (Table 11). In all three seasons, plots kept weed-free for 15 DAP yielded as much as the check kept weed-free until harvest. Yields of the weed-infested treatments were significantly reduced when weed interference lasted beyond 60 DAP in the spring and 30 DAP in the summer and fall. Weed interference reduced the number of branches in the spring and fall (Table 12), and the number of pods per plant in all seasons (Table 13). Seed size actually increased at longer periods of weed infestation (Table 14). This can be most clearly seen by comparing

the weed-free check with the weedy check. Because weed infestation reduced the number of pods which needed to be filled by photosynthate, the 100-seed weight increased from 13.8 to 15.2 g in the spring, 14.05 to 15.3 g in the summer, and 13.5 to 12.2 g in the fall.

Statistical analysis showed no significant interaction in any season between spacing and the duration of weed interference; under these experimental conditions the critical time of weed competition remained the same at both spacings. This could be due, however, to the rather low levels of weed infestation which occurred throughout the year.

Table 11. The effects of weed interference upon soybean seed yield, 1983.[z]

Interference duration (DAP)	Yield		
	Spring (t/ha)	Summer (t/ha)	Fall (t/ha)
Weed-free			
0 - 15	2.95a	3.52a	2.21ab
0 - 30	2.83ab	3.40a	2.12ab
0 - 45	2.88a	3.32a	2.44a
0 - 60	3.02a	3.43a	2.46a
0 - 75	2.85a	3.52a	2.44a
to harvest	2.98a	3.44a	2.42a
Weed-infested			
0 - 15	2.88a	3.44a	2.34a
0 - 30	2.87a	3.36a	2.28ab
0 - 45	2.92a	2.60b	1.99bc
0 - 60	2.87a	2.75b	2.01bc
0 - 75	2.54bc	2.34b	1.78cd
to harvest	2.35c	2.54b	1.52d

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 12. The effects of weed interference upon soybean branch number, 1983.

Interference duration (DAP)	Branch number		
	Spring[z]	Summer[ns]	Fall[z]
	--------no/plant----------		
Weed-free			
0 - 15	1.5bc	1.1	1.0abc
0 - 30	2.1a	1.2	1.0abc
0 - 45	2.0a	1.1	1.2a
0 - 60	1.9ab	1.2	1.2a
0 - 75	2.2a	1.5	1.1ab
to harvest	2.0a	1.1	1.2a
Weed-infested			
0 - 15	1.8abc	1.3	0.9abcd
0 - 30	2.0a	1.4	1.0abc
0 - 45	2.1a	1.3	0.5e
0 - 60	1.9ab	1.3	0.8bcde
0 - 75	2.0a	1.2	0.7cde
to harvest	1.4c	1.4	0.6de

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
ns = not significant.

Table 13. The effects of weed interference upon soybean pod number, 1983.[z]

Interference duration (DAP)	Pod		
	Spring	Summer	Fall
	--------no/plant----------		
Weed-free			
0 - 15	14.85c	35.4abc	22.56cd
0 - 30	24.35a	35.18abc	21.21d
0 - 45	23.69ab	38.93a	25.79abc
0 - 60	25.70a	35.95abc	25.53abc
0 - 75	26.30a	37.74ab	26.76a
to harvest	26.06a	34.75abc	26.33ab
Weed-infested			
0 - 15	24.76a	38.36a	23.41abcd
0 - 30	24.16b	36.13abc	23.03bcd
0 - 45	25.93a	33.08abc	20.01de
0 - 60	24.15ab	29.95c	20.90d
0 - 75	21.29b	30.41c	17.48ef
to harvest	17.43c	31.49bc	14.95f

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 14. The effects of weed interference upon soybean seed size, 1983.[z]

Interference duration (DAP)	100-seed wt.		
	Spring (gm)	Summer (gm)	Fall (gm)
Weed-free			
0 - 15	15.73a	14.09b	14.51abcd
0 - 30	14.45b	13.89b	14.89ab
0 - 45	13.35d	13.93b	13.90def
0 - 60	13.46d	14.04b	13.73ef
0 - 75	13.63cd	13.91b	13.96def
to harvest	13.84bcd	14.05b	13.53f
Weed-infested			
0 - 15	13.66bcd	13.79b	13.96def
0 - 30	13.48d	13.66b	13.98def
0 - 45	13.48d	13.96b	14.24bcde
0 - 60	14.36bc	13.68b	14.69abc
0 - 75	14.41bc	14.41b	14.99a
to harvest	15.28a	15.36a	14.21cdef

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Conclusions

Weed interference reduces soybean seed yield by decreasing the number of pods and branches per plant. Soybean appears to be able to tolerate such interference, however, until 60 DAP in the spring and 30 DAP in the summer and fall. Because most of the ground is covered by the crop canopy, few additional weeds can emerge, and weeding once at those times should be sufficient to sustain high yields.

Mungbean Herbicide Evaluation

Introduction

Butralin is usually used at AVRDC to control weeds in mungbean. During the spring and fall its performance is satisfactory, but it has proven unreliable in the summer, when grasses are the dominant weed. Previous trials showed that metolachlor performs better than butralin in the summer. To further assess its effectiveness, additional trials were conducted in 1983.

Materials and Methods

Field experiments were conducted in the spring, summer, and fall of 1983. AVRDC breeding line VC 1973 A was planted in the spring, and VC 1628 A was planted in the summer and fall. Plants were spaced 10 cm apart, with 25 cm between rows. Herbicides tested were butralin, metolachlor, metolachlor + oxyfluorfen, and pendimethalin. All were applied pre-emergence. The 2 x 6 m plots were arranged in an RCB design with four replications. Twenty kg/ha N, 100 kg/ha P_2O_5, and 100 kg/ha K_2O were broadcast and incorporated into the soil before planting. Twenty kg/ha N was added at the flowering stage. Water was supplied through furrow irrigation. Plants were harvested at 94 DAP in the spring, 89 DAP in the summer, and 90 DAP in the fall.

Results

In the spring, plant height, weed density, and seed yield were all significantly affected by herbicide (Table 15). Regardless of the rate of application, plant height was not affected by metolachlor alone. Plant height was reduced, however, when metolachlor was applied in combination with oxyfluorfen, regardless of the rate of oxyfluorfen applied. Because of weed competition, mungbean plants were tallest in the weedy check. Metolachlor alone controlled grasses effectively, but gave poor control of broadleaf weeds. When combined with oxyfluorfen, it gave good control of both. Butralin and pendimethalin controlled broadleaf weeds satisfactorily, but controlled grasses less effectively than did metolachlor. Yield losses due to weed interference were about 51%. Plots treated with butralin, pendimethalin, or metolachlor at 2.0 kg/ha yielded as well as the weed-free check. Adding 0.23 kg/ha of

oxyfluorfen, on the other hand, caused crop injury and actually reduced yields.

Results of the fall trial (Table 16) were similar to those observed in the spring. In the summer, when the interference from broadleaf weeds was minimal, metolachlor-treated plots gave the highest yields (1.33 to 1.34 t/ha). Again, oxyfluorfen caused crop injury at 0.23 kg/ha, but not at 115 g/ha (Table 17).

Table 15. The effects of selected herbicides on weed density and mungbean height and yield, spring, 1983.[z]

Herbicide rate (kg ai/ha)	Plant heigt at 50 DAP (cm)	Weeds at 50 DAP G (no/m²)	Weeds at 50 DAP BL (no/m²)	Yield (t/ha)
Weedy check	14.1a	515.0a	907.5a	0.50d
Weed-free check	11.5b	0.0d	0.0c	1.02a
Butralin				
2.0	10.9b	180.0bc	175.0c	0.89ab
Metolachlor				
1.5	11.9b	45.0cd	535.0b	0.56cd
2.0	12.6ab	35.0cd	987.5a	0.81abc
Metol.+Oxyfluorfen				
1.5 + 0.115	8.7c	25.0cd	90.0c	0.88ab
1.5 + 0.23	8.3c	17.5d	22.5c	0.71bcd
2.0 + 0.115	8.9c	15.0d	87.5c	0.86ab
2.0 + 0.23	8.1c	37.5cd	15.0c	0.58cd
Pendimethalin				
1.0	10.7b	282.5b	240.0c	0.80abc
1.5	11.1b	300.0b	142.5c	0.88ab

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Grass (G), Broadleaf (BL).

Table 16. Height and yield of mungbean and weed density after herbicide application, fall 1983.[z]

Herbicide rate (kg ai/ha)	Plant height at 50 DAP (cm)	Weed at 50 DAP G (no/m²)	Weed at 50 DAP BL (no/m²)	Yield (t/ha)
Weedy check	43.3a	256.9a	105.0bc	0.16d
Weed-free check	42.0ab	0.0c	0.0d	0.82a
Butralin				
2.0	40.6abc	146.9b	3.8d	0.58abc
Metolachlor				
1.5	35.6bc	47.5c	190.6a	0.43c
2.0	43.8a	50.0c	138.1ab	0.64abc
Metol.+Oxyfluorfen				
1.5 + 0.115	37.2abc	57.5c	61.2cd	0.63abc
1.5 + 0.23	34.4c	43.1c	8.8d	0.52bc
2.0 + 0.115	44.0a	37.5c	19.4d	0.78a
2.0 + 0.23	38.0abc	30.0bc	2.5d	0.66abc
Pendimethalin				
1.0	44.0a	181.2b	3.8d	0.70ab
1.5	35.8bc	155.6b	0.6d	0.60abc

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Grass (G), Broadleaf (BL).

Yield differences in all three seasons can be traced to differences in the number of plants per m^2 (Table 18) and in the number of pods per plant (Table 19).

Table 17. The effects of selected herbicides on weed density and mungbean height and yield, summer 1983.[z]

Herbicide rate (kg ai/ha)	Plant height at 50 DAP (cm)	Weeds at 50 DAP G (no/m^2)	Weeds at 50 DAP BL (no/m^2)	Yield (t/ha)
Weedy check	65.7ab	131.9a	5.1abc	0.18c
Weed-free check	65.7ab	0.0d	0.0c	1.19ab
Butralin				
2.0	67.2ab	44.0b	7.5ab	1.08b
Metolachlor				
1.5	68.2ab	5.6cd	3.1bc	1.34a
2.0	68.4ab	1.2cd	4.4bc	1.33a
Metol.+Oxyfluorfen				
1.5 + 0.115	62.9b	5.0cd	8.1ab	1.13ab
1.5 + 0.23	50.2c	1.9cd	4.4bc	1.14ab
2.0 + 0.115	62.2b	13.8bcd	3.8bc	1.13ab
2.0 + 0.23	53.0c	19.4bcd	7.5ab	1.06b
Pendimethalin				
1.0	69.5a	31.9bc	10.6a	1.08b
1.5	65.7ab	32.5bc	4.4bc	1.08b

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT. Grass (G), Broadleaf (BL).

Table 18. The effects of selected herbicides upon mungbean stand at harvest, 1983.[z]

Herbicide rate (kg ai/ha)	Plant stand Spring (no/m^2)	Plant stand Summer (no/m^2)	Plant stand Fall (no/m^2)
Weedy check	26.6ab	24.6d	19.9c
Weed-free check	32.7ab	31.0ab	29.9a
Butralin			
2.0	31.1ab	32.0a	29.8a
Metolachlor			
1.5	28.2ab	30.7ab	24.3b
2.0	30.9ab	32.1a	30.0a
Metolachlor + Oxyfluorfen			
1.5 + 0.115	26.6ab	28.9abc	29.6a
1.5 + 0.23	23.4b	28.0bc	31.4a
2.0 + 0.115	30.8ab	31.6a	31.3a
2.0 + 0.23	23.9ab	26.1cd	30.0a
Pendimethalin			
1.0	29.3ab	30.6ab	28.9a
1.5	36.2a	29.0abc	28.7a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 19. The effects of selected herbicides upon mungbean pod number, 1983.[z]

Herbicide rate (kg ai/ha)	Number of pods		
	Spring	Summer	Fall
	---------no./plant---------		
Weedy check	4.9b	2.1c	3.4c
Weed-free check	6.6ab	8.2b	7.4ab
Butralin			
2.0	6.5ab	9.1ab	5.2bc
Metolachlor			
1.5	5.6ab	10.8a	6.2bc
2.0	5.4ab	8.8ab	7.2ab
Metol.+Oxyfluorfen			
1.5 + 0.115	6.9ab	9.4b	7.1ab
1.5 + 0.23	7.3a	8.5ab	6.2bc
2.0 + 0.115	6.6a	9.1ab	9.0a
2.0 + 0.23	6.9ab	9.5ab	7.2ab
Pendimethalin			
1.0	6.1ab	8.4ab	7.5ab
1.5	7.3a	7.4b	5.9bc

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Conclusions

Metolachlor alone provides effective weed control in summer mungbean fields. Application rates should vary from 1.5 to 2.0 kg/ha, depending on the degree of weed infestation.

Butralin gives good results in the spring and fall. Under heavy weed infestation, though, the combination of metolachlor at 1.5 kg/ha and oxyfluorfen at 115 g/ha could be a better choice, even though it might result in some degree of crop injury.

Comparison of Nursery Methods for Growing Chinese Cabbage and Tomato Seedlings

Introduction

To avoid the yield loss and transplanting shock associated with plantings in flats, seedlings are usually grown in small pots, a costly and time-consuming procedure. In 1982, however, AVRDC scientists developed a new technique for raising seedlings. Called slot planting, it appears to be more economical and efficient than pot planting. In 1982, Chinese cabbage plants from seedlings grown with the slot planting method produced yields about 14% higher than those associated with the more conventional flat planting technique; tomato yields were about 6%

higher. Trials designed to further evaluate the effectiveness of this method in comparison with the pot and conventional flat planting methods were conducted in three different seasons of 1983.

Materials and Methods

Chinese cabbage:

Seedlings were raised in three different types of containers: 50 x 30 x 7 cm plastic flats; tapered plastic pots (7.2 cm high), with inside bottom and top dimensions of 4.1 and 6.2 cm; and plastic flats partitioned with PVC strips to form 48 individual slots per flat. Nursery soil was composed of 50% soil, 30% compost, 10% sand, and 10% rice hulls. The soil, enough for 40 flats, received 325 g ammonium sulfate, 225 g superphosphate, and 135 g potassium chloride.

An RCB design was used with either five or six replications. Hybrid No. 62 was planted in the summer trial, and Bing Luh was planted in the spring and fall. Seedlings were transplanted at 40 DAP in the spring, 21 DAP in the summer, and 20 DAP in the fall.

Tomato:

Seedlings of Tainan #2 were raised in three different types of containers: 50 x 30 x 7 cm plastic flats, tapered PE pots (7.2 cm) high with bottom and top inside diameters of 4.1 and 6.2 cm, and plastic flats partitioned with PVC strips into 48 individual slots. The nursery soil was composed of 50% soil, 30% compost, 10% sand, and 10% rice hulls. The soil, enough for 40 flats, received 360g ammonium sulfate, 225 g superphosphate, and 135 g potassium chloride.

An RCB design was used with five replications. Seedlings were transplanted at 27 days after planting.

Results

Tomato:

Growth parameters as measured at various stages are shown in Table 20. Plants from the seedlings grown with the flat method were significantly shorter than those from seedlings grown with the pot and slot methods. There were no height differences between the pot and slot treatments. Plant and root fresh weights were also affected by seedling nursery method (Table 21). These effects were most apparent at 30 DAT. Both the lowest plant weight (92.5 g/plant) and the lowest root weight (5.13 g/plant) were from the flat method. There were no differences in fresh root or plant weights between the pot and slot methods. Although marketable yield did not vary significantly between treatments, yields of the pot and slot treatments tended to be slightly higher than those of the flat treatments (Table 21). Yields averaged 68.9 t/ha for the flat method, 71.3 t/ha for the slot method, and 73.0 t/ha for the pot method.

Table 20. Plant heights of tomatoes grown from seedlings raised by three different methods, 1983.[z]

Seedling nursery	Fall, DAT		
	15 (cm)	23 (cm)	30 (cm)
Flat	17.4b	27.9b	39.5b
Pot	20.5a	33.6a	45.6a
Slot	20.2a	33.1a	45.0a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 21. Fresh plant weight, fresh root weight, and marketable yield of tomatoes grown from seedlings raised by three different methods, 1983.[z]

Seedling nursery	Plant fresh weight, DAT			Root fresh weight, DAT			Yield (t/ha)
	15	23	30	15	23	30	
	-------(gm/plant)------			-------(gm/root)--------			
Flat	15.0a	47.2a	92.5b	1.75a	3.93a	5.13b	68.9a
Pot	20.4a	66.8a	138.3a	1.87a	5.07a	7.43a	73.0a
Slot	18.4a	64.8a	137.5a	1.67a	4.90a	7.30a	71.3a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Chinese cabbage:

Growth parameters at various stages are shown in Table 22. Root injury during transplanting significantly reduced the fresh weight of plants from seedlings grown with the flat method. This reduction was most obvious in the fall, when the fresh weight of plants from seedlings grown with the flat planting method was much lower than that of those grown with the pot and slot methods, even at 28 DAT. The response of root development to various seedling nursery methods was similar (Table 23); more rapid root development resulted with the pot and slot methods, especially in the fall, when temperatures were relatively low. Total plant weights and head yields are shown in Table 24. Although there were no significant differences in either total plant weight or head yield, yields with both pot and slotted flat methods tended to be higher than those of the conventional flat planting. Average head yields over all three seasons were 19.6 t/ha for the slotted flat method, 18.8 t/ha for the pot method, and 18.4 t/ha for the conventional flat method.

Table 22. Fresh weights of Chinese cabbage plants[z] grown from seedlings raised by three different methods, 1983.

Seedling nursery	Spring, DAT			Summer, DAT			Fall, DAT		
	15	20	25	15	20	25	14	21	28
	(gm/plant)								
Flat	82b	310a	468b	69b	202a	511a	62c	310b	699b
Pot	118a	361a	529a	95a	241a	487a	174a	560a	1030a
Slot	90ab	307a	476b	100a	247a	494a	135b	519a	1023a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 23. Fresh weights of Chinese cabbage plants[z] grown from seedlings raised by three different methods, 1983.

Seedling nursery	Spring, DAT			Summer, DAT			Fall, DAT		
	15	20	25	15	20	25	14	21	28
	(gm/root)								
Flat	1.4a	4.8b	5.9b	3.0a	6.0b	16.1a	1.2b	4.9b	10.2b
Pot	1.8a	5.9a	7.1a	3.4a	8.0a	15.0a	2.7a	8.7a	15.1a
Slot	1.4a	5.4ab	6.7a	3.7a	7.5ab	14.6a	2.3a	8.1a	13.8a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 24. Head yields and total plant weights of Chinese cabbage grown from seedlings raised in three different ways, 1983.[z]

Seedling nursery	Total plant weight			Head yield		
	Spring (t/ha)	Summer (t/ha)	Fall (t/ha)	Spring (t/ha)	Summer (t/ha)	Fall (t/ha)
Flat	47.9	31.8	61.2	21.6	9.7	23.8
Pot	50.7	33.2	62.4	22.6	9.6	24.1
Slot	50.8	35.5	65.1	22.4	11.7	24.8

[z] There were no sifnificant differences in either total plant weight or head yield between different treatments.

Conclusions

The roots of both Chinese cabbage and tomato grown from seedlings raised with the pot and slot methods developed more quickly than did the roots of plants grown from seedlings raised with the flat method. They should be thus able to exploit nutrients and soil moisture more effectively than could the roots of plants from seedlings grown with the flat method. There was little yield difference in these trials, but nutri-

ents and soil water were not limiting factors. Vigorous root development could prove advantageous where soil is relatively dry and infertile. Although traditional plantings in individual pots can provide the same results, slotted flats appear able to save the farmer a great deal of time and labor, and would thus seem to be the best method of the three.

Optimum Times for Tying the Leaves of Summer Chinese Cabbage

Introduction

The head formation of Chinese cabbage is governed both by temperature and light. Dense, high quality heads can be produced at temperatures ranging from 15 to 20° C, but Chinese cabbage usually performs poorly when grown at temperatures above 25° C. The low yields obtained at high temperatures once made it unprofitable to grow Chinese cabbage during the summer in the lowland tropics, but previous research at AVRDC has revealed that because hyponastic movement and hence head formation is stimulated by darkness, the head formation of moderately heat tolerant cultivars can be improved by tying the outer leaves together to form a protective shield. This study was designed to determine the optimum growth stage for performing such an operation.

Materials and Methods

Two field experiments employing a split plot design were conducted during the summer of 1983. Three cultivars (Bing Luh, Wen Wu, and Fong Luh) were planted in the main plots; and in the subplots leaves were tied at 21, 24, 27, 30, 33, or 36 DAT. In the first experiment, 30-day-old seedlings were transplanted on June 10, and the last harvest was on August 3. In the second experiment, 21-day-old seedlings were transplanted on August 10 and harvested on September 23.

Results

Temperatures during the study ranged from 23 to 35° C. Rainfall was unusually low, especially during the first experiment. This favored the proliferation of diamondback moth, which seriously damaged both crops.

In both experiments, all leaf-tying treatments significantly increased heading rates over those of the control (Table 25). Heading rates ranged from 89 to 99% for Bing Luh, 68 to 96% for Fong Luh, and 85 to 100% for Wen Wu. Without leaf tying, heading rates ranged from 20 to 38% for Bing Luh, 25 to 51% for Fong Luh, and 28 to 63% for Wen Wu. Heading rates were equally high for all leaf-tying treatments. Head weight was also increased by leaf tying (Table 26). The highest head weights were obtained when leaves were tied at 30 to 33 DAT for Bing Luh and 27 to 33 DAT for Wen Wu and Fong Luh. In all cases, leaf tying

made heads denser and more solid than those of the control. As one might expect from their higher heading rates and more solid heads, the leaf-tying treatments yielded significantly more than the control (Table 27). Yields of all three cultivars were highest when leaves were tied at 30 to 33 DAT. Fong Luh and Wen Wu, however, showed no reduction in yield when their leaves were tied as early as 27 DAT.

Table 25. Effect of leaf-tying at various times on the heading rate of summer Chinese cabbage, 1983.[z]

Leaf-tying (DAT)	Bing Luh A (%)	Bing Luh B (%)	Fong Luh A (%)	Fong Luh B (%)	Wen Wu A (%)	Wen Wu B (%)
Control	19.8b	38.2b	25.5d	50.9b	28.5b	62.9b
21	94.7a	-	68.1c	-	91.5a	-
24	96.1a	99.1a	77.2bc	79.1a	93.3a	91.0a
27	97.5a	95.5a	86.7ab	85.2a	94.6a	97.1a
30	98.7a	98.1a	83.9ab	90.8a	96.1a	100.0a
33	97.5a	98.1a	95.3a	80.4a	100.0a	85.1a
36	97.5a	88.6a	95.9a	78.4a	94.7a	88.3a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Transplanted on June 10 (A) and on August 10 (B).

Table 26. Effect of leaf-tying at various times on the heading weight of summer Chinese cabbage, 1983.[z]

Leaf-tying (DAT)	Bing Luh A (gm)	Bing Luh B (gm)	Fong Luh A (gm)	Fong Luh B (gm)	Wen Wu A (gm)	Wen Wu B (gm)
Control	370c	480b	500bc	570a	520bc	520ab
21	500b	-	410c	-	390d	-
24	530b	410b	480bc	430b	450cd	420b
27	590ab	480b	560ab	510ab	650a	480ab
30	650a	540ab	590ab	620a	590ab	610a
33	650a	610a	660a	600a	620ab	490ab
36	510b	540ab	530b	550ab	540bc	590a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Transplanted on June 10 (A) and on August 10 (B).

Table 27. Effect of leaf-tying at various times on the marketable yield of summer Chinese cabbage, 1983.[z]

Leaf-tying (DAT)	Bing Luh A (t/ha)	Bing Luh B (t/ha)	Fong Luh A (t/ha)	Fong Luh B (t/ha)	Wen Wu A (t/ha)	Wen Wu B (t/ha)
Control	2.36d	6.52d	3.22d	7.20b	4.89c	10.84c
21	11.03c	-	3.60d	-	8.61b	-
24	12.05bc	11.17c	5.79cd	6.54b	10.67b	10.49c
27	14.79b	13.86c	9.10bc	12.29a	18.65a	14.31bc
30	20.21a	20.82a	10.52b	15.13a	18.53a	19.37a
33	20.03a	19.49ab	15.80a	14.12a	19.57a	13.86bc
36	15.12b	14.82bc	14.19a	10.74ab	16.36a	17.09ab

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Transplanted on June 10 (A) and on August 10 (B).

Conclusions

Leaf tying can significantly increase the head yields of moderately heat tolerant Chinese cabbage cultivars grown during the summer season in the tropical lowlands. The optimum time for leaf tying appears to be between 30 and 33 DAT.

Sweet Potato Herbicide Evaluation

Introduction

Weeds are a major constraint of summer sweet potato production in the lowland tropics. Increased production, especially for industrial purposes in countries where labor is expensive and in short supply, may require the use of herbicides. Before this study, however, most herbicide evaluations for sweet potato had been conducted in the temperate regions. This study was designed to identify the herbicide which could best control weeds in sweet potato grown in the tropics.

Materials and Methods

AVRDC selection CN 1108-13 served as the test crop. An RCB design was used with four replications. Individual 3 x 6 m plots were planted to three rows of sweet potato, with 30 cm between plants and 1 m between rows. Treatments were DCPA applied pre-emergence one week after planting (WAP), or 2 WAP at a rate of 7.5 kg/ha; diphenamid applied pre-emergence or 1 WAP at a rate of 5.0 kg/ha; metolachlor applied pre-emergence at a rate of 1 or 2 kg/ha with or without 115 g/ha oxyflourfen; a weedy check; and a weed-free check which was weeded by hand. The crop was planted on July 12, using 30 cm cuttings, and was harvested on November 14. Irrigation was administered on July 13, August 27, and October 27.

Results

The development of grassy weeds was significantly affected by the herbicides tested (Table 28). When compared with the weedy check, both Eleusine indica and Echinochloa colonum developed more slowly in the plots treated with diphenamid, metolachlor, or metolachlor + oxyflourfen. The one exception was that E. colonum's growth was not retarded by diphenamid applied 1 WAP. Although grasses grew more slowly when DCPA was applied pre-emergence, they were not effectively controlled when DCPA was applied 1 or 2 WAP.

The growth of broadleaf weeds in each treatment is shown in Table 29. Diphenamid generally gave better control of broadleaf weeds when applied pre-emergence than when applied post-emergence (1 WAP). DCPA gave poor control of portulaca, and weed fresh weight at harvest showed DCPA to be ineffective in controlling grasses in general (Table 30). Of all herbicide treatments, vine weights were the lowest

for the DCPA treatment (Table 30). Marketable yields were also significantly reduced by weed growth (Table 31). Although the yields of the treatment which had DCPA applied pre-emergence were as high as those of the weed-free check, they were not significantly higher than those of the weedy check. Yields from plots treated with diphenamid, metolachlor, and metolachlor + oxyflourfen were as high as those of the weed-free check. The highest yield (15.9 t/ha) was from the treatment which had diphenamid applied pre-emergence. Weed competition lowered yields by reducing both the size and number of roots.

Conclusions

Although DCPA does not appear to control weeds effectively, it does seem to give better control if applied pre-emergence than if applied post-emergence. Plants treated with diphenamid applied pre-emergence at a rate of 5 kg/ha gave the highest yields (15.9 t./ha). Yield increases can be attributed to the development of more and larger roots.

Table 28. The effects of selected herbicides upon the development of grassy weed and purple nutsedge summer, 1983.[z]

Leaf-tying (kg/ha)	E. Indica A (no/m^2)	E. Indica B (no/m^2)	E. Chloronum A (no/m^2)	E. Chloronum B (no/m^2)	C. Rotundus A (no/m^2)	C. Rotundus B (no/m^2)
Weedy check	38.8a	20.8a	47.5a	18.3a	7.9a-d	4.2cd
Weed-free check	0.0b	0.0d	0.0d	0.0b	0.0d	0.0d
DCPA						
7.5 (pre)	17.5b	9.6bc	8.3c	7.1b	8.7a-d	19.6bc
7.5 (1 WAP)	42.9a	17.9ab	32.9ab	19.2a	20.0ab	32.9ab
7.5 (2 WAP)	42.1a	21.2a	47.5a	21.2a	1.2d	1.7cd
Diphenamid						
5.0 (pre)	0.0b	0.0d	3.3d	2.5b	10.4abcd	12.1cd
5.0 (1 WAP)	1.2b	1.7cd	21.2bc	17.9a	17.9abc	19.6bc
Metolachlor						
1.0 (pre)	0.0b	0.0d	0.4d	2.9b	22.1a	40.8a
2.0 (pre)	0.0b	0.0d	0.0d	2.1b	4.2cd	20.0bc
Moto.+Oxy.						
1 + 0.115	0.0b	0.0d	1.2d	4.6b	6.2bcd	17.9bcd
2 + 0.115	0.0b	0.0d	0.4d	0.4b	9.6abcd	42.9a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Weed density determined at 20 DAP (A) and 48 DAP (B).

Table 29. The effects of selected herbicides upon the development of broadleaf weeds, summer 1983.[z]

Leaf-tying (kg/ha)	Amaranth A (no/m²)	Amaranth B (no/m²)	Chenopodium A (no/m²)	Chenopodium B (no/m²)	Portulaca A (no/m²)	Portulaca B (no/m²)
Weedy check	4.2a	1.7ab	7.9a	1.2a	2.50a	3.8a
Weed-free check	0.0b	0.0b	0.0b	0.0a	0.0c	0.0b
DCPA						
7.5 (pre)	2.1ab	1.2ab	3.3b	0.0a	16.2ab	1.2ab
7.5 (1 WAP)	0.4b	0.0b	0.0b	0.0a	2.9c	0.0b
7.5 (2 WAP)	0.4b	0.4ab	7.1ab	0.0a	23.8a	0.8ab
Diphenamid						
5.0 (pre)	0.4b	0.4ab	0.4b	0.0a	9.2bc	0.0b
5.0 (1 WAP)	0.0b	0.4ab	1.2b	0.8a	21.1a	3.3a
Metolachlor						
1.0 (pre)	0.4b	2.1a	2.9b	2.5a	10.0bc	0.8ab
2.0 (pre)	0.0b	0.0b	3.3b	1.7a	5.4c	0.8ab
Moto.+Oxy.						
1 + 0.115	0.4b	0.8ab	1.7b	1.7a	0.4c	0.0b
2 + 0.115	0.8b	1.2ab	2.1b	0.4a	0.8c	0.0b

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.
Weed density determined at 20 DAP (A) and 48 DAP (B).

Table 30. The effects of selected herbicides upon weed fresh weight and sweet potato vine weight at harvest, summer 1983.[z]

Herbicide rate (kg/ha)	Grass (t/ha)	Amaranth (t/ha)	Vine weight (t/ha)
Weedy check	5.5a	0.5a	18.7d
Weed-free check	0.0c	0.0a	51.1a
DCPA			
7.5 (pre)	4.5ab	0.4a	28.7bcd
7.5 (1 (WAP)	4.5ab	0.2a	22.5cd
7.5 (2 WAP)	7.0a	0.0a	18.7d
Diphenamid			
5.0 (pre)	0.0c	0.0a	41.6ab
5.0 (1WAP)	1.5bc	0.0a	34.6bc
Metolachlor			
1.0 (pre)	1.2c	4.0a	37.3abc
2.0 (pre)	0.0c	3.3a	53.0a
Meto.+Oxy.			
1.0 + 0.115	0.0c	0.7a	44.2ab
2.0 + 0.115	0.0c	0.0a	43.8ab

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 31. The effects of selected herbicides upon sweet potato's marketable yield and yield components, summer 1983.[z]

Herbicide rate (kg/ha)	Marketable yield (t/ha)	Root number (no/plant)	Root size (gm/root)
Weedy check	4.4bc	0.8c	139.9c
Weed-free check	13.1a	2.6a	151.2bc
DCPA			
7.5 (pre)	10.4abc	1.4bc	226.8a
7.5 (1 (WAP)	5.6bc	1.2bc	127.0c
7.5 (2 WAP)	4.0c	0.9c	125.1c
Diphenamid			
5.0 (pre)	15.9a	3.0a	169.9abc
5.0 (1WAP)	13.7a	2.2ab	165.8abc
Metolachlor			
1.0 (pre)	10.7ab	2.2ab	159.8bc
2.0 (pre)	10.1abc	1.9abc	167.9abc
Meto.+Oxy.			
1.0 + 0.115	15.8a	2.2ab	214.8ab
2.0 + 0.115	12.4a	2.3ab	167.5abc

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Effect of Planting Density Upon Tomato Yield

Introduction

Planting density and spacing greatly affect tomato yield. Yield generally increases with population density, but only to a certain point. In some developing countries farmers try to improve yields by increasing planting density or by planting more than one plant per hill. Although this seems reasonable, it may not always produce the desired result. This study was designed to determine the influence of spacing and the number of plants per hill upon tomato's growth and yield.

Materials and Methods

Twenty-eight-day-old seedlings of Tainan No. 2 were transplanted to the field on October 6, 1983. Individual plots consisted of four 1 x 6 m raised beds, each of which had planted on it one row of tomato. An RCB design was used with three replications. Treatments included hill

spacings of 30, 40, 50, and 60 cm, with either one or two plants per hill. The standard spacing recommended by AVRDC (one plant/hill, 30 cm between hills, and 150 cm between rows) was used as a control. Fruits were harvested at 83, 90, 97, 104, 111, and 113 days after transplanting.

Results

Plant height was not affected by spacing or the number of plants per hill. Plant fresh weight was affected, however (Table 32). Plants were generally healthier and heavier when there was only one per hill. This can be seen most clearly by comparing treatments 3 and 4 four weeks after transplanting (WAT). Plants from treatment 3 (one plant/hill) weighed an average of 149.3 grams, but plants from treatment 4 (two plants/hill) weighed an average of only 74.0 g. Due to competition for light and space, most hills with two plants had only one which was vigorous.

Plants spaced further apart had significantly more fruit clusters (Table 33). This effect was most pronounced at 10 WAT. With one plant per hill, the number of clusters per plant was 22.87, 23.50, 36.33, and 31.03 for spacings of 30, 40, 50, and 60 cm, respectively. Similar responses were noted for treatments with two plants per hill, even though plantings with one plant per hill had consistently more clusters per plant than did those with two plants per hill. Plantings with one plant per hill had an average of 29.2 clusters per plant, and those with two plants per hill had an average of 16.1 clusters per plant.

Although fruit size was unaffected by row spacing or the number of plants per hill, the number of fruits per plant was affected by both factors (Table 34). At 6 WAT, the effects were negligible, and at 8 WAT only the number of plants per hill had a significant effect on the number of fruits per plant. By 10 WAT, however, the number of fruits per plant was influenced by both spacing and the number of plants per hill.

Marketable yield per plant was greater with one plant per hill than with two plants per hill (Table 35). This effect was most striking when plants were spaced further apart. When plants were spaced 30 cm apart, the yield difference was an average of 1.02 kg, and ranged from 0.91 to 1.93. When they were spaced 60 cm apart yield differences averaged 1.66 kg, and ranged from 1.80 to 3.46 kg. Although the treatment with only one plant per hill gave a higher yield per plant, its lower population density meant that there was no difference in yield/ha.

Conclusions

There appears to be no advantage to planting more than one plant per hill. The higher population density gained by planting two plants per hill is offset by fewer fruit clusters per plant, fewer fruits per plant, and lower yields per plant. When one considers the additional labor and seedlings involved, it would seem best to plant only one plant per hill. The best spacing under these experimental conditions was either 30 x 100 cm or 40 x 100 cm.

Table 32. The effects of plant spacing and number of plants per hill upon plant height and fresh weight at various growth stages.

Treatment	Spacing (cm)	Plant density (no/hill)	Plant height		Plant fresh weight	
			2 WAT (cm)	4 WAT (cm)	2 WAT (gm/plant)	4 WAT (gm/plant)
1	30 x 100	1	22.7a	46.3a	16.7ab	128.7abc
2	30 x 100	2	20.3a	41.3a	12.3b	102.3abc
3	40 x 100	1	23.0a	47.0a	15.3ab	149.3ab
4	40 x 100	2	23.3a	46.3a	12.7b	74.0c
5	50 x 100	1	22.0a	47.0a	23.3a	166.7a
6	50 x 100	2	22.3a	45.7a	20.0ab	118.7abc
7	60 x 100	1	21.3a	43.0a	18.3ab	156.0ab
8	60 x 100	2	22.0a	43.0a	11.0b	95.0bc
9	30 x 150	1	19.7a	40.3a	20.0ab	165.0a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 33. The effects of plant spacing and number of plants per hill upon number of clusters with fruit at various growth stages.[z]

Treatment	Spacing (cm)	Plant density (no/hill)	Cluster number	
			8 WAT	10 WAT
			-----no/plant-----	
1	30 x 100	1	15.57a	22.87bc
2	30 x 100	2	7.4c	11.13e
3	40 x 100	1	15.57a	23.57bc
4	40 x 100	2	9.93bc	13.73de
5	50 x 100	1	16.13a	36.33a
6	50 x 100	1	10.33bc	19.30cde
7	60 x 100	1	15.0a	32.03a
8	60 x 100	2	8.97be	20.27cd
9	30 x 150	1	13.13ab	31.03ab

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 34. The effects of plant spacing and number of plants per hill upon the weight and number of fruits at varous growth stages.[z]

Treat-ment	Spacing (cm)	Plant density (no/hill)	Fruit number			Fruit weight		
			6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
			------(no/plant)-------			--------(gm/fruit)------		
1	30 x 100	1	14.0ab	61.33a	86.87b	7.6a	11.6a	22.6ab
2	30 x 100	2	9.67ab	30.0c	40.83d	6.2a	10.9a	24.9a
3	40 x 100	1	14.30a	62.33a	89.67b	5.4a	11.6a	22.3ab
4	40 x 100	2	11.67ab	41.33bc	49.13dc	7.4a	9.8a	21.1ab
5	50 x 100	1	12.67ab	67.33a	143.23a	6.3a	10.6a	19.3b
6	50 x 100	2	11.33ab	44.0bc	74.4 bcd	5.8a	11.5a	20.7ab
7	60 x 100	1	14.67a	63.0a	129.77a	7.5a	10.3a	21.0ab
8	60 x 100	2	7.33b	39.33bc	80.63bc	5.6a	10.6a	19.3b
9	30 x 150	1	12.0 ab	53.0ab	127.23a	5.5a	11.5a	21.9ab

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 35. The effects of plant spacing and number of plants per hill upon marketable yield and green fruit weight.[z]

Treatment	Spacing (cm)	Plant density (no/hill)	Marketable yield		Green fruit (t/ha)
			Plant (kg/plant)	Area (t/ha)	
1	30 x 100	1	1.93cd	59.72a	20.7a
2	30 x 100	2	0.91f	55.77ab	28.9a
3	40 x 100	1	2.37c	57.53ab	25.4a
4	40 x 100	2	1.21ef	57.99ab	28.4a
5	50 x 100	1	2.93b	51.52ab	23.4a
6	50 x 100	2	1.64de	60.13a	23.3a
7	60 x 100	1	3.46a	50.15b	32.2a
8	60 x 100	2	1.80d	52.43ab	32.2a
9	30 x 150	1	1.48de	36.34c	28.2a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Garden Programs

Background

In 1982, the first year of garden research and development at AVRDC, emphasis was placed on determining which crops would give the highest yields and the most significant output of selected nutrients. Results were too good; yields were often greater than a family could use on a daily basis, and thus rendered superfluous the costly inputs that had been required to produce such yields.

The second year was used to "fine-tune" the gardens. Inputs were reduced, and netting was used instead of insecticides. Increasing the number of crops grown in the home gardens at any one time not only made them less attractive to pests which prefer a mono-crop environment, but also ensured a steady supply of a variety of vegetables. In 1983 fifty-two crops were grown in the gardens (Table 1).

The results reported here can be useful to those who are responsible for planning and implementing agriculture/nutrition, income generation, food production, or women-in-development projects.

School Gardens

Introduction

Although school children need energy and protein foods to meet the demands of their growing bodies, they also require the vitamins and minerals that vegetables provide. A small amount of cooked vegetables added to the rice-box lunches that Asian children bring to school could make a significant contribution to their daily needs of several vitamins and minerals.

The objective of this project was to develop a garden which could be grown at school and provide 80 children with a half a cup (approximately 113 gram edible portion) of nutritious vegetables, five days per week, throughout the school year.

Materials and Methods

Four "seasonal" gardens were grown from July of 1982 through June of 1983 on a 10 x 18 m plot consisting of twelve 1.5 x 10 m raised beds, 24 cm high. Variations in the four plantings reflected seasonal changes

in the AVRDC environment. Garden I (hot and wet) was grown from July through September, garden II (hot and dry) from October through December, garden III (cool and dry) from January through March, and garden IV (cool and wet) from April through June. Twenty-four vegetables were chosen on the basis of their nutritional value and cultural acceptability. Low input agricultural practices were followed with minimal use of pesticides. Hand weeding and pest control were practiced when possible. Beds were covered with screening during the early stages of crop growth. Yields were recorded for each vegetable in every planting period, and samples were analyzed for their contents of protein, calcium, iron, and vitamins A and C. The contributions that a half cup of the cooked vegetable would make to an average 10-year-old school child's recommended daily allowance (RDA) of selected nutrients was also calculated.

Results

Yields and nutritional components of vegetables grown in each season are shown in Tables 2 through 5. During the equivalent of a 260 day school year, the garden produced a daily average of 18.57 kilograms of nutritious, culturally acceptable vegetables. This corresponds to a daily average of 273 g protein, 484 g iron, 1.66 kg calcium, 33,560 ugRE vitamin A, and 6.08 g vitamin C, and translates to one hundred sixty-four 113 g servings per day over a 260 day school year. Each of those servings could contribute substantially to the RDA of a ten-year-old schoolchild, especially in terms of iron and vitamins A and C (Table 6).

Conclusions

A 10 x 18 m school garden can provide 164 children with a half a cup of vegetables per day. If there are fewer children in the school, the garden can be made smaller, the children can take the excess vegetables home to their families, or the school can sell the vegetables. In all three cases, the garden is an inexpensive means of increasing the availability of vitamins and minerals in the community.

Home Gardens

Introduction

Vegetables, especially leafy green vegetables, contain protein, calcium, iron, and vitamins A and C, most of which are lacking in the diets of people in developing countries. The nutritional status of small-farm families could be improved if they were shown how to grow home gardens containing nutritious and culturally acceptable crops.

The objective of this project was to develop small home gardens containing an intercrop of nutritious vegetables (and a few fruits) which are culturally acceptable in Southeast Asia and which could

provide a typical family of five with 40% of their RDA of calcium and iron, 80% of their RDA for vitamin A, 100% of their RDA of vitamin C, and measurable amounts of protein. The gardens were not expected to produce a great deal of protein, but it must be remembered that the protein from dark, green leafy vegetables is of very high quality.

Home gardens have been developed at AVRDC for Indonesia, the Phillipines, and Thailand. Because many Asian diets are deficient in Vitamin A, a "Vitamin A garden" has also been developed to see how much of this nutrient can be produced in a small garden.

Materials and Methods

In each of the four gardens, a culturally acceptable intercrop of vegetables and a few fruits was planted on a 4 x 4.5 m plot consisting of three 25 cm high 1.5 x 4 m raised beds. Garlic, shallot, and hot pepper were planted around the edges of the beds in each garden. As with the school gardens, each type of garden was planted four times during the year in response to seasonal changes in the AVRDC environment. Low input practices, were used i.e. hand weeding and pest removal, rice-straw mulching, and covering the beds with plastic screen during the early growth stages.

During each season, the yield of each crop was monitored in all gardens, and samples of each crop were analyzed for their content of protein, calcium, iron, and vitamins A and C. By comparing these data with FAO's RDA for a typical family of five (Table 7), it was possible to determine the percentage of a family's RDA supplied by each crop and each garden.

Results

The yield and nutritional composition of the vegetables grown in each season are shown for the Indonesia (Tables 8 through 11), Thailand (Tables 12 through 15), Phillipines (Table 16 through 19), and the vitamin A gardens (Tables 20 through 23). The four season mean contribution of each garden is summarized in Table 24. In all but the hot and wet season, each garden more than met the objectives set for it, in terms of both yield and the contribution it could make to the RDA of a family of five.

Conclusions

Yields were slightly lower than in previous years; attempts to reduce input costs resulted in slight yield reductions. Yields still fell within the range that an Asian family of five is likely to consume on a daily basis, and this year's figures accordingly more realistically show the value of the garden and present a truer picture of its contribution to a family's RDA.

Table 1. The 52 crops grown in the AVRDC gardens, 1982-83.

Common name	Scientific name
Amaranth	Amaranthus mangostanus
Bitter gourd (Balsam pear)	Momordica charantia L.
Broccoli	Brassica oleracea var. italica
Cabbage	Brassica oleracea var. capitata
Carrot	Daucus carota var. sativa DC.
Cassava	Manihot esculenta
Cauliflower	Brassica oleracea var. botrytis
Celery	Apium graveolens L.
Cherry radish	Raphanus sativus L.
Chinese cabbage	Brassica pekinensis
Chinese leek	Allium odorum
Ching-chiang pai-tsai (Spoon cabbage)	Brassica Rapa L. var. chinensis Kitam
Coriander	Coriandrum sativum
Corn	Zea mays
Cow pea	Vigna unguiculata subsp. unguiculata
Cucumber	Cucumis Sativus
Egg plant	Solanum melongena L.
Garland Chrysanthemum (Crown daisy)	Chrysanthemum coronarium L.
Garlic	Allium sativum L.
Hot pepper	Capsicum frutescens
Hyacinth bean	Dolichos lablab L.
Ipil ipil	Leucaena leucocephala De Wit
Kale	Brassica oleracea var. acephala
Kang kong (Water convolvulus)	Ipomoea aquatica Forsk.
Kohlrabi	Brassica oleracea L. var. gongylodes
Lettuce	Lactuca sativa L.
Lemon grass	Cymbopogon citratus
Lima bean	Phaseolus lunatus var. macrocarpus
Mustard	Brassica juncea
Mango	Mangifera indica
Mungbean	Phaseolus mungo
Okra	Hibiscus esculentus L.
Papaya	Carica papaya
Pai-tsai	Brassica chinensis L.
Peanut	Arachis hypogaea
Pumpkin	Cucurbita moschata
Radish	Raphanus sativus L.
Rape green	Brassica campestris
Snake gourd	Trichosanthes anguina
Snap bean (kidney bean)	Phaseolus vulgaris L.
Snow pea (garden pea)	Pisum sativum L.
Spinach	Spinacia oleracea L.
Shallot	Allium ascalonicum
Sponge gourd	Luffa cylindrica
Sweet pepper	Capsicum annuum L.
Sweet potato tips	Ipomoea batatas
Sweet corn	Zea mays L.
Tomato	Lycopersicum esculentum Mill
Vegetable soybean	Glycine max. Merr.
Welsh onion	Allium fistulosum L.
Winged bean	Psophocarpus tetragonolobus
Yardlong bean	Vigna sesquipedalis Wight

Table 2. Yield and nutrient contribution of school garden I, July to September, 1982, AVRDC.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day				
						Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1-2	Water convolvulus[z]	71	142.9	2.01	6	52.3	2291.4	102.5	6572.7	964.8
1	Rape greens	27	25.0	0.93	3	19.5	1209.0	27.9	5049.9	389.6
3-4	Pai-tsai[z]	9	27.8	3.09	3	55.6	5222.1	105.1	5500.2	2286.6
	Amaranth	58	102.0	1.76	4	52.8	5121.6	251.7	3467.2	528.0
3	Ching-chiang	27	5.3	0.20	1	5.0	416.0	6.8	796.0	171.4
4	Pai-tsai	27	23.5	0.87	2	15.7	1470.3	29.6	1548.6	643.8
5-6	Amaranth[z]	17	20.8	1.22	1	36.6	3550.2	174.5	2403.4	366.0
	Pai-tsai	43	43.7	1.02	4	18.4	1723.8	34.7	1815.6	754.8
5	Rape greens[y]	25	10.4	0.42	2	8.8	546.0	12.6	2280.6	176.0
6	Ching-chiang	25	16.7	0.67	1	18.1	1554.4	25.5	2559.4	518.6
7-8	[Pai-tsai[z]	32	19.6	0.61	1	11.0	1030.9	20.7	1085.8	451.4
	[Yardlong bean[z]	74	48.3	0.65	11	14.7	209.3	15.2	3315.0	122.9
7	Amaranth	27	19.4	0.72	3	25.1	1698.2	48.2	3744.0	259.6
9-10	[Pai-tsai[z]	32	2.5	0.08	1	1.4	135.2	2.7	142.4	59.2
	[Cabbage[z]	62	38.6	0.62	2	8.7	260.4	2.5	142.6	251.7
	Ching-chiang	38	26.7	0.70	2	17.5	1456.0	23.8	2786.0	599.9
10	Amaranth[z]	26	21.7	0.83	3	24.9	2415.3	118.7	1635.1	249.0
11-12	Broccoli[z]	52	10.9	0.21	1	6.3	73.5	1.7	489.3	104.2
	Rape greens[z]	42	45.0	1.07	4	22.5	1391.0	32.1	5810.1	448.3
11	Pai-tsai	27	29.1	1.08	3	19.4	1825.2	36.7	1922.4	799.2
Total			679.9	18.76		434.3	33599.8	1073.4	53066.3	10145.0

[z] Continued from garden IV, April to June, 1982.
[y] Intercropped with coriander and snap bean, which were not harvested in this period.
[= Intercropped.
Additional: Sponge gourd, sweet corn, okra and hot pepper grown on the sides of the garden as a windbreak; 49.1, 16.7, 8.1 and 8.0 kg harvested, respectively.

Table 3. Yield and nutrient contribution of school garden II, October to December, 1982, AVRDC.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1	[Pai-tsai[z]	35	14.6	0.42	3	7.6	709.8	14.3	747.6	310.8
	[Garland chrysanthemum[z]	50	15.8	0.32	5	9.6	492.8	34.2	1104.0	43.2
	[Garland chrysanthemum	42	5.4	0.13	1	3.9	200.2	13.9	448.5	17.6
	[Water convolvulus	39	1.5	0.04	1	1.0	45.6	2.1	130.8	19.2
2	Spinach[z]	38	1.8	0.05	1	0.6	45.5	1.5	271.5	12.2
	[Water convolvulus	36	25.7	0.71	3	18.5	809.4	36.2	2321.7	340.8
	[Lettuce	26	10.6	0.41	1	12.7	492.0	19.3	224.7	51.3
	Amaranth	31	1.9	0.06	1	1.8	174.6	8.6	118.2	18.0
3	Ching-chiang	12	18.5	1.54	1	38.5	3203.2	52.4	6129.2	1319.8
	[Amaranth	35	23.2	0.66	5	19.8	1920.6	94.4	1300.2	198.0
	[Lettuce	33	12.8	0.39	4	12.1	468.0	18.3	213.7	48.8
	Spinach[y]	30	0.3	0.01	1	0.1	9.1	0.3	54.3	2.4
4	[Rape greens[z]	33	19.0	0.58	4	12.2	846.8	19.1	2395.4	256.9
	[Spinach[z]	33	0.2	0.01	1	0.1	9.1	0.3	54.3	2.4
	[Water convolvulus	37	9.5	0.26	4	8.8	395.2	15.6	850.2	124.8
	[Snap bean	56	3.3	0.06	3	11.2	20.2	0.8	9.0	4.2
5	[Rape greens[z]	29	1.5	0.05	1	1.1	73.0	1.7	206.5	22.2
	[Snap bean[z]	67	41.0	0.61	10	113.9	205.0	8.0	91.5	42.8
	Chinese mustard	15	0.5	0.03	1	0.7	53.4	0.6	94.5	34.2
6	Water convolvulus[z]	38	27.2	0.72	4	24.5	1094.4	43.2	2354.4	345.6
	Amaranth	41	26.8	0.65	4	19.5	1891.5	93.0	1280.5	195.0
7	Amaranth[z]	18	32.1	1.78	2	53.4	5179.8	254.5	3506.6	534.0
	[Pai-tsai	28	22.8	0.81	1	14.6	1368.9	27.5	1441.8	599.4
	[Lettuce	28	6.7	0.24	1	7.4	288.0	11.3	131.5	30.0
	Garland chrysanthemum[z]	46	9.7	0.21	4	6.3	323.4	22.5	724.5	28.4
8	Water convolvulus	53	38.7	0.73	5	24.8	1109.6	43.8	2387.1	350.4
	Garland chrysanthemum	65	28.9	0.44	6	13.2	677.6	47.1	1518.0	59.4
9	[Garland chrysanthemum[z]	60	7.7	0.13	3	3.9	200.2	13.9	448.5	17.6
	[Rape greens[z]	33	15.6	0.47	4	9.9	686.2	15.5	1941.1	208.2
	[Lettuce	27	11.2	0.41	1	12.7	492.0	19.3	224.7	51.3
	[Rape greens	31	13.1	0.42	2	8.8	613.2	13.9	1734.6	186.1
10	Amaranth[z]	22	33.8	1.54	3	46.2	4481.4	220.2	3033.8	462.0
	Ching chiang	22	5.0	0.23	1	5.8	478.4	7.8	915.4	197.1
	[Rape greens	22	4.4	0.20	1	4.2	260.0	6.0	1086.0	83,8
	Lettuce	22	6.9	0.31	2	9.6	372.0	14.6	169.9	38.8
	Spinach	48	17.6	0.37	4	4.4	336.7	11.1	2009.1	89.9
11	[Pai-tsai[z]	36	4.7	0.13	3	2.3	219.7	4.4	231.4	96.2
	[Egg plant[z]	73	43.0	0.59	10	11.2	112.1	6.5	88.5	35.4
	Water convolvulus[x]	35	0.9	0.03	1	1.0	45.6	1.8	98.1	14.4
12	Rape greens[z]	29	20.3	0.70	1	14.7	910.0	21.0	3801.0	293.3
	Garland chrysanthemum	42	2.4	0.06	1	1.8	92.4	6.4	207.0	8.1
	[Spinach	37	1.2	0.03	1	0.4	27.3	0.9	162.9	7.3
	Lettuce	41	23.8	0.58	3	18.0	696.0	27.3	317.8	72.5
	Kale[y]	23	0.9	0.04	1	0.7	76.0	1.6	219.2	10.2
Total			612.5	18.16		593.5	32205.9	1276.7	46799.2	6884.0

[z] Continued from garden I.
[y] Intercropped with lettuce, not harvested in this period.
[c] Intercropped with snap bean, not harvested in this period.
[= Intercropped.
Additional: Sponge gourd and cowpea grown on the sides of the garden as a windbreak; 84.2 and 3.1 kg harvested, respectively. Shallot and coriander planted around the edges of beds; 57.4 and 3.7 kg harvested, respectively.

Table 4. Yield and nutrient contribution of school garden III, January to March 1983, AVRDC.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1	Rape greens[z]	34	31.1	0.91	3	19.1	1183.0	27.3	4941.3	381.3
	[Lettuce	52	15.6	0.30	1	9.3	360.0	14.1	164.4	37.5
	[Spinach	55	5.1	0.09	2	1.1	81.9	2.7	488.7	21.9
2	Garland chrysanthemum[z]	51	19.1	0.37	6	11.1	569.8	39.6	1276.5	50.0
	Lettuce[z]	34	4.9	0.14	1	4.3	168.0	6.6	76.7	17.5
	Ching-chiang	36	35.2	0.98	3	26.5	2273.6	37.2	3743.6	758.5
3	[Spinach[z]	42	19.7	0.47	4	5.6	427.7	14.1	2552.1	114.2
	[Lettuce[z]	35	4.3	0.12	1	3.7	144.0	5.6	65.8	15.0
	Pai-tsai	35	11.6	0.33	2	5.9	557.7	11.2	587.4	244.2
	Garland chrysanthemum	33	2.7	0.08	1	2.4	123.2	8.6	276.0	10.8
4	Snap bean[z]	29	24.1	0.83	10	155.0	279.0	10.9	124.5	58.2
	Rape greens	42	51.0	1.21	3	25.4	1573.0	36.3	6570.3	507.0
5	[Chinese mustard[z]	24	36.0	1.50	4	36.0	2670.0	30.0	4725.0	1710.0
	[Lettuce	46	8.6	0.19	1	5.9	228.0	8.9	104.1	23.8
	Garland chrysanthemum	56	17.7	0.32	4	9.6	492.8	34.2	1104.0	43.2
6	Pai-tsai[z]	30	21.0	0.70	3	12.6	1183.0	23.8	1246.0	518.0
	Ching-chiang	34	42.5	1.25	2	33.8	2900.0	47.5	4775.0	967.5
	Pai-tsai[y]	27	0.5	0.02	1	0.4	33.8	0.7	35.6	14.8
7	[Garland chrysanthemum[z]	11	11.3	1.03	3	30.9	1586.2	110.2	3553.5	139.1
	[Lettuce[z]	33	8.9	0.27	4	8.4	324.0	12.7	148.0	33.8
	Kale	57	16.0	0.28	2	4.8	532.0	11.2	1534.4	71.4
8	Garland chrysanthemum[z]	7	7.0	1.00	3	30.0	1540.0	107.0	3450.0	135.0
	[Pai-tsai	34	18.9	0.56	3	10.1	946.4	19.0	996.8	414.4
	[Lettuce	33	4.0	0.12	1	3.7	144.0	5.6	65.8	15.0
	Rape greens	34	10.2	0.30	2	6.3	390.0	9.0	1629.0	125.7
9	[Water convolvulus[z]	49	12.7	0.26	3	8.8	395.2	15.6	850.2	124.8
	[Lettuce[z]	36	15.4	0.43	6	13.3	516.0	20.2	235.6	53.8
	Chinese mustard	50	37.5	0.75	1	18.0	1335.0	15.0	2362.5	855.0
10	[Rape greens[z]	36	15.6	0.43	2	9.0	559.0	12.9	2334.9	180.2
	[Lettuce	63	42.7	0.68	3	21.1	816.0	32.0	372.6	85.0
	[Ching-chiang	45	8.9	0.20	2	5.4	464.0	7.6	764.0	154.8
11	[Water convolvulus[z]	25	15.1	0.60	3	20.4	912.0	36.0	1962.0	288.0
	[Snap bean[z]	93	16.6	0.18	9	33.6	60.5	2.4	27.0	12.6
12	[Kale[z]	22	17.3	0.79	2	13.4	1501.0	31.6	4329.2	201.5
	[Lettuce[z]	60	21.4	0.36	5	11.2	432.0	16.9	197.3	45.0
	[Spinach	42	10.4	0.25	3	3.0	227.5	7.5	1357.5	60.8
	Pai-tsai	33	8.7	0.26	2	4.7	439.4	8.8	462.8	192.4
Total			649.3	18.56		623.8	28368.7	840.5	59490.1	8681.7

[z] Continued from garden II.
[y] Damaged by rain.
[= Intercropped.
Additional: Celery and hot pepper grown on the sides of the garden as a windbreak; 0.8 and 0.66 kg harvested, respectively. Shallot, garlic and coriander planted around the edges of beds; 67, 17.1 and 7.7 kg harvested, respectively.

Table 5. Yield and nutrient contribution of school garden IV, April to June 1983, AVRDC.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1	Water convolvulus[z]	48	14.5	0.30	1	10.2	456.0	18.0	981.0	144.0
	[Ching-chiang	39	23.3	0.60	1	16.2	1392.0	22.8	2292.0	464.4
	[Lettuce	26	1.9	0.07	1	2.2	84.0	3.3	38.4	8.8
2	Chinese mustard[z]	41	36.5	0.89	1	21.4	1584.2	17.8	2803.5	1014.6
	Water convolvulus	50	57.0	1.14	4	38.8	1732.8	68.4	3727.8	547.2
3	Garland chrysanthemum[z]	20	13.1	0.66	4	19.8	1016.4	70.6	2277.0	89.1
	[Pai-tsai	28	31.1	1.11	1	20.0	1875.9	37.7	1975.8	821.4
	[Lettuce	45	8.3	0.18	1	5.6	216.0	8.5	98.6	22.5
	[Rape greens	35	8.6	0.25	1	5.3	325.0	7.5	1357.5	104.8
4	Water convolvulus[z]	52	20.3	0.39	2	13.3	592.8	23.4	1275.3	187.2
	[Chinese mustard	35	25.7	0.73	1	17.5	1299.4	14.6	2299.5	832.2
	[Lettuce	25	1.7	0.07	1	2.2	84.0	3.3	38.4	8.8
5	Ching-chiang	34	23.8	0.70	3	17.5	1456.0	23.8	2786.0	599.9
	Pai-tsai	26	40.9	1.57	1	28.3	2653.3	53.4	2794.6	1161.8
	Amaranth	38	5.1	0.13	2	3.9	378.3	18.6	256.1	39.0
6	Pai-tsai	28	3.5	0.13	1	2.3	219.7	4.4	231.4	96.2
	[Amaranth	54	23.8	0.44	4	13.2	1280.4	62.9	866.8	132.0
	[Lettuce	35	1.6	0.05	1	1.6	60.0	2.4	27.4	6.3
	Chinese mustard	30	4.7	0.16	1	3.8	284.8	3.2	504.0	182.4
7	Ching-chiang[z]	35	32.8	0.94	1	25.4	2180.8	35.7	3590.8	727.6
	Rape greens	25	22.3	0.89	1	18.7	1157.0	26.7	4832.7	372.9
8	Chinese mustard[z]	40	40.1	1.00	1	24.0	1780.0	20.0	3150.0	1140.0
	Water convolvulus	50	65.8	1.32	4	44.9	2006.4	79.2	4316.4	633.6
9	Amaranth	87	46.4	0.53	7	15.9	1542.3	75.8	1044.1	159.0
	Rape greens	30	7.7	0.26	1	5.5	338.0	7.8	1411.8	108.9
10	Garland chrysanthemum[z]	31	1.5	0.05	1	1.5	77.0	5.4	172.5	6.8
	[Rape greens	28	28.8	1.03	1	21.6	1339.0	30.9	5592.9	431.6
	[Lettuce	45	9.3	0.21	1	6.5	252.0	9.9	115.1	26.3
	[Pai-tsai	42	14.3	0.34	2	6.1	574.6	11.6	605.2	251.6
11	Rape greens[z]	33	10.4	0.32	3	6.7	416.0	9.6	1737.6	134.1
	[Pai-tsai	27	22.6	0.84	1	15.1	1419.6	28.6	1495.2	621.6
	[Lettuce	37	4.7	0.13	1	4.0	156.0	6.1	71.2	16.3
	[Ching-chiang	42	24.4	0.58	2	14.5	1206.4	19.7	2308.4	497.1
12	[Rape greens	34	15.9	0.47	1	9.9	611.0	14.1	2552.1	196.9
	[Yardlong bean[z]	87	28.5	0.33	15	7.5	106.1	7.7	280.5	62.4
Total			720.9	18.81		470.9	32153.2	853.4	59907.6	11849.3

[z] Continued from garden III.
[= Intercropped.
Additional: Celery, sweet corn, coriander and hot pepper grown on the sides of the garden as a windbreak; 68, 17.1, 16.2 and 1.9 kg harvested, respectively. Shallot and garlic planted around the edges of beds; 74.7 and 19.8 kg harvested, respectively.

Table 6. Percentage of a 10-year-old child's RDA[z] contained in 113 grams (½ cup) of garden vegetables.

	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
RDA for a 10-year-old	38.00	650.00	7.00	575.00	20.00
Contents of 113 g vegetables	3.23	192.17	6.16	333.23	57.00
Contribution of 113 g to the RDA of a 10-year-old (%)	8.50	29.56	88.00	57.95	285.00

[z] Recommended dietary allowance. Source: Food and Agriculture Organization. 1974. Handbook on Human Nutritional Requirement. FAO, Rome.

Table 7. Recommended dietary allowance (RDA) for a family of five (two adults and three children, ages 1 to 12).

	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
Father	37	450	7	750	30
Pregnant mother	38	1100	21	750	50
Child (ages 1 to 3)	16	450	7	250	20
Child (ages 4 to 6)	20	450	7	300	20
Child (ages 10 to 12)	38	650	7	575	20
Total	149	3100	49	2625	140

Source: Food and Agriculture Organization. 1974. Handbook on Human Nutritional Requirements. FAO, Rome.

Table 8. Yield and nutrient contribution of Indonesia home garden I, November 1982 to February 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1-1&2	Chinese leek	116	1.29	0.0111	14	0.33	9.66	0.24	102.68	3.89
2	Kale	56	1.32	0.0236	6	0.50	59.24	1.13	59.00	22.14
	Kale	49	1.96	0.0400	14	0.84	100.40	1.92	100.00	37.52
3	Egg plant	111	0.79	0.0071	6	0.13	1.35	0.08	1.07	0.43
4	Spinach	51	0.36	0.0071	2	0.09	6.46	0.21	38.55	1.73
	Spinach	51	1.96	0.0384	14	0.46	34.94	1.15	208.51	9.33
5	Lettuce	57	4.06	0.0712	6	2.21	85.44	3.35	39.02	8.90
6	Water convolvulus	55	0.93	0.0169	8	0.44	19.27	0.86	55.26	8.11
	Ching-chiang	51	10.48	0.2055	20	5.14	427.44	6.99	817.89	176.11
7	Chinese mustard	48	0.97	0.0202	12	0.48	35.96	0.40	63.63	23.03
	Chinese mustard	51	5.48	0.1075	18	2.58	191.35	2.15	338.63	122.55
8	Pai-tsai	48	1.62	0.0338	13	0.54	43.60	1.08	52.39	23.32
	Pai-tsai	48	5.01	0.1044	15	1.67	134.68	3.34	161.82	72.04
9	Amaranth	51	0.94	0.0184	8	0.48	66.24	0.86	50.23	9.75
	Rape greens	47	5.34	0.1136	17	2.39	147.68	3.41	616.85	47.60
Total			42.51	0.8188		18.28	1363.71	27.17	2705.53	566.45
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						12.27	43.99	55.45	103.07	404.61

Additional: Cassava grown as an edible fence.
Tomato grown on a bamboo fence.

Table 9. Yield and nutrient contribution of Indonesia home garden II, March to May, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1-1&2	Chinese leek[z]	65	2.76	0.0425	23	1.28	36.98	0.94	393.13	14.88
1-3	Celery[z]	87	3.46	0.0398	16	0.56	24.68	1.00	68.85	7.96
2	Kale[z]	22	2.76	0.1255	19	3.51	331.32	8.16	549.69	156.50
	Cherry radish	43	2.62	0.0609	6	0.61	19.49	0.85	tr.	15.83
3	Water convolvulus	75	2.79	0.0372	8	0.97	42.41	1.90	121.64	17.86
4-3	Spinach[z]	3	0.60	0.2000	3	2.40	182.00	6.00	1086.00	48.60
4	Ching Chiang[z]	48	4.55	0.0948	21	2.37	197.18	3.22	377.30	81.24
	Ching Chiang	31	1.25	0.0403	5	1.01	83.82	1.37	160.39	34.54
5	Lettuce[z]	68	5.79	0.0851	14	1.02	46.81	1.87	242.54	30.55
	Water convolvulus	56	4.01	0.0716	7	1.86	81.62	3.65	234.13	34.37
6-3	Ching Chiang[z]	3	1.21	0.4033	3	10.89	935.66	15.33	1540.61	312.15
6	Lettuce	58	3.87	0.0667	11	0.93	40.69	2.13	118.06	15.34
7-3	Chinese mustard[z]	9	2.33	0.2589	7	6.21	460.84	5.18	815.54	295.15
7-182	Rape greens[z]	45	0.39	0.0087	7	0.18	12.70	0.29	35.93	3.85
7-3	Rape greens	26	0.08	0.0031	1	0.07	4.53	0.10	12.80	1.37
7	Rape greens	38	1.14	0.0300	5	0.63	43.80	0.99	123.90	13.29
8	Chinese mustard[z]	46	0.77	0.0167	7	0.40	29.73	0.33	52.61	19.04
	Chinese mustard	34	0.86	0.0253	4	0.61	45.03	0.51	79.70	28.84
9-3	Rape greens[z]	3	0.38	0.1267	3	2.66	184.98	4.18	523.27	56.13
	Pai-tsai	36	0.49	0.0136	7	0.20	24.89	0.24	21.76	6.20
	Pai-tsai	38	1.50	0.0395	7	0.59	72.29	0.71	63.20	18.01
Total			43.61	1.7902		38.96	2901.45	58.95	6621.05	1211.70
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						26.15	93.60	120.31	252.23	865.50

[z] Continue from garden I.
Additional: Tomato growing on a bamboo fence (continued from garden I); 5.05 kg harvested.

Table 10. Yield and nutrient contribution of Indonesia home garden III, June to August, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1.	Chinese leek[z]	92	2.232	0.0243	31	0.73	0.53	21.14	224.70	8.51
2.	Kale[z]	43	0.108	0.0025	3	0.06	0.08	5.83	6.25	2.88
	Kale	42	0.045	0.0011	1	0.03	0.04	2.56	2.75	1.27
3.	Kang kong[z]	14	0.846	0.0604	6	1.81	3.62	70.06	197.51	28.99
	Kang kong	76	5.894	0.0776	30	2.33	4.66	90.02	253.75	37.25
4.	Ching chiang[z]	30	0.306	0.0102	3	0.26	0.35	21.22	40.60	8.74
	Ching chiang	50	0.531	0.0106	6	0.27	0.36	22.05	42.19	9.08
5.	Kang kong[z]	92	18.189	0.1977	50	5.93	11.86	229.33	646.48	94.90
6.	Amaranth[z]	48	0.426	0.0089	5	0.27	0.418	25.90	24.30	4.72
	Lettuce	27	0.199	0.0074	3	0.13	0.50	6.81	33.08	1.78
	Amaranth	40	0.035	0.0009	1	0.03	0.04	2.62	2.46	0.48
7.	Rape green[z]	30	0.108	0.0036	3	0.08	0.21	5.18	14.87	1.72
	Rape green	62	0.504	0.0081	9	0.17	0.47	11.66	33.45	3.88
8.	Mustard[z]	30	0.108	0.0036	3	0.09	0.07	6.41	11.34	4.10
	Mustard	60	0.594	0.0099	9	0.24	0.20	17.62	31.19	11.29
9.	Pai-tsai[z]	30	0.055	0.0018	3	0.03	0.09	2.66	3.20	1.33
Fence:	Cassava	92	4.114	0.0447	20	0.98	4.92	67.50	94.76	16.67
Total			34.294	0.4733		13.44	28.42	608.57	1662.88	237.59
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						9.02	58.00	19.63	63.35	169.71

[z] Continued from garden II.

Table 11. Yield and nutrient contribution of Indonesia home garden IV, September to November, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1.	Chinese leek[z]	91	0.99	0.0109	15	0.33	0.24	9.48	100.83	3.82
2.	Kale[z]	14	0.32	0.0229	8	0.55	0.76	53.36	57.25	26.34
	Pai-tsai	77	8.53	0.1108	25	1.99	5.32	163.98	197.22	81.99
3.	Kang kong[z]	27	1.65	0.0611	11	1.83	3.67	70.88	199.80	29.33
	Kale	64	1.88	0.0294	7	0.71	0.97	68.50	73.50	33.81
4.	Ching chiang[z]	19	0.50	0.0263	10	0.66	0.89	54.70	104.67	22.54
	Mustard	72	4.50	0.0625	15	1.50	1.25	111.25	196.88	71.25
5.	Kang kong[z]	41	8.18	0.1995	25	5.99	11.97	231.42	652.37	95.76
	Amaranth	58	2.11	0.0364	10	1.09	1.71	105.92	99.37	19.29
6.	Amaranth[z]	19	0.33	0.0174	8	0.52	0.82	50.63	47.50	9.22
	Ching chiang	91	3.95	0.0434	16	1.09	1.48	90.27	172.73	37.19
7.	Rape green[z]	4	0.16	0.0400	4	0.84	2.34	57.60	165.20	19.16
	Radish	91	2.53	0.0278	11	0.17	0.19	5.04	2.92	4.78
8.	Mustard[z]	19	0.47	0.0247	7	0.59	0.49	43.97	77.81	28.16
	Kang kong	84	4.09	0.0487	20	1.46	2.92	56.49	159.25	23.38
9.	Snap bean	50	0.65	0.0130	4	0.40	0.16	3.90	3.90	3.64
	Chinese cabbage	72	1.15	0.0160	1	0.27	0.42	16.32	61.47	8.48
Fence:	Cassava[z]	91	10.25	0.1126	40	2.48	12.39	170.03	238.71	42.00
Total			52.24	0.9034		22.47	47.97	1363.74	2611.38	560.14
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						15.08	97.90	43.99	99.48	400.10

[z] Continued from garden III.

Table 12. Yield and nutrient contribution of Thailand home garden I, November 1982 to February 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1-3	Coriander	62	0.30	0.0048	1	0.12	6.38	0.22	22.85	3.74
2	Sweet pepper	113	0.99	0.0088	5	0.11	1.06	0.08	25.67	9.06
3	Radish	102	6.03	0.0591	10	0.59	15.96	0.24	tr.	24.82
4	Lettuce	57	2.95	0.0518	5	0.70	47.80	2.20	168.35	11.78
4-1&2	Head lettuce	54	6.05	0.1120	8	3.47	134.40	5.25	61.38	14.00
5	Carrot	105	1.81	0.0172	2	0.17	6.19	0.36	279.84	18.25
6	Water convolvulus	55	0.65	0.0118	7	0.31	13.45	0.60	38.59	5.66
	Ching Chiang	51	8.20	0.1608	20	4.34	373.06	6.11	614.26	124.46
7	Mustard	49	2.71	0.0553	15	1.33	98.43	1.11	174.20	63.04
	Mustard	56	2.95	0.0527	16	1.26	93.81	1.05	166.01	60.08
8	Pai-tsai	49	3.40	0.0694	17	0.97	102.71	1.80	129.78	43.03
	Pai-tsai	48	3.51	0.0731	15	1.17	94.30	2.34	113.31	50.44
9	Amaranth	50	1.07	0.0214	9	0.64	62.27	3.06	42.16	6.42
	Rape greens	47	5.35	0.1138	16	2.39	147.94	3.41	617.93	47.68
Total			45.97	0.8120		17.57	1197.76	27.84	2454.33	482.46
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						11.79	38.64	56.82	93.50	344.61

Additional: Snap bean grown on bamboo fence; 3.40 kg harvested.
Ipil ipil grown on edges of garden; 2.4 kg leaves harvested.
Tomato grown on bamboo fence.

Table 13. Yield and nutrient contribution of Thailand home garden II, March to May 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day				
						Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1-1	Hot pepper[z]	146	0.28	0.0019	4	0.12	1.63	0.07	20.90	1.82
1-2	Lemon grass[z]	146	0.68	0.0047	5	0.05	1.50	0.08	3.33	0.05
1-3	Coriander[z]	85	2.01	0.0236	15	0.61	31.39	1.06	112.34	18.41
2	Sweet pepper[z]	13	0.20	0.0154	2	0.20	1.85	0.14	44.92	15.86
	Amaranth	81	2.37	0.0280	8	0.73	100.80	1.32	76.44	14.84
3	Cherry radish[z]	48	1.02	0.0213	5	0.21	6.82	0.30	0	5.54
	Water convolvulus	42	0.66	0.0157	1	0.41	17.90	0.80	51.34	7.54
4-3	Head lettuce	70	1.49	0.0213	5	0.66	25.56	1.00	11.67	2.66
4-1&2	Ching chiang[z]	40	4.10	0.1025	20	2.77	237.80	3.90	391.55	79.34
4-3	Ching chiang	40	1.09	0.0273	5	0.74	63.34	1.04	104.29	21.13
4-1&2	Ching chiang	33	1.56	0.0473	3	1.28	109.74	1.80	180.69	36.61
5	Carrot[z]	47	3.50	0.0745	8	0.75	26.82	1.56	1212.12	7.67
	Carrot[z]	135	4.19	0.0310	6	0.31	11.16	0.65	504.37	3.19
6-3	Ching chiang[z]	3	0.59	0.1967	3	5.31	456.34	7.47	751.39	152.25
6	Carrot[z]	93	1.04	0.0112	1	0.11	4.03	0.24	182.22	1.15
7-3	Mustard[z]	9	2.23	0.2478	7	5.95	441.08	4.96	780.57	282.49
7	Rape greens[z]	35	0.42	0.0120	6	0.25	15.60	0.36	65.16	5.03
	Rape greens	35	1.50	0.0429	7	0.90	55.77	1.29	232.95	17.98
8	Mustard[z]	46	0.60	0.0130	7	0.26	15.86	0.31	34.71	12.74
	Mustard	35	1.50	0.0429	8	1.03	76.36	0.86	135.14	48.91
9-3	Rape greens[z]	3	0.31	0.1033	2	2.17	134.29	3.10	560.92	43.28
9	Pai-tsai[z]	36	0.62	0.0172	6	0.24	25.46	0.45	32.16	10.66
	Pai-tsai	39	2.22	0.0569	10	0.80	84.21	1.48	106.40	35.28
Total			34.08	1.1584		25.86	1945.31	34.24	5595.58	824.43
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						17.36	62.75	69.88	213.16	588.88

[z] Continued from garden I.

Additional: Snap bean grown on bamboo fence (continued from garden I); 0.84 kg harvested.
Ipil ipil grown on edges of garden; 6.92 kg leaves harvested.
Tomato grown on bamboo fence (continued from garden I); 9.34 kg harvested.
Yardlong bean grown on bamboo fence; 0.94 kg harvested.
Sweet potato grown on edges of garden; 0.78 kg leaves harvested.

Table 14. Yield and nutrient contribution of Thailand home garden III, June to August, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1.	Shallot[z]	17	0.528	0.0311	1	0.65	0.62	32.34	39.81	4.07
	Soybean[z]	22	0.325	0.0148	1	2.17	0.76	2.31	5.67	2.42
	Lemon grass	75	6.012	0.0802	5	1.41	3.70	93.38	112.28	16.75
	Lettuce	30	0.608	0.0203	3	0.35	1.38	18.68	90.74	4.87
2.	Amaranth	82	1.836	0.0224	16	0.67	1.05	65.18	61.15	11.87
	Cucumber	68	3.357	0.0494	8	0.20	0.15	6.92	1.24	3.41
3.	Kang Kong[z]	16	0.545	0.0341	6	1.02	2.05	39.56	111.51	16.37
	Kang Kong	75	5.922	0.0790	29	2.37	4.74	91.64	258.33	37.92
4.	Ching Chiang[z]	30	4.320	0.1440	4	3.60	4.90	299.52	573.12	123.41
	Ching Chiang	68	1.980	0.0291	17	0.73	0.99	60.53	115.82	24.94
5.	Lettuce[z]	16	0.504	0.0315	3	0.54	2.14	28.98	140.81	7.56
	Peanut	85	2.561	0.0301	8	7.75	0.54	4.42	-	-
6.	Kang Kong	92	6.665	0.0724	35	2.17	4.34	83.98	236.75	34.75
7.	Rape green[z]	29	0.531	0.0183	8	0.38	1.06	26.35	75.58	8.77
	Rape green	63	0.756	0.0120	10	0.25	0.70	17.28	49.56	5.75
8.	Mustard[z]	34	0.918	0.0270	8	0.65	0.54	48.06	85.05	30.78
	Mustard	68	1.602	0.0235	16	0.56	0.47	41.83	74.03	26.79
9.	Pai-tsai	30	0.673	0.0226	4	0.41	1.08	33.45	40.23	16.72
	Pumpkin	92	0.353	0.0038	1	0.02	0.03	0.12	14.82	0.21
Fence:	Yardlong bean	92	4.508	0.0490	24	1.37	0.88	24.99	16.32	13.72
	Ipil ipil	92	0.736	0.0080	5	0.54	0.58	4.45	56.64	4.05
Total			45.240	0.8026		27.81	32.70	1023.97	2159.46	359.13
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						18.66	66.73	33.03	82.27	282.24

[z] Continued from garden II.

Table 15. Yield and nutrient contribution of Thailand home garden IV, September to November, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1.	Lemon grass[z]	91	7.57	0.0832	23	1.46	3.84	96.87	116.48	17.37
2.	Pai-tsai	91	7.48	0.0822	19	1.48	3.95	121.66	146.32	60.83
	Lettuce	42	0.63	0.0150	2	0.26	1.02	13.80	67.05	3.60
3.	Kang kong[z]	26	3.27	0.1258	15	3.77	7.55	145.93	411.37	60.38
	Kale	85	3.09	0.0364	7	0.87	1.20	84.81	91.00	41.86
4.	Ching chiang[z]	19	0.15	0.0079	4	0.20	0.27	16.43	31.44	6.77
	Mustard	84	6.07	0.0723	19	1.74	1.45	128.69	227.75	82.42
5.	Peanut[z]	19	3.93	0.2068	17	53.23	3.70	30.34	-	-
	Amaranth	68	2.91	0.0428	12	1.28	2.01	124.55	116.84	22.68
6.	Kang kong[z]	41	6.90	0.1683	22	5.05	10.10	195.23	550.34	80.78
	Ching chiang	82	3.65	0.0445	13	1.11	1.51	92.56	177.11	38.14
	Lettuce	42	1.40	0.0333	4	0.57	2.26	30.64	148.85	7.99
7.	Rape green[z]	19	0.29	0.0153	7	0.32	0.89	22.03	63.19	7.33
	Radish	85	3.27	0.0385	13	0.23	0.27	6.98	4.04	6.62
8.	Mustard[z]	19	0.43	0.0226	7	0.54	0.45	40.23	71.19	25.76
	Kang kong	91	3.45	0.0379	14	1.14	2.27	43.96	123.93	18.19
9.	Pumpkin[z]	26	2.71	0.1042	3	0.60	0.76	3.42	406.38	5.67
	Lettuce	42	0.98	0.0233	3	0.40	1.58	21.44	104.15	5.59
Fence:	Shallot	61	0.34	0.0056	1	0.12	0.11	5.82	7.17	0.73
	Sweet potato tips[z]	91	0.39	0.0043	4	0.17	0.49	5.92	5.38	2.04
	Ipil ipil[z]	91	1.90	0.0209	17	1.40	1.52	11.63	147.97	10.58
	Snap bean[z]	47	0.30	0.0064	2	0.20	0.08	1.92	1.92	1.79
	Yardlong bean[z]	30	8.55	0.2850	6	7.98	5.13	145.35	94.91	79.80
Total			69.66	1.4825		84.12	52.41	1390.21	3114.78	586.92
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						56.46	106.96	44.85	118.66	419.23

a: continued from garden III.

Table 16. Yield and nutrient contribution of Philippines home garden I, November 1982 to February 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1-2	Shallot	107	1.89	0.0177	3	0.37	18.41	0.35	22.66	2.32
1-3	Garlic	93	0.50	0.0054	5	0.13	6.05	0.11	6.16	1.76
2	Sweet pepper	107	1.66	0.0155	8	0.20	1.86	0.14	45.26	15.97
3	Egg plant	110	0.42	0.0038	4	0.07	0.72	0.04	0.57	0.23
4	Radish	90	11.18	0.1242	10	1.24	33.53	0.50	0	52.16
5	Lettuce	51	3.89	0.0763	4	1.68	89.27	5.57	305.20	18.31
	Lettuce	32	2.86	0.0894	9	1.97	104.60	6.53	357.60	21.46
6	Water convolvulus	48	0.77	0.0160	7	0.42	18.24	0.82	53.32	7.68
	Ching chiang	51	8.38	0.1643	19	3.78	348.32	7.89	463.33	148.36
7	Mustard	42	2.07	0.0493	11	1.18	87.75	0.99	155.30	56.20
	Mustard	58	7.07	0.1219	18	2.93	216.98	2.44	383.99	138.97
8	Pai-tsai	42	3.10	0.0738	15	1.18	95.20	2.36	114.39	50.92
	Pai-tsai	48	6.16	0.1283	15	2.05	214.26	4.49	350.26	74.41
9	Amaranth	45	0.60	0.0133	4	0.35	47.88	0.63	36.31	7.05
	Rape greens	46	6.53	0.1420	18	2.98	184.60	4.26	771.06	59.50
Total			57.08	1.0412		20.53	1467.67	37.12	3064.41	655.30
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						13.78	47.34	75.76	116.74	468.07

Additional: Snow pea and tomato grown on bamboo fence.

Table 17. Yield and nutrient contribution of Philippines home garden II, March to May, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1-2	Shallot[z]	41	4.45	0.1085	4	2.28	112.84	2.17	138.88	14.21
1-3	Garlic[z]	40	0.18	0.0045	1	0.11	5.04	0.09	5.13	1.46
1-1	Shallot	36	0.05	0.0014	1	0.03	1.46	0.03	1.79	0.18
2	Sweet pepper[z]	13	0.20	0.0154	2	0.20	1.85	0.14	44.97	15.86
	Water convolvulus	67	2.49	0.0374	8	0.97	42.41	1.90	121.64	17.86
3	Egg plant[z]	10	0.13	0.0130	2	0.25	2.47	0.14	1.95	0.78
	Coriander[y]	67	0.81	0.0121	8	0.31	16.09	0.54	57.60	9.44
4	Ching chiang[z]	55	2.88	0.0524	15	1.21	111.09	2.52	147.77	47.32
	Ching chiang	28	1.57	0.0561	5	1.29	118.93	2.69	158.20	50.66
5	Lettuce[z]	38	3.25	0.0855	12	1.03	47.03	1.88	243.68	30.69
	Cherry radish	40	2.00	0.0500	5	0.50	16.00	0.70	tr.	13.00
6-3	Ching chiang[z]	3	1.14	0.3800	3	8.74	805.60	18.24	1071.60	343.14
6	Lettuce[z]	59	6.96	0.1180	15	1.65	71.98	3.78	208.86	27.14
7-3	Mustard[z]	7	2.32	0.3314	5	6.63	404.31	7.95	884.84	324.77
7	Amaranth	86	2.23	0.0259	9	0.78	75.37	3.70	51.02	7.77
8	Mustard[z]	46	1.41	0.0307	13	0.74	54.65	0.61	96.71	35.00
	Mustard	35	1.41	0.0403	8	0.97	71.73	0.81	126.95	45.94
9-3	Rape greens[z]	3	0.52	0.1733	3	3.64	225.29	5.20	941.02	72.61
	Pai-tsai[z]	36	0.63	0.0175	6	0.28	29.23	0.61	47.78	10.15
	Pai-tsai	40	1.90	0.0475	8	0.76	79.33	1.66	129.68	27.55
Total			36.53	1.6007		32.37	2292.70	55.36	4480.07	1095.53
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						21.72	73.96	112.98	170.67	782.52

[z] Continued from garden I.
[y] Intercropped with cucumber and okra, not harvested during this period.
Additional: Snow pea grown on bamboo fence (continued from garden I), 1.14 kg harvested.
Tomato grown on bamboo fence (continued from garden I), 3.74 kg harvested.
Yardlong bean grown on bamboo fence; 1.49 kg harvested.
Sweet potato grown on edges of garden; 0.92 kg leaves harvested.

Table 18. Yield and nutrient contribution of Philippines home garden III, June to August, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1.	Shallot[z]	17	0.430	0.0253	1	0.53	0.51	26.31	32.38	3.31
	Soybean[z]	22	0.350	0.0159	1	2.33	0.81	2.48	6.09	2.59
	Lettuce	30	0.456	0.0152	3	0.26	1.03	13.98	67.94	3.65
	Kang kong	27	0.216	0.0080	2	0.24	0.48	9.28	26.16	3.84
	Lemon Grass	75	1.755	0.0234	13	0.41	1.08	27.24	32.76	4.89
2.	Kang kong	17	1.485	0.0874	6	2.62	5.24	101.38	285.80	41.95
	Kang kong	75	5.123	0.0683	26	2.05	4.10	79.23	223.34	32.78
3.	Cucumber[z]	6	0.054	0.0900	1	0.36	0.27	12.60	22.50	6.21
	Okra[z]	49	0.144	0.0029	4	0.05	0.03	2.61	0.68	0.52
	Peanut	85	2.646	0.0311	8	8.01	0.56	4.56	-	-
4.	Ching chiang[z]	34	0.549	0.0161	5	0.40	0.55	33.49	64.08	13.80
	Ching chiang	62	1.503	0.0242	14	0.61	0.82	50.34	96.32	20.74
5.	Mungbean	71	0.858	0.0121	17	2.85	0.54	2.66	-	-
	Pai-tsai	33	0.182	0.0055	2	0.10	0.26	8.14	9.79	4.07
6.	Kale[z]	37	0.369	0.0100	2	0.24	0.33	23.30	25.00	11.50
	Cucumber	67	5.832	0.0870	12	0.35	0.26	12.18	21.75	6.0
7.	Amaranth	82	2.357	0.0287	20	0.86	1.35	83.52	78.35	15.21
8.	Mustard[z]	34	1.179	0.0347	10	0.83	0.69	61.77	109.31	39.56
	Mustard	58	1.062	0.0183	11	0.44	0.37	32.57	57.65	20.86
9.	Pai-tsai[z]	23	0.573	0.0249	4	0.45	1.20	36.85	44.32	18.43
	Pumpkin	92	2.226	0.0242	2	0.14	0.18	0.79	94.38	1.32
Fence:	Yardlong bean	92	5.292	0.0575	28	1.61	1.04	29.33	19.15	16.10
	Sweet potato tips	92	2.260	0.0246	4	1.06	3.01	36.35	33.00	12.50
Total			36.901	0.7353		26.80	24.71	690.96	1350.75	279.83
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						18.00	50.43	22.29	51.46	190.88

[z] Continued from garden II.

Table 19. Yield and nutrient contribution of Philippines home garden IV, September to November, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1.	Lemon grass[z]	91	6.99	0.0768	21	1.35	3.54	89.42	107.52	16.04
	Kang kong[z]	34	1.77	0.0521	10	1.56	3.13	60.44	170.37	25.00
2.	Kang kong[z]	6	0.71	0.1183	3	3.55	7.10	137.23	386.84	56.78
	Pai-tsai	91	11.02	0.1211	28	2.18	5.81	179.23	215.56	89.61
3.	Peanut[z]	19	2.53	0.1332	13	34.29	2.38	19.54	-	-
	Kale	72	5.38	0.0747	13	1.79	2.47	174.05	186.75	85.91
4.	Ching chiang[z]	26	0.63	0.0242	7	0.61	0.82	50.34	96.32	20.74
	Mustard	65	5.03	0.0774	21	1.86	1.55	137.77	243.81	88.24
5.	Pai-tsai[z]	26	0.81	0.0312	7	0.56	1.50	46.18	55.54	23.09
	Amaranth[z]	62	3.04	0.0490	11	1.47	2.30	142.59	133.77	25.97
6.	Cucumber[z]	6	1.23	0.2050	4	0.82	0.62	28.70	5.13	14.15
	Ching chiang	85	9.46	0.1113	26	2.78	3.78	231.50	442.97	95.38
7.	Amaranth[z]	16	0.36	0.0225	4	0.68	1.06	65.48	61.43	11.93
	Radish	85	6.31	0.0742	16	0.45	0.51	13.46	7.79	12.75
8.	Mustard[z]	26	0.77	0.0296	11	0.71	0.59	52.69	93.24	33.74
	Kang kong	82	2.78	0.0339	11	1.02	2.03	39.32	110.85	16.27
9.	Pumpkin[z]	26	2.57	0.0988	4	0.57	0.72	3.24	385.32	5.37
Fence:	Yardlong bean[z]	19	1.89	0.0995	9	2.79	1.79	50.75	33.13	27.86
	Malunggay pods[z]	91	0.31	0.0034	2	0.09	0.11	0.11	-	4.39
	Malunggay leaf[z]	91	0.68	0.0075	3	0.38	1.34	17.34	51.38	8.64
	Snap bean[z]	60	0.31	0.0052	2	0.16	0.06	1.56	1.56	1.46
	Sweet potato tips[z]	91	0.40	0.0044	1	0.18	0.50	6.06	5.50	2.08
Total			64.98	1.4533		59.85	43.71	1547.00	2794.78	665.40
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						40.17	89.20	49.90	106.47	475.29

[z] continued from garden III.

Table 20. Yield and nutrient contribution of Vitamin A home garden I, November 1982 to February 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
1-1	Shallot	96	4.34	0.0452	3	0.95	47.01	0.90	57.86	5.92
1-2&3	Fresh soybean	119	0.61	0.0051	5	0.66	3.98	0.19	3.06	1.38
3	Carrot	106	0.68	0.0064	3	0.06	2.30	0.13	104.13	0.66
4	Kohlrabi	57	8.69	0.1525	5	3.97	79.30	1.98	507.83	103.70
	Head lettuce[z]	44	2.08	0.0473	6	1.47	56.76	2.22	25.92	5.91
5	Garland chrysanthemum	53	3.90	0.0736	9	2.21	113.34	7.88	253.92	9.94
	Garland chrysanthemum	52	5.57	0.1071	14	3.21	164.93	11.46	369.50	14.46
6	Water convolvulus	55	0.88	0.0160	8	0.42	18.24	0.82	52.32	7.68
	Ching chiang	50	9.84	0.1968	20	4.92	409.34	6.69	783.26	168.66
7	Mustard	49	3.41	0.0696	14	1.39	84.91	1.67	185.83	68.21
	Mustard	56	4.48	0.0800	18	1.60	97.60	1.92	213.60	78.40
8	Pai-tsai	48	5.02	0.1046	17	1.67	174.68	3.66	285.56	60.67
	Pai-tsai	48	4.76	0.0992	15	1.59	165.66	3.47	270.82	57.54
9	Amaranth	51	0.92	0.0180	9	0.54	52.38	2.57	35.46	5.40
	Rape greens	46	6.61	0.1437	19	3.02	186.81	4.31	780.29	60.21
Total			61.79	1.1651		27.68	1657.24	49.87	3929.36	648.74
RDA of a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						18.58	53.46	101.78	149.69	463.39

[z] Intercropped with sweet pepper, not harvested in this period.
Additional: Cowpea and tomato grown on bamboo fence.

Table 21. Yield and nutrient contribution of Vitamin A home garden II, March to May, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µgRE)	Vitamin C (mg)
2	Celery[z]	146	7.79	0.0534	26	0.75	33.1	1.34	92.38	10.68
	Water convolvulus	40	0.82	0.0205	2	0.53	23.37	1.05	67.04	9.84
3	Carrot[z]	26	3.32	0.1277	9	1.28	45.97	2.68	2077.68	13.15
4	Sweet pepper[z]	127	1.45	0.0114	7	0.15	1.37	0.10	33.29	11.74
	Coriander[z]	69	0.16	0.0023	1	0.06	3.06	0.10	10.95	1.79
5-3	Garland chrysanthemum	3	0.75	0.2500	3	7.50	385.00	26.75	862.50	33.75
5	Ching chiang[z]	44	2.58	0.0586	13	1.58	135.95	2.23	223.85	45.36
	Ching chiang	33	1.30	0.0394	7	1.06	91.41	1.50	150.51	30.50
6	Ching chiang[z]	3	1.29	0.4300	3	11.61	997.60	16.34	1642.60	332.82
	Garland chrysanthemum[z]	45	1.03	0.0229	8	0.69	35.27	2.45	79.01	3.09
6-1	Amaranth	54	0.61	0.0113	3	0.34	32.88	1.62	22.26	3.39
7-2&3	Mustard[z]	9	2.25	0.2500	7	5.00	305.00	6.00	667.50	245.00
	Rape greens	33	0.50	0.0152	7	0.32	22.19	0.50	62.78	6.73
	Rape greens	35	1.61	0.0460	8	0.97	67.16	1.52	189.98	20.38
8	Mustard[z]	45	0.47	0.0104	4	0.21	12.69	0.25	27.77	10.19
	Mustard	36	1.52	0.0422	8	0.84	51.48	1.01	112.67	41.36
9-3	Rape greens[z]	3	0.98	0.3267	3	6.86	476.98	10.78	1349.27	144.73
9	Pai-tsai[z]	36	0.31	0.0086	5	0.14	14.36	0.30	23.48	4.99
	Pai-tsai	39	2.09	0.0536	9	0.86	89.51	1.88	146.33	31.09
Total			30.83	1.7802		40.75	2824.36	78.40	7841.85	1000.58
RDA for a family of five						149.00	3100.00	49.00	2625.00	140.00
% of RDA contributed by garden						27.35	91.11	160.00	298.74	714.70

[z] Continued from garden I.
Additional: Cowpea grown on bamboo fence (continued from garden I); 0.17 kg harvested.
Tomato grown on bamboo fence (continued from garden I); 4.52 kg harvested.
Yardlong bean grown on bamboo fence; 0.33 kg harvested.
Sweet potato grown on edges of garden; 0.86 kg leaves harvested.

Table 22. Yield and nutrient contribution of Vitamin A home garden III, June to August, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1.	Fresh soy bean[z]	22	0.53	0.0241	5	3.54	1.23	3.76	9.23	3.93
	Kang kong[z]	69	3.42	0.0500	18	1.50	3.00	58.00	163.50	24.00
2.	Kang kong[z]	17	0.87	0.0512	7	1.54	3.07	59.40	167.42	24.58
	Kang kong	75	6.25	0.0833	33	2.50	5.00	96.63	272.39	39.98
3.	Chinese leek[z]	92	2.59	0.0282	24	0.85	0.62	24.53	260.85	9.87
4.	Sweet potato tip[z]	92	7.80	0.0848	11	3.40	9.68	116.77	106.00	40.17
5.	Ching chiang	30	0.34	0.0113	2	0.28	0.38	23.50	44.97	9.68
	Ching chiang	62	0.51	0.0082	7	0.21	0.28	17.06	32.64	7.03
6.	Amaranth[z]	23	0.26	0.0113	3	0.34	0.53	32.88	30.85	6.00
	Amaranth	82	2.10	0.0256	16	0.77	1.20	74.50	69.89	13.57
7.	Rape green[z]	30	0.71	0.0237	9	0.50	1.37	34.13	97.89	11.35
	Rape green	47	0.68	0.0145	8	0.30	0.84	20.88	59.89	6.95
8.	Mustard[z]	30	0.981	0.0327	8	0.78	0.65	58.21	103.01	37.28
	Mustard	85	0.774	0.0091	11	0.22	0.18	16.20	28.67	10.37
9.	Pai-tsai[z]	30	0.227	0.0076	2	0.14	0.36	11.25	13.53	5.62
Fence:	Yardlong bean	92	12.81	0.1392	40	3.90	2.51	70.99	46.35	38.98
	Sweet potato tips	92	0.92	0.0100	2	0.40	1.14	13.77	12.50	4.74
	Mango	92	0.677	0.0074	2	0.04	0.02	0.74	23.18	2.66
Total			42.449	0.6222		21.21	32.06	733.20	1542.76	296.76
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						14.24	65.43	23.65	58.77	211.97

[z] Continued from garden II.

Table 23. Yield and nutrient contribution of Vitamin A home garden IV, September to November, 1983.

Plot	Crop	Growing period (days)	Edible yield (kg)	Edible yield/day (kg)	Times harvested	Nutrient yield/day Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (μgRE)	Vitamin C (mg)
1.	Lemon grass[z]	30	4.19	0.1397	12	2.46	6.44	162.65	195.58	29.17
	Kang kong[z]	34	2.14	0.0629	7	1.89	3.77	72.96	205.68	30.19
2.	Kang kong[z]	34	3.08	0.0906	17	2.72	5.44	105.10	296.26	43.49
	Pai-tsai	85	5.14	0.0605	13	1.09	2.90	89.54	107.69	44.77
3.	Chinese leek[a]	91	1.49	0.0164	18	0.49	0.36	14.27	151.70	5.74
4.	Sweet potato tips[z]	27	3.46	0.1281	15	5.14	14.63	176.39	160.13	60.68
	Rape green	85	5.62	0.0661	15	1.39	3.83	95.18	272.99	31.66
5.	Ching chiang[z]	19	0.16	0.0084	4	0.21	0.29	17.47	33.43	7.20
	Mustard	72	7.17	0.0996	24	2.39	1.99	177.29	313.74	113.54
6.	Amaranth[z]	19	0.05	0.0026	1	0.08	0.12	7.57	7.10	1.38
	Kale	85	0.77	0.0091	3	0.22	0.30	21.20	22.75	10.47
7.	Rape green[z]	30	1.22	0.0407	11	0.85	2.36	58.61	168.09	19.50
	Radish	82	2.66	0.0324	11	0.19	0.22	5.88	3.40	5.57
8.	Mustard[z]	30	1.46	0.0487	11	1.17	0.97	86.69	153.41	55.52
	Kang kong	72	4.17	0.0579	17	1.74	3.47	67.16	189.33	27.79
9.	Pumpkin[z]	26	5.18	0.1992	8	1.16	1.45	6.53	776.88	10.84
	Spinach	58	1.09	0.0188	2	0.49	0.56	17.11	102.08	7.76
	Coriander	42	0.02	0.0005	1	0.01	0.02	0.39	2.64	0.42
Fence:	Yardlong bean[z]	30	0.15	0.0050	2	0.14	0.09	2.55	1.67	1.40
	Sweet potato tips[z]	91	1.47	0.0162	2	0.65	1.85	22.31	20.25	7.67
	Mango[z]	91	1.63	0.0179	3	0.11	0.05	1.79	56.08	6.44
Total			52.32	1.1213		24.59	51.11	1208.00	3240.88	521.20
RDA for a family of five						149.00	49.00	3100.00	2625.00	140.00
% of RDA contributed by garden						16.50	104.31	38.99	123.46	372.29

[z] Continuted from garden III.

Table 24. Results from four AVRDC home gardens Nov. 1982 to Nov. 1983. Means over four seasons.

	Yield/day (kg)	Percent contribution to RDA[z] of a family of five				
		Protein	Calcium	Iron	Vitamin A	Vitamin C
Indonesia garden	1.00	15.6	50.3	82.9	129.5	460.0
Thailand garden	1.06	26.0	44.8	35.1	126.9	402.3
Philippine garden	1.21	23.4	48.4	82.0	111.3	481.4
Vitamin A garden	1.17	19.2	51.8	108.0	157.6	440.6

[z] Recommended daily dietary allowance.

New Vegetable Crop Program

By December 1983 AVRDC had received 700 samples of germplasm for the six crops which it had chosen for further research (Table 1). These samples were obtained from 71 seed companies in 7 countries.

Table 1. Collection of New Crops.

Crops	No. of varieties received
Cauliflower (*Brassica oleracea* L. *var. botrytis*, L.)	122
Mustard (*Brassica juncea*, Cosson)	41
Radish (*Raphanus sativus*, L.)	161
Sweet and hot pepper (*Capsicum annuum*, L.)	222
Snapbean (*Phaseolus vulgaris*, L.)	154
Total	700

Cauliflower Observational and Advanced Yield Trials

A total of 116 cauliflower varieties were evaluated in the spring of 1983. F_1 hybrid 402 gave the highest yield (Table 2). Summer trials were heavily infested by blackrot, and were later completely destroyed by two heavy rainfalls. In the autumn, 15 varieties were selected for advanced yield trials. Of these, F_1 hybrid Zu-kwang 50 Days outyielded the local check by 76%, and Snow Comet outyielded it by 54% (Table 3).

Mustard Observational and Advanced Yield Trials

In spring trials "Mustard Green" yielded 17.2 t/ha, outyielding the local check by 67% (Table 4). In summer trials, "Pao Hsin Mustard" yielded 14 t/ha, more than any other cultivar (Table 5). Eight cultivars were selected from advanced yield trials held in the fall. Of these, Tendergreen and Embrapa/Cenargen No. 1 gave yields of 32.3 and 30.2 t/ha, 50% and 40% more than those of the local check (Table 6).

Radish Advanced Yield Trials

Heavy rainfalls wiped out the spring and summer trials, and no yield data was collected. Eighteen varieties were selected from the

fall trials, and of those the most outstanding was Radish No. 3, which yielded 57.2 t/ha, 96% more than the local check (Table 7).

Sweet Pepper Observational and Advanced Yield Trials

In spring trials cultivars P705 and P7118 gave yields of 14.3 t/ha and 31.2 t/ha, 57% and 45% higher than those of the check "Blue Star" (Table 8). In summer trials Chui Feng yielded 24.8 t/ha, 51% more than the local check (Table 9). Twelve varieties were selected from the fall's advanced yield trials. One, "Dalbon", yielded 32.8 t/ha, 32% more than the local check (Table 10).

Hot Pepper Observational and Advanced Yield Trials

Shinshin House, the highest yielder in the spring trials, yielded 34.2 t/ha, 93% more than the check (Table 11). In the summer trial, F_1 Passion and Farmers Newcomers yielded 22.6 t/ha and 18.6 t/ha, 64% and 35% more than the local check (Table 12). In the fall 18 varieties were selected for advanced yield trials (Table 13). At 22.2 t/ha, Known You Seed Company's "Passion" was again the highest yielder.

Snapbean Observational and Advanced Yield Trials

In spring trials Geong Shou No. 1 yielded 15.7 t/ha, 82% more than the local check (Table 14). The summer trial was attacked by charcoal rot, and was later completely destroyed by heavy rains. In fall trials four pole-type cultivars and thirteen bush-type varieties were selected for advanced yield trials (Table 15). At 23.4 t/ha, Black Cresback's yield was the highest, and was 144% higher than that of the check. In fact, all pole-type varieties gave significantly higher average yields than did the bush-type varieties.

Viruses Occurring on AVRDC's Sweet Pepper and Chili Pepper Accessions

Introduction

Before it can be decided which accessions of AVRDC's new vegetable crops are to be utilized for breeding purposes, more must be known about their susceptibility to diseases. The aim of this study was to determine which viruses occur on sweet pepper and chili pepper in Taiwan, and which occur on AVRDC accessions. Cucumber mosaic virus (CMV), tobacco mosaic virus (TMV), potato virus Y (PVY), and a virus resembling pepper mottle virus (PeMV) have all been reported to infect Capsicum sp. in Taiwan.

Materials and Methods

Seventy-six leaf samples from each of 16 different sweet pepper

accessions and 35 leaf samples from 16 different chili pepper accessions showing such virus-like symptoms as mosaic, mottle, vein clearing, leaf distortion, yellowing, necrosis, stunting, and bushiness were serologically tested against antisera of tobacco mosaic virus (TMV), cucumber mosaic virus (CMV), potato virus Y (PVY), potato virus X (PVX), tobacco etch virus (TEV), and pepper mottle virus (PeMV).

The leaf samples were homogenized at 10:1 in ELISA extraction buffer (pH 7.4), and were then immediately tested by ELISA.

Results

Results are shown in Tables 16 and 17.

Five different viruses (TMV, CMV, PVY, TEV, and PeMV) were detected in sweet pepper accessions planted in the fall at AVRDC. Potato virus Y was the one most frequently found in sweet pepper, but CMV was more common in chili pepper. PVX was not detected in any of the samples tested. Some of the new accessions were infected with more than one virus. "California Wonder", which was infected with TMV, CMV, PVY, and PeMV, does not appear very desirable from the standpoint of virus resistance.

Four different viruses (TMV, CMV, PVY, and PeMV) were detected on chili pepper accessions. Several of the new accessions were infected with more than one virus. "Hot Long" was infected with all four viruses- TMV, CMV, PVY, and PeMV.

Conclusions

This preliminary study should serve only as a guideline. The absence of one or all of the above mentioned viruses in some of the new accessions does not necessarily mean they carry resistance to those viruses, and it will be necessary to screen them through artificial inoculation before resistance to a particular virus can be ascertained with any degree of confidence.

Table 2. Yields and horticultural characteristics of entries in the cauliflower observation trial, Spring 1983.*

Entry	Yield (t/ha)	Index	Days to maturity (DAT)	Head weight (g)	Black rot (%)	Soft rot (%)	Downy mildew (%)	Curd breakdown (%)	Open florets (%)
F 402 (45 days)	9.7	129	40	395	0	20	20	0	30
Tai Nong hybrid 45 days	8.4	112	30	350	0	10	40	10	40
F_1 Zu-kwang 50 days	8.3	111	40	520	0	55	0	5	0
F_1 451 (40 days)	8.3	111	40	316	0	35	15	60	16
T.S.S. No. 1	8.3	111	40	370	0	20	45	40	15
Snow Queen	8.3	111	40	471	5	5	15	15	20
Fengshan medium califlower	8	107	52	310	0	25	40	5	20
F_1 812 (65 days)	7.9	105	75	595	0	100	30	38	62
Summer earliest 40 days	7.7	103	40	200	0	10	30	25	0
Fengshan extra early	7.5	100	40	400	0	0	35	10	50

* Date sown: March 15, Date transplanted: April 12, Date harvested: May 19 - June 27.

Table 3. Yield and horticultural characteristics of selected entries in the cauliflower advanced yield trial, Autumn, 1983.*

Entry	Yield** (t/ha)	Index	Days to maturity	Head weight (g)	Head color	Harvest period (days)	Black rot (%)	Virus (%)	Downy mildew (%)	Curd breakdown (%)	Open florets (%)
F_1 Zu-kwang 50 days	20.3	176	50	761	creamy	8	0	0	0	14	2
Snow comet	17.7ab	154	58	664	creamy	5	10	0	0	0	0
Piracicada de Verao	16.9bc	147	50	612	creamy	22	17	10	16	21	5
Santa Elisa No. 2	16.6bc	144	50	622	creamy	5	15	4	18	16	0
Kibo Reuzen R. S.	16.4bc	143	58	617	creamy	10	30				
F_1 451 (40 days)	16.2bcd	141	40	613	creamy	4	0	0	0	10	0
Mikado 40 days No. 3C0120	15.5bcde	135	40	589	white	4	0	0	0	8	9
Califlower (Chia Tsai #1)	15.1bcde	131	40	574	creamy	4	3	0	0	10	10
Snow Queen	15 bcde	130	40	557	white	4	0	0	8	0	0
Mikado 55 days No. 3C0120	14.2cdef	123	58	534	creamy	5	0	0	0	0	0
Summer early	13.6cdef	118	40	510	white	4	0	0	0	0	0
Tai Nong hybrid 45 days	13.2defg	115	40	495	creamy	4	0	0	0	6	7
T.S.S. No. 1	13 defg	113	40	488	white	4	0	0	0	15	6
Fengshan extra early (CK)	11.5fg	100	40	432	creamy	4	0	0	5	5	2
Mikado 50 days No. 4C0123	11.2g	97	40	419	white	4	0	0	0	17	0

* Date sown: September 30.
Date transplanted: October 26.
Date harvested: December 5, 1983 - January 5, 1984.
**Experimental design: RCBD, 4 replications.

Table 4. Yield and horticultural characteristics of entries in the mustard observation trial, Spring 1983*.

Entry	Yield ($kg/10m^2$)	Index	Plant weight (g)	Days to maturity (DAT)	Bolting rate (%)	Virus (%)	Soft rot (%)	Downy mildew (%)	Plant type
Mustard Green	17.2	167	647	40	0	15	75	20	Heading
Florida Broadleaf	16.3	158	611	30	0	15	20	10	Non heading
Tendergreen	16.0	155	600	30	0	0	0	70	Non heading
Florida Broadleaf**	14.1	137	528	36	0	20	60	30	Non heading
Feng Wei Chung	13.9	135	520	30	100	0	30	0	Non heading
Brown Mustard	13.3	129	500	30	15	0	75	35	Non heading
Pao Hsin Mustard	12.7	123	478	36	0	0	90	0	Heading
Szu-Chuan Mustard	12.4	120	474	30	0	0	30	10	Non heading
Chih Yeh Pao Shin (CK)	10.3	100	388	40	0	0	90	35	Heading
Shinkoku Seisai	10.2	99	389	30	0	10	20	20	Non heading

* Date sown: March 15.
Date transplanted: April 13.
Date harvested: May 11-19.
Entry: 39.
** Deference source.

Table 5. Yield and horticultural characteristics of selected entries in the mustard observation trial, Summer 1983*.

Acc. No.	Entry	Yield ($kg/10m^2$)	Index	Plant weight (g)	Days to maturity (DAT)	Bolting rate (%)	Virus (%)	Soft rot (%)	Downy mildew (%)	Plant type
20	Pao Hsin Mustard	14	161	525	36	25	0	40	15	Heading
18	Florida Broadleaf	12.8	147	482	34	0	0	60	25	Non heading
8	Feng Wei Chung	11.3	130	464	30	100	0	15	15	Non heading
14	Chinese Broadleaf	11.2	129	422	30	0	0	0	0	Non heading
35	Chinese Mustard	10.7	123	400	40	5	10	55	70	Heading
37	Florida Braodleaf	10.1	116	378	30	0	0	0	0	Non heading
17	Savanuah	10.1	116	381	30	0	0	20	0	Non heading
6	Nan Fang Peih Chia	10.1	116	380	30	100	0	0	0	Non heading
7	Chin Yeh Pao Hsin	8.7	100	325	40	0	30	10	10	Heading

* Date sown: April 19.
Date transplanted: May 13.
Date harvested: June 16-29.
Entry: 39.

Table 6. Yield and horticultural characteristics of selected entries in the mustard advanced yield trial, Autumn 1983*.

Entry	Yield** (t/ha)	Index	Plant weight (g)	Days to maturity (DAT)	Bolting rate (%)	Virus (%)	Soft rot (%)	Downy mildew (%)	Plant type
Tendergreen	32.3a	150	1212	30	0	12	0	0	Non heading
Embrapa/Cenargen No. 1	30.2a	140	1131	30	0	16	0	0	Non heading
Crespa	21.6b	100	811	80	0	0	0	0	Non heading
Chih Yeh Pao Hsin (CK)	21.5b	100	805	42	0	17	0	0	Heading
Mustard Green	20.5b	95	770	42	0	32	2	0	Heading
Chinese Mustard	18.3b	85	687	42	0	9	0	0	Heading
Giant Curled	16.7b	78	625	30	0	0	0	4	Non heading
LSD	5.3710								

* Date sown: September 30, 1983.
Date transplanted: October 24, 1983.
Date harvested: November 21, 1983 - December 5, 1983.
** Experimental design: RCBD, 4 replications.

Table 7. Yield and horticultural characteristics of selected entries in Chinese radish advanced yield trial, Autumn 1983*.

Entry	Yield (t/ha)**	Index	Days to maturity (DAT)	Root size L x W (cm)	Root wt. (g)	Root shape	Virus (%)	rot (%)	Mildew (%)
Radish No. 3	57.2a	196	60	16.2 x 7.4	541	I	0	0	0
House King	47.4b	162	60	23.3 x 5.5	418	J	0	0	0
Young-kwang	46.8b	160	64	16.6 x 7.6	470	L	0	0	0
Summer Radish	45.6b	156	64	23 x 7	473	I	0	0	0
Summer Tope	33.2c	114	64	20 x 6.2	374	I	0	0	0
Back Kyung	32.1cd	110	64	16.3 x 6.7	358	I	0	0	0
Keunbangseok	30.2cde	103	64	16 x 6.8	341	I	0	0	0
Winter Keeper	30.1cde	103	64	17.1 x 6.2	311	H	0	0	0
Muzingang	29.9cde	102	64	20 x 6.9	365	I	0	4	4
40 days Early (CK)	29.2cde	100	55	21 x 5	342	J	10	0	0
Kan Tzu	27.6cde	94	55	15.8 x 6	285	I-K	0	0	0
Pu-Tong Kan	25.9cde	88	55	16.4 x 6.5	324	L-I	0	0	8
Wuan-Hseng	23 cdef	78	55	16 x 6.4	280	K	8	0	4
Dacburyong	22.3def	76	64	16.7 x 6.5	362	I	0	5	0
Radish	21.9def	75	55	23.2 x 4.3	242	H	0	0	0
Natsuninowasei No. 3	21.8def	74	55	25.5 x 3.9	251	B-D	0	0	0
Hsia Hsueh Kan	20.6ef	70	55	15.1 x 6.3	257	I-K	0	0	0
Radish No. 5	15.3f	52	64	24 x 5.9	635	D	0	8	0

* Date sown: October 4, 1983.
Date transplanted: November 29 - December 19, 1983.
Date harvested:

** Experimental design: RCBD, 4 replications.

Table 8. Yield and horticultural characteristic of selected entries in the sweet pepper observation trial, Spring 1983*.

Entry	Yield (t/ha)	Index	Fruit size L x w (cm)	Days to maturity (DAT)	Fruit color	Virus (%)	Late Blight (%)
P 705	14.3	157	8 x 5.9	64	Green	10	20
P 7118	13.2	145	8.2 x 3.9	56	Green	40	0
Green Belle	13.1	143	7.6 x 4.3	56	Green	40	0
Green Boy	12	132	7 x 4	56	Green	60	10
Cypsy	12	132	10 x 4	46	Waxed Yellow	10	20
Redgold	11.3	124	6.8 x 4.9	50	Green	10	70
P 720	11.2	123	9.6 x 4.2	56	Green	10	20
673 Lady Bell	10.8	119	6.3 x 4.8	50	Green	10	10
California Wonder	10.8	119	6.6 x 4.4	50	Green	10	10
Pepper Maor 954-2	10.7	117	7.9 x 4	56	Green	25	15
E 6156 F_1	10.6	116	8.3 x 5.5	50	Green	30	20
P 522	10.2	112	8.2 x 4.4	56	Green	30	20
Yolo Wonder L.	9.4	103	6 x 4.6	60	Green	10	20
E 1104 F_1	9.4	103	7.5 x 4.4	56	Green	40	20
Ruby King	9.2	101	8.8 x 4	56	Green	20	20
Blue Star (F_1)	9.1	100	11.2 x 5	50	Green	25	20

* Date sown: March 3.
Date transplanted: April 13.
Date harvested: June 9 - September 6.

Table 9. Yield and horticultural characteristics of selected entries in the sweet pepper observation trial, Summer 1983*.

Entry	Yield (t/ha)	Index	Fruit size L x w (cm)	Days to maturity (DAT)	Fruit color	Virus (%)	Late blight (%)
Chiu Feng	24.8	151	5.8 x 4.8	58	Green	10	30
P 705	21.7	132	7.3 x 6	58	Green	0	20
673 Lady Bell	20.2	123	8 x 6	58	Green	20	15
Green Boy	19.7	120	7 x 4.2	54	Green	20	5
P 720	18.8	115	6.7 x 6.1	58	Green	20	20
Green Star No. 2	18.2	111	6.1 x 3.6	58	Green	20	35
New Star	17	104	6.6 x 4.3	58	Green	10	10
Blue Star (F_1)	16.4	100	9.5 x 4.5	58	Green	20	0
Green Belle	15.4	94	8 x 5.8	58	Green	30	20
Cubanelle	14.2	86	7 x 5.4	58	Green	20	0
Gypsy	14.2	86	7.7 x 3.8	58	Waxy yellow	40	15
Dalbon	13.7	83	6.5 x 4.3	58	Green	25	10

* Date sown: April, 1983.
Date transplanted: May 13, 1983.
Date harvested: July 15 - Oct. 20, 1983.

Table 10. Yield and horticultural characteristics of selected entries in sweet pepper advanced yield trial in Autumn 1983*.

Entry	Yield (t/ha)	Index	Days to maturity	Fruit size L x W (cm)	Fruit set rate	Mean fruit wt.(g)	Virus (%)	Blight (%)	Remarks
Dalbon	32.8a	132	70	11 x 5.4	4	117.9	40	0	Peto Co.
Belle Star (F_1)	28.9b	116	60	9.5 x 6.2	4	104.9	40	0	Ferry-Morse
Resistant Florida Giant	26.6c	107	60	9.8 x 5.8	4	104.4	10	0	Ferry-Morse
Yolo Wonder B	26.5c	107	60	8.7 x 5.8	4	85.5	50	0	A.C.V.P.C.**
Blue Star (F_1) (CK)	24.8d	100	60	10.5 x 5.7	3	123.5	60	5	Known You
Gypsy	23.1e	93	60	11.5 x 4.6	5	73	40	5	Peto Co.
VR 2	22.5e	91	110	10 x 4	3	83.6	0	10	Peto Co.
Green Boy	22.4e	90	80	10.5 x 4	4	31	0	0	Kaneko
Four Corners (F_1)	22.3e	90	60	8.8 x 5.7	3	95.8	10	0	Ferry-Morse
Citadel	20.1f	81	60	9.5 x 5.4	3	99	0	10	Peto Co.
Cubanelle	18.0g	72	70	12.2 x 3.5	5	45	100	0	A.C.V.P.C.
California Wonder	13.1h	53	80	7.5 x 4.4	3	76	100	0	Royal Sluis
S. P. 83301***	22.3	90	60	8 x 5.8	4	74	0	0	Houng-Nong
Oriental Glory***	21.3	86	60	8.6 x 6	3	89	0	0	Houng-Nong
S. P. 83352***	13.9	56	70	8.3 x 6	3	83	10	0	Houng-Nong
Hung Nong Ace***	7.3	29	60	8 x 4.2	3	41	40	0	Houng-Nong

* Date Sown: Spet. 30, 1983. Date transplanted: Oct. 27, 1983. Date harvested: Jan. 5 - April 3, 1984.
** A.C.V.P.G.: Agrigentics Crop Vegetable Products Group.
*** No replication.

Table 11. Yield and horticultural characteristics of selected entries in the hot pepper observation trial, Spring 1983*.

Entry	Yield (t/ha)	Index	Fruit size L x w (cm)	Days to maturity (DAT)	Fruit color	Virus (%)	Late Blight (%)
Shinshin House	34.2	193	12 x 1.5	55	Green	0	20
Twist Hot	32.1	181	7.5 x 1.3	55	Green	10	10
Hong-Shanho	31	176	10.7 x 1.9	64	Green	50	10
Early to Coloring	30	169	11.6 x 1.5	60	Green	0	20
Hot Long	27.3	154	8.7 x 1.9	55	Green	15	0
Whangshil day	26.7	151	10.4 x 1.9	64	Green	10	10
New Seoul	23.2	131	9 x 1.8	60	Green	30	10
Twist Green	22.6	128	8.1 x 1.5	55	Green	20	40
Chinheung Early	22.2	125	13 x 1.3	60	Green	50	10
Keunjang No. 1	22.2	125	8.8 x 2	60	Green	30	10
King Horn	22	124	8 x 1.9	55	Green	10	10
Passion	21.2	120	10.2 x 2.6	80	Green	10	10
Farmers Newcomer(F_1)	19.2	108	13 x 2.1	64	Green	10	10
Slam Chili (CK)	17.7	100	11.5 x 1.8	64	Green	10	10

* Date sown: March 3, 1983.
Date transplanted: April 13, 1983.
Date harvested: June 20 - October 20, 1983.

Table 12. Yield and horticultural characteristics of selected entries in the hot pepper observation trial, Summer 1983*.

Entry	Yield (t/ha)	Index	Fruit size L x w (cm)	Days to maturity (DAT)	Fruit color	Virus (%)	Late blight (%)
Passion	22.6	164	11 x 2.5	70	Green	30	10
Farmers Newcomer(F_1)	18.6	135	14 x 2.1	70	Green	20	10
Keunjang No. 1	17.4	126	10.2 x 2.1	60	Green	40	0
Shinshin House	16.4	119	16 x 2	60	Green	30	5
Early to Coloring	15	109	16 x 1.4	70	Green	10	30
Whangshil day	15	109	11.7 x 1.6	70	Green	0	25
New Seoul	15	109	10.5 x 2	60	Green	10	40
Twist Green	14.7	106	8.7 x 1.9	60	Green	50	10
Hong-Shanho	14.7	106	12.8 x 2	70	Green	10	30
Big Star	14.5	105	10 x 1.9	70	Green	80	10
King Horn	14.5	105	7.6 x 2.6	60	Green	10	60
Slam Chili (CK)	13.8	100	14 x 1.8	70	Green	30	25

* Date sown: April 8, 1983.
Date transplanted: May 13, 1983.
Date harvested: July 27 - November 15, 1983.

Table 13. Yield and horticultural characteristics of selected entries in hot pepper advanced yield trial in Autumn 1983*.

Entry	Yield (t/ha)	Index	Days to maturity	Fruit size L x W (cm)	Fruit set rate	Mean fruit wt.(g)	Virus (%)	Blight (%)	Remarks
Passion	22.2a	222	120	15 x 3.7	3	30	50	0	Known-you
Farmers Nowcomer (F_1)	20.2b	202	110	18.2 x 3.5	3	29	30	0	Known-you
Hot Long	15.2c	152	100	13 x 3.5	3	13	0	0	Hung-Nong
Chili Jalapeno	14.5c	145	100	12 x 1.8	4	5.5	0	0	Keystone
Shinshin House	13.5d	135	80	16 x 1.6	3	11	20	15	Shinshin Co.
Hong San Ho	13.1de	131	100	14 x 1.8	3	13	0	0	Hung-Nong
Hong Il Pum	12.7e	127	110	12 x 1.8	2	17	0	0	Hung-Nong
Young Chiao Chiao	11.6f	116	140	9.6 x 2.8	5	5.2	0	0	Nong-Tsan
672 Hungarian Wax	11.6f	116	90	14 x 2.2	3	25.5	0	0	Celanese
Hong Shan Ho	11.1f	111	100	15 x 1.8	2	14.3	0	0	Hung-Nong
Early to Coloring (CK)	10.0g	100	110	15 x 1.4	3	6.1	10	10	Shinshin Co.
Chu Rae Hong	9.9g	99	100	14 x 1.9	3	11.2	0	0	Hung-Nong
Long Green	9.0h	90	100	15 x 1.4	3	13.7	0	0	Hung-Nong
Hot Long	8.5h	85	100	11 x 1.3	2	13.7	0	0	Hung-Nong
Early Spring Green	7.5i	75	90	15 x 1.4	3	9.6	0	0	Choony Ann
Hanulcho	7.5i	75	110	10 x 1.1	5	1.8	0	0	Hong-Nong
Bulam House Pepper	6.8ij	68	90	14 x 1.8	3	10.3	0	0	Hong-Nong
Twist Hot	6.6j	66	100	11 x 1.6	3	5.5	0	0	Hong-Nong

* Date sown: September 30, 1983.
Date transplanted: October 27, 1984.
Date harvested: January 30 - May 5, 1984.
Experimental design: RCBD, 4 replications.

Table 14. Yield and horticultural characteristics of selected entries in the snapbean observation trial, Spring 1983*.

Entry	Yield (t/ha)	Index	Days to maturity (DAT)	Pod size L x W (cm)	Pod cross section	Rust (%)	Downy mildew (%)	Charcoal rot (%)	Virus (%)	Plant type
Geng Shou No. 1	15.7	182	50	15.5 x 1.3	Oval	40	0	3	13	Pole
Black Cresback (Yuang Ching)	14.9	173	50	15 x 0.8	Round	8	22	11	0	Pole
Black Cresback (Hsin Yi)	12.3	143	50	12.5 x 0.9	Round	10	20	20	30	Pole
Heh Tzu Yi-chi	9.4	109	50	12 x 0.8	Round	10	0	0	0	Pole
Heh Gen Pai Chia	8.9	103	56	13 x 0.7	Oval	20	33	5	0	Pole
Heh Gen 4"	8.6	100	56	13 x 0.8	Oval	20	10	5	0	Pole
Shinedogawa	8.3	138	52	11 x 1.1	Round	10	0	80	0	Bush
Iprin	8	133	52	9 x 0.7	Round	2	0	50	0	Bush
Admires	6.3	105	52	13 x 1.6	Flat oval	10	0	60	10	Bush
No. 8A0411	6.2	103	58	14 x 1.0	Round	40	20	70	0	Bush
Edogawa	6	100	52	15 x 1.1	Round	10	10	90	0	Bush
Saxa	6	100	52	9 x 0.7	Round	10	0	80	0	Bush

* Date sown: April 14, 1983.
Date harvested: June 3, 1983 - July 14, 1983.

Table 15. Yield and horticultural characteristics of selected entries in the snapbean advanced yield trial, Autumn 1983*.

Entry	Yield** (t/ha)	Index	Days to maturity (DAT)	Pod size L x W (cm)	Harvest period (days)	Rust (%)	Downy mildew (%)	Virus (%)	Plant type
Black Cresback (Yuang Ching)	23.4a	244	70	11 x 2.9	14	0	0	0	Pole
Heh Gen 4"	23.2a	242	64	12.5 x 0.9	22	0	0	0	Pole
Pai Chia 7"	22.5a	234	64	13 x 0.9	22	0	0	0	Pole
Witsa	21.2a	221	70	15 x 0.8	22	0	0	0	Pole
Cascade	11.5b	120	56	13 x 1	30	0	0	0	Bush
B.E.F.R.S.	11.2bc	117	60	11 x 0.8	22	0	0	0	Bush
Raider	10.7bc	111	56	13 x 1	22	10	0	0	Bush
Stringless (CK)	9.6bcd	100	60	11 x 0.9	22	0	0	0	Bush
Gator Green 15	9.6bcd	100	56	14 x 0.9	22	0	0	0	Bush
Blue Beach	9.1bcd	95	60	9 x 1	22	0	0	0	Bush
Admires	8.7bcd	91	56	16 x 1.8	22	0	0	10	Bush
Provider	8.6bcd	89	56	13.5 x 1	22	22	0	10	Bush
Felitop	8.4bcd	87	56	9.5 x 0.8	22	0	0	10	Bush
Producer (E-8268)	8.1bcd	84	56	13 x 1.1	17	0	0	0	Bush
Jolanco	7.9bcd	82	56	12 x 0.8	12	0	0	0	Bush
Satsukimidori No. 2	7.8cd	81	56	14 x 1	30	0	0	0	Bush
R. S. 1301 (CIMBOLA)	6.8d	71	60	11 x 0.9	16	18	0	5	Bush

* Date sown: October 4, 1983.
Date harvested: November 30, 1983 - January 17, 1983.
** Experimental design: RCBD, 4 replications.

Table 16. Presence of six viruses on AVRDC sweet pepper accessions.

Sweet pepper cv.	Total no. of samples	No. samples infected with					
		TMV	CMV	PVY	PVX	TEV	PeMV
S.P. 83352	5	0	0	1	0	0	2
S.P. 83301	4	0	0	0	0	0	0
Hung Nong Ace	5	0	0	0	0	0	1
Oriental Glory	3	0	0	0	0	0	0
Dalbon	5	0	0	3	0	0	0
Gypsy	4	0	0	0	0	0	0
Belle Star	5	0	0	1	0	0	0
Cubanelle	9	2	1	1	0	0	0
Yolo Wonder B	3	0	1	2	0	0	0
Four Corners	4	0	0	1	0	1	0
Green Boy	8	1	0	1	0	0	1
Blue star	3	0	1	1	0	0	0
Resistant Florida Giant	2	0	1	0	0	0	0
Citadel	6	2	0	0	0	0	0
California Wonder	4	1	1	2	0	0	2
VR 2	6	0	0	0	0	0	0
Total	76	6	5	13	0	1	5

Table 17. Presence of six viruses on AVRDC's chili pepper accessions.

Chili pepper cv.	Total no. of samples	No. samples infected with					
		TMV	CMV	PVY	PVX	TEV	PeMV
Hong II Pum	5	1	2	0	0	0	0
Hot Long	5	1	1	1	0	0	1
Chu Rae Hong	2	0	0	0	0	0	0
Bulam House	4	0	0	0	0	0	0
Early to Coloring	10	1	2	0	0	0	1
Young Chiao Chiao	3	0	0	0	0	0	0
Hanul Cho	6	3	0	0	0	0	3
Chili Jalapeno	2	0	0	0	0	0	0
Hong Shanho	4	0	1	1	0	0	1
672 Hungarian Wax	2	0	1	0	0	0	0
Twist Hot	8	1	3	0	0	0	1
Farmers Newcomer	7	0	0	4	0	0	0
Passion	3	0	1	2	0	0	0
Long Green	6	2	0	1	0	0	1
Early Spring Green	5	0	0	0	0	0	1
Shin Shin House	4	0	0	0	0	0	0

Training

The 90 scholars from 17 countries who participated in AVRDC training programs during 1983 included the Center's first trainees from Bangladesh, Ethiopia, Kenya, Nepal, Somalia, France, and West Germany. The enrollment figures for 1983 were 26 percent higher than those of 1982, an increase mainly due to the establishment of the Center's production training program in Thailand.

Fifty percent of all trainees received monetary support from the AVRDC core budget in the form of scholarships or in-kind services. Training sponsors in 1983 included: The German Agency for Technical Cooperation (GTZ), the Government of Indonesia, Bayer Thailand Co., Ltd, the Hung Nong Seed Company, the Lincoln Institute for Land Policy, the Osnabruck School of Horticulture, the Government of the Philippines, SIPTA-Formexa, U.S. AID Somalia, and Wageningen Agricultural University.

Training Scholars

Tomato

Antonio S. Benollas, Philippines
Bekru, Bogale, Ethiopia
You-ming Chang, ROC
Sasitorn Chantara-o-tan, Thailand
Dae Whan Cho, Korea
V. S. Ginigaddara, Sri Lanka
Perng Hwang, ROC
P. M. Karunaratne, Sri Lanka.
Rong-huei Ke, ROC
Duhng-liarng Lin, ROC
Srisomvong Manit, Thailand
Evan W. Mbinga, Kenya
Sudawan Meecharoen, Thailand
Mohd Shukor bin Nordin, Malaysia
Abdullahi Mohamed Musse, Somalia
B. D. Pathak, Nepal
Etti Purwati, Indonesia
Abdur Rashid, Bangladesh
Twatchai Sasiphalin, Thailand
Rustaman Soeriaatmadja, Indonesia
Pattana Srefah, Thailand
Somchai Sukhakul, Thailand
Yoyo Sulyo, Indonesia
Nani Sumarni, Indonesia
Prapa Teerapolvichitra, Thailand
Bee-lan Teh, ROC
Kozo Toshimitsu, Japan
Jae-fen Wang, ROC

Chinese Cabbage

Vissanu Apichartpat-tanasiri, Thailand
Jen How Chen, ROC
Catalina G. De La Cruz, Philippines
Mina Sta. Maria Javier, Philippines
Lional B. Hettimulla, Sri Lanka
Omar Isa, Malaysia
Kalalinggi Kadang, Indonesia
Mohd. Nizam Haji Khamis, Malaysia
Sang Eun Lee, Korea
Anan Musikapan, Thailand
Nimit Rodwattanakul, Thailand
Aroon Saenghirun, Thailand
Hyo Duk Suh, Korea

Sweet Potato

Ar-miin Hwang, ROC
Yeong-ching Leu, ROC
Antonio Rizalde Veloso, Philippines

Shyh-shyan Wang, ROC

Mungbean

A. Illangantilaka, Sri Lanka
R. M. K. Sumanasinghe, Sri Lanka
Nirat Vanitvanalunlug, Thailand
Asela Wijesundera, Sri Lanka

Soybean

Bakri Biran, Indonesia
Keng-feng Chen, ROC
Josephine Ding, ROC
Lucena B. Gajete, Philippines
Kathryn E. Harlow, USA
R. Kandiah, Sri Lanka
K. Kulendran, Sri Lanka
Tze-an Kuo, ROC
Edison M. Magtibay, Philippines
Srisuk Poonpolgul, Thailand
In Man Song, Korea
D. B. Jayasundera, Sri Lanka
Darmijati Syariffudin, Indonesia
Azran Tanjung, Indonesia
Ester C. Vergara, Philippines
S. E. Wijesena, Sri Lanka
Mann-miaw Yang, ROC

Other Crops

Cipriano Bayangan, Philippines
Marina Becker, West Germany
Antonio S. Benollas, Philippines
Gisela Fockenbrock, West Germany
Tobias van Hameren, Netherlands
Orencio L. Juan, Philippines
Rodolfo A. Mendoza, Philippines
Restituto A. Pangan, Philippines
Winai Rushtapakornchai, Thailand
Margarita H. Soberano, Philippines
Cesario C. Tomas, Philippines
Yong-heong Kim, Korea
Bye-whein Wu, ROC
Yaw-guang Liang, ROC
Tzuoo-chyi Yang, ROC

Entomology

Sant Kongsomboon, Thailand

Agricultural Chemistry

Onanong Naivikul, Thailand
Anchanee Utaipatana-cheep, Thailand

Soil Science

Wen-inn Lee, ROC

Gardens

Dhupal Chiranjeewa Nanayakkara, Sri Lanka

Farm and Station Management

Nakorn Nalampang, Thailand
Jamlong Pothacharean, Thailand

General Training

Jantana Boon-long, Thailand
Sandrine Du Chouchet, France
William D. Dar, Philippines

Genetic Conservation

The responsibilities of the AVRDC Seed Laboratory include the characterization, maintenance, and regeneration of the Center's germplasm collection, as well as training activities related to AVRDC's five mandate crops. The following are highlights of the unit's accomplishments in 1983.

IBPGR Activities: The arrival of an IBPGR intern marked the beginning of the second phase of a joint IBPGR-AVRDC program for regenerating, characterizing, and maintaining the Center's Chinese cabbage germplasm collection. Agreements were also signed with IBPGR establishing similar programs for AVRDC's mungbean and soybean collections. In addition, IBPGR designated AVRDC as the official repository for sweet potato germplasm in the Asian-Pacific region.

Facilities: Plans were completed for the construction of a new seed laboratory building. The new facility will increase the space available for medium-term seed storage, and will provide larger work areas for seed research, training, tissue culturing, and seed distribution.

Germplasm Distribution: A total of 34,682 seed samples were distributed to cooperators in 97 countries (Table 1 and "Germplasm Recipients").

New Accessions: Six hundred new accessions were added to the Center's germplasm collection (Table 2).

Regeneration: Approximately 4,900 accessions were regenerated: tomato, 510; Chinese cabbage, 106; sweet potato, 1,317; mungbean, 838; soybean, 1,524, and blackgram, 156.

Table 1. Germplasm distribution 1983

Crop	Samples distributed
Tomato	2,950
Chinese cabbage	1,996
Sweet potato	1,180
Mungbean	6,264
Soybean	21,555
Other Crops	737
Total	34,682

Table 2. Germplasm holdings 1983

Crop	New accessions	Total
Tomato	97	5,211
Chinese cabbage	6	793
Sweet potato	366	1,169
Mungbean	13	4,941
Soybean	142	9,331
Other crops		795
Total	624	21,445

Germplasm Recipients

Argentina

Secretaria de Asuntos Academicos

Australia

Department of Primary Production
H. J. Heinz Company
Queensland Agricultural College
University of Sydney
Department of Agriculture, Perth
Sunraysia Horticultural Research Institute
Commonwealth Scientific and Industrial Research Organization
Horticultural Research Station

Austria

Landeskammer Fur Land und Forstwirtschaft in Steiermark

Bahamas

Department of Agriculture

Bangladesh

Institute of Nuclear Agriculture
Pulse and Oil Seed Project

Barbados

Hi-GRO Gardens, Ltd.

Belgium

BAFOR

Belize

Carribean Agricultural Research and Development Institute

Bolivia

Est Experimental "Green Chaco"

Brazil

Programa De Pesquisa, OCEPAR
UFRRJ Seropedica Itahuai

Brunei

Sinaut Agricultural Training Center

Burma

IRRI - Burma

Canada

King Grain, Ltd.
Stocks Seed, Ltd.

Caroline Islands

Office of the President
OISCA I.D.M.

Central African Republic

Institute Technique Agricole

Chile

Pontificia Universidad Catholica de Chile

Colombia

International Center for Tropical Agriculture
Universidad del Valle
Collegio de Bachillerato Agrotecnico

Costa Rica

Rancho Las Manchas Project
Ministerio De Agricultura y Ganaderia
ROC Technical Mission
Universidad de Costa Rica

Dominican Republic

Centro de Desarrollo Agropecuario

Egypt

National Research Centre
Cairo University

El Salvador

Centro Nacional de Tecnologia Agricola

Ethiopia

Nazareth Agricultural Research Station
International Livestock Centre for Africa

Fiji

Legalega Research Station

France

INRAAVI
Societe Cooperative Agricole
Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres

Gabon

UN Food and Agriculture Organization

Ghana

Crops Research Institute
Ministry of Agriculture

Guadeloupe

Institut National de la Recherche Agronomique

Guatemala

Instituto de Cinecia y Tecnologia Agricolas

Guyana

Gyuana Sugar Corporation

Haiti

Faculte' d' Agronomie
Department of Agriculture

Holland

Stichting Proefstation voor de Akkerbouw en de Groenteteelt in de Vollegrond
Wageningen Agricultural University

Hong Kong

Department of Agriculture and Fisheries
Hong Kong University

India

Shri Girivanavasi Pragati Mandal
Yantra Vidyalay Punjab Agricultural Univ.
All India Coordinated Pulse Improvement Project
Rajasthan College of Agriculture
Indian Agricultural Research Institute
University of Agricultural Science
Drought Prone Area Programme Research Station
J and K University of Agricultural Sciences and Technology
Center for Water Resources Development and Management
National Agricultural Services
Murugappa Chettiar Research Center
Tamil Nadu Agricultural University
Mahatma Phule Agricultural University
Haryana Agricultural University
National Agricultural Services
G. B. Pant University of Agricultural and Technology
Marathwada Agricultural University
NE Hill University
Pallavi Agro-Hort Consultants
Department of Vegetable Crops and Floriculture
Indo-American Hybrid Seeds
Nimbkar Agricultural Research Institute
Pulse Research Station
FIPPAT
Sakthi Sugars Limited
Mahatma Phule Krishi Vidyapeeth
Soya Production and Research Association
Tamil Nadu Rice Research Institute

Indonesia

National Seed Corporation
Agronomy Department - Unpatti
Program Pembangunan Perserikatan
Sukamandi Research Institute for Food Crops
Universitas Gadjah Mada
Bogor Central Research Institute for Food Crops
National Agriculture Extension Project
Agency for Agricultural Research and Development
East Kalimantan Transmigration Area Development Project
Satya Wacana Christian University
ROC Technical Mission
MARIF
P. T. Uniroyal Sumatra Plantations
Lembang Research Inst.
Universitas Sriwijaya
P. T. Patra Tani
Dinas Pertanian Tanaman Pangan
Pilot Project on Integrated Soya and Food crop Production
General Soedirman Univ.
Dinas Pertanian Tanaman Pangan
SURIF
NIT Livestock Development Project
Laboratory for Plant Physiology
P. T. Melati Gambir Mas
Seed and Plant Improvement Institute

Iraq

General Body for Applied Agriculture Research

Israel

Isreali Extension Service
Ministry of Agriculture
Division of Plant Introduction
IKN Agricultural Services

Italy

UN Food and Agricultural Organization

Jamaica

Ministry of Agriculture

Japan

Takii and Company, Ltd.
Institute of Tropical Agriculture
Kyushu University
Kirin Brewery Co., Ltd.
Ginowan-Shi Agricultural Cooperative
Kanedo Seed Company
Nihon University

Jordan

Jordan Valley Agricultural Project
Agricultural Materials Co.

Kenya

University of Nairobi
Kenya Seed Company
Jomo Kenyatta College of Agriculture and Technology
Dryland Farming Research and Development Project
UN Food and Agriculture Organization

Korea

Office of Rural Development
AVRDC Korean Sub-Center
Gyeongsang National University

Laos

Department of Agriculture

Lesotho

ROC Technical Mission
Department of Agriculture
Plenty Agriculture Project

Liberia

Ministry of Agriculture
UN Food and Agriculture Organization

Malawi

ROC Technical Mission
Bunda College of Agric.
Lilongwe Agricultural Development Division
Bumbwe Research Station
Chitedze Research Station

Malaysia

Universiti Pertanian Agriculture Research Centre

Mauritius

University of Mauritius
Union Sugar Estate, Ltd.
Ministry of Agriculture, Fisheries, and Natural Resources

Mexico

Instituto Nacional de Investigaciones Agricolas
Instituto Tecnologica y de Estudios Superiores de Monterrey

Morocco

Institut National de la Research Agronomique

Nepal

Agronomy Experimental Farm
Tinan Watershed Project
Institute of Agriculture and Animal Science

New Zealand

Horticulture Research Station

Nigeria

Ahmadu Bello University
Department of Agriculture
International Institute of Tropical Agriculture

Niue Islands

Department of Agriculture and Fisheries

Pakistan

National Agricultural Research Center
Technical Services Assoc.
Nuclear Institute for Agriculture and Biology
Atomic Energy Agricultural Research Centre
Intensive Agricultural Project
P. C. SIR Laboratories

Panama

Instituto de Investigacion Agropecuaria de Panama
Smithsonian Tropical Research Institute

Papua New Guinea

University of Papua New Guinea

Paraguay

ROC Technical Mission

Peru

Instituto de Investigacion y Promocion Agropecuaria
Nacional Leguminosas de Grano

Philippines

Abra Diocesan Rural Development Project
Mountain State Agricultural College
AVRDC Philippine Outreach Project
Ministry of Agriculture
Mindanao State University
University of Eastern Philippines
Botanique Philippines Inc.
Center for Rural Technology Development
Bicol University
Mariano Marcos State University
Bureau of Plant Industry
Ateneo de Davao Univ.
Southern Mindanao Agricultural Research Center
Pangasinan State Univ.
Xavier University
Zamboanga del Sur Development Project
International Rice Research Institute
Agricultural Research and Development Services
Second Laguna de Bay Irrigation Project
Kanlaon Foundation
Central Philippine Univ.
Cagayan State University
Agricultural Service Center
San Miguel Corporation

Puerto Rico

Tropical Agriculture Research Station

Qatar

Industrial Development Technical Center

Western Samoa

Department of Agriculture and Forestry

Saudi Arabia

Ministry of Agriculture and Water
ROC Technical Mission

Senegal

ATA/CNRA

Sierra Leone

University of Sierra Leone

Singapore

Primary Production Dept.
Save the Children
International Potash Institute

Solomon Islands

Ministry of Home Affairs

Somalia

UN Food and Agriculture Organization
UN Development Project
Save the Children
Ministry of Agriculture

South Africa

Division of Seed Control

Spain

Departamento de Horto-fruticultura

Sri Lanka

Department of Agriculture
Coconut Research Inst.

St. Lucia

St. Judes Hospital

Sudan

Kenana Sugar Company
University of Gezira

Surinam

Ministerie Van Landbouw

Swaziland

Swaziland Cropping System Research and Extension Training Project
Malkerns Research Station
ROC Technical Mission
University of Swaziland
Farm Chemicals, Ltd.

Taiwan

Taiwan Agricultural Research Center
Kaohsiung DAIS
Taichung Senior Vocational Agricultural School
National Chung Hsing University
National Taiwan Univ.
Taiwan Seed Improvement Station
Chiayi Agricultural Coll.

Tanzania

University of Dar Es Salaam
Ministry of Agriculture
Tanzania Agricultural Research Institute, Ilonga

Tonga

Ministry of Agriculture Forests and Fisheries

Tahiti

Mission de Recherche Agronomique

Thailand

AVRDC Thailand Outreach Program
Mae Joe Institute of Agricultural Tech.
Thailand Institite of Scientific and Technological Research
Department of Agriculture
Kasetsart University
Chiang Mai University
Chainat Field Crop Research Center
Mennonite Central Comm.
Pacific Seeds
Royal Northern Project Office
Prince Songkhla Univ.
International Board for Plant Genetic Resources

Trinidad and Tobago

The University of the West Indies
Ministry of Agriculture

United Kingdom

University of Nottingham
University of Durham
National Vegetable Research Station
University of Reading
Southampton University

Upper Volta

UN Food and Agriculture Organization

USA

NifTAL Project
LSU Plaquemines Parish
USREP/JECOR
Wilbur-Ellis Company
Mississippi State Univ.
US Department of Agric.
Texas A & M University
University of Arizona
University of N.Iowa
Sacramento Valley Milling
Iowa State University
H. J. Heinz Co.
Pioneer Hi-Bred Int'l. W.
Atlee Burpee Co.
Tsukegee Institute
Stauffer Chemical Co.
Joseph Harris Co., Inc.
University of Georgia
Nickerson IPB Seeds
University of Hawaii at Hilo
Asgrown Seed Company
Alabama Agricultural and Mechanical University
Michigan State University
Oklahoma State University
Honolulu Botanical Gardens
Dairyland Seed Co.
Epcot Center
International Soybean Project
Boyce Thompson Institute for Plant Research
Brigham Young University
Purdue University
Sluis and Groot
University of Florida
Mountain Horticultural Crop Research Station
Land O'Lakes, Inc.
University of New Hampshire
Johnston Seed Company
Ohio State Univeristy
Moran Seeds Inc.
Water Isle Botanical Garden
University of Hawaii at Manoa

Cold Spring Harbor Lab
Keystone International Seed Co.
SIFAT Training Center
International Agricultural Development Service
North American Plant Breeders Inc.

Vietnam

University of Can Tho
Hau Giang Provincial Committee for Science and Technology
Ministry of Agriculture

Venezuela

Universidad Nacional Experimental de los Llanos Occidentales

Virgin Islands

Virgin Islands Agricultural Experimental Station
Virgin Island Cooperative Extension Service

Yemen

UNDP/FAO

Yugoslavia

Agricultural Center of Croatla

Zaire

SEDA
US Agency for International Development

Zimbabwe

Crop Breeding Institute
Rattray Arnold Research Station
Ministry of Agriculture

Seminars

The following seminars were presented in 1983 by Center staff and guest speakers. Please note that seminar papers are not available for distribution.

January 6 - Control of soybean nitrogen fixation in the tropics, Ichiro Tanabe, AVRDC Soil Scientist.

January 20 - Proposed organization of the AVRDC outreach program in Malaysia, Chong-seng Tay, AVRDC Seed Technologist.

February 17 - Mungbean beanfly resistance, Goh Hyun Gwan, AVRDC Training Scholar.

February 24 - Soybean mutation breeding, Hi Sup Song, Senior Researcher, Korean Atomic Energy Research Institute.

February 25 - Tomato production systems in Israel, E. Kopeliovitch.

March 3 - Diamondback moth resistance to insecticides, Chih-ning Sun, Professor of Entomology, National Chiung Hsing University.

March 10 - The development of a pesticide, G. W. Selleck, AVRDC Director General.

March 17 - A manpower development program for the vegetable industry, D. V. Castro, AVRDC Training Specialist.

March 24 - Trypsin inhibitors in sweet potatoes: Genotypic and environmental effects, John C. Bouwkamp, Associate Professor of Horticulture, University of Maryland.

March 30 - ELISA and ISEM - sensitive methods for the detection and identification of plant viruses, J. J. Vetten, Virologist, BBA Braunschweig, West Germany.

April 7 - Provitamin A activity of vegetables and fruits, Samson C. S. Tsou, AVRDC Biochemist.

April 14 - Soybean diseases in Thailand, Srisuk Poonpolgul, AVRDC Special Purpose Trainee.

April 21 - Soil properties affecting the nitrogen fixing activities of peanut nodules, Kun-huang Houng, Professor of Soil Science, National Taiwan University.

May 5 - Ammonium toxicity of rice seedlings, Hong-chi Lin, Professor of Plant Nutrition, National Taiwan University.

May 12 - a) Interpretation of Soil O_2 and b) Regimes in relation to crop growth, T. C. Yang, Professor of Soil Science, National Chung Hsing University.

May 19 - Reaching the farmer with research results, S. Shanmugasundaram, AVRDC Soybean Breeder.

May 30 - Horticulture in Australia's Northern Territory, Terry Piggott, Australian Department of Primary Production.

June 2 - A farming systems approach for working with farm families, Albert Hagan, Professor Emeritus, University of Missouri.

July 25 - Evaluation of land for irrigation, T. H. Seldon, World Bank Consultant.

August 4 - Insect pest problems of AVRDC crops in Indonesia, N. S. Talekar, AVRDC Entomologist.

August 11 - Error control on field experiments, K. Kamiyama, AVRDC Associate Scientist in Statistics and Computers.

August 18 - The cell and tissue of ginseng, W. C. Chang, Physiologist, Academia Sinica.

August 25 - The potential of AVRDC crops in Saudi Arabia, T. C. Wang, AVRDC Associate Specialist in Plant Pathology.

September 9 - Experiences in the rural development of Philippine business for social progress (PBSP), Jaime Aristotle B. Alip, PBSP Program Manager.

September 15 - Response of mungbean to various soils, Hideo Imai, AVRDC Soil Scientist.

September 22 - Acquisition of thermo-tolerance in soybean seedlings: Synthesis and accumulation of heat stock proteins and their cellular localization, Chu-yung Lin, Professor of Botany, National Taiwan University.

October 27 - Research experience in Indonesia: A postmortem analysis, R. T. Opena, AVRDC Plant Breeder.

November 3 - The application of plant tissue culture in Taiwan, W. J. Ho, Taiwan Seed Service.

November 10 - Natural occurrence of Fusarium mycotoxins in grains and feeds in Taiwan, Tsung-che Tseng, Research Fellow, Academia Sinica.

November 24 - Liquid mixed fertilizers: Their production and use on cane and corn fields in Taiwan, Chwan-chau Wang, Associate Director, Taiwan Sugar Research Institute.

December 8 - Stem and pod blight of soybean, Wen-shi Wu, Professor of Plant Pathology at National Taiwan University.

December 15 - The effects of drought stress on the physiological characteristics of soybean, Hsin-hsiung Chang, Associate Professor of Agronomy, National Taiwan University.

December 29 - Recent advances in soybean rust research at AVRDC, Arnold T. Tschanz, AVRDC Associate Plant Pathologist.

Conference and Miscellaneous Papers

The following is a list of conference and miscellaneous papers presented by AVRDC scientists in 1983. Please note that these papers are not available for distribution.

Bouwkamp, J. C., S. C. S. Tsou, and S. S. M. Lin. Trypsin inhibitors in sweet potato: Genotype and environment effects. Breeding New Sweet Potatos for the Tropics, Proceedings of the American Society for Horticultural Science, Mayaguez, Puerto Rico.

Gershon, Jack. Alleviating vitamin A problems with home gardens Fourth Asian Congress of Nutrition, Bangkok, Thailand.

Green, S. K. Strategies for the development of virus resistant tropical vegetables at AVRDC. Workshop on plant virus and MLO, National University of Singapore.

Green, S. K., Y. Sulyo, and D. R. Lee. Investigation of the tomato leafcurl disease in Taiwan. Annual Meeting of the Plant Protection Society of the Republic of China.

Green, S. K. and T. C. Deng. The detection of peanut mosaic virus on soybean in Taiwan. Annual Meeting of the Plant Protection Society of the Republic of China.

Inouye, Jun and S. Shanmugasundaram. Effect of photoperiod and temperature on the growth and reproductive behavior of less photoperiod-sensitive soybeans. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Kuo, C. G. Characterization of heat tolerance in Chinese cabbage. Canadian Society for Horticultural Science.

Lin, S. S. M., C. C. Peet, D. M. Chen, and H. F. Lo. Breeding goals for sweet potato in Asia and the Pacific: A survey of sweet potato production and utilization. Breeding New Sweet Potatoes for the Tropics, Proceedings of the American Society for Horticultural Science, Mayaguez, Puerto Rico.

Opeña, R. T. Genetic improvement of quality among selected vegetables. Journal of the Korean Society Horticultural Science, 24(4): 302-324.

Opeña, R. T., C. Y. Yang, S. H. Lo, and S. H. Lai. Breeding of vegetables adapted to the lowland tropics. ASPAC Tech. Bull. 77:16.

Opeña, R. T. Development of tomato and Chinese cabbage cultivars adapted to the hot, humid tropics. International Society of Horticultural Science, Ninth Africa Horticultural Symposium, Seychelle Islands.

Sajjapongse, A., G. W. Selleck, and Y. C. Roan. Effect of metribuzin, diphenamid, and DCPA on weed growth and yield of transplanted tomato. Symposium on Weed Control in the Tropics, Malaysia.

Sajjapongse, A., G. W. Selleck, and M. H. Wu. Weed control for mungbean (Vigna radiata (L.) Wilczek). Ninth Asian-Pacific Weed and Soil Science Society Conference, Philippines.

Sajjapongse, A. and M. H. Wu. Weed control in soybeans. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Selleck, G. W. Soybean, a crop of promise for the tropics and subtropics. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Selleck, G. W. AVRDC, the next decade. AVRDC Tenth Anniversary Ceremony, Shanhua, Taiwan, ROC.

Shanmugasundaram, S. Limited popularity of soybean cultivation in south and southeast Asia. International Symposium on Soybean in the Tropics and Subtropics, Tsukuba, Japan.

Shanmugasundaram, S. and C. S. Ahn. The soybean and mungbean improvement programs at AVRDC. Proceedings of the Third Research Co-ordination Meeting on the Use of Induced Mutations for Improvement of Grain Legume Production in Southeast Asia.

Shanmugasundaram, S. and Chen Li-Feng. Selection for field resistance to soybean rust. Soybean Rust Newsletter 6:25-27, AVRDC, Taiwan, ROC.

Shanmugasundaram, S. and T. S. Toung. Soybean genotypic responses for minimum and maximum input in different seasons. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Summerfield, R. J., S. Shanmugasundaram, and E. H. Roberts. Adaptation of soybean to photo-thermal environments and implications for screening germplasm. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Talekar, N. S. and B. S. Chen. Beanfly pest complex of tropical soybean. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

Tschanz, A. T., T. C. Wang, and B. Y. Tsai. Recent advances in soybean rust research at AVRDC. International Symposium on Soybean in Tropical and Subtropical Cropping Systems, Tsukuba, Japan.

J. E. Yuen, H. C. Huang, and J. F. Wang. Corynespora cassiicola on tomato in Taiwan. Plant Protection Bulletin, Vol. 25:306, Taiwan, ROC.

Publications

How to Order

The publications listed below can be ordered from the AVRDC Office of Information Services. Most are available free of charge and will be posted upon request via surface mail. If airmail delivery or multiple copies are required, please check the price list located on page 438. It lists airmail charges and the cost of multiple copies according to publication type, e.g. technical bulletins, journal papers, etc.

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Single copies of all AVRDC publications are available to libraries free of charge. If more than one copy is required, or if our records show that your library received a free copy in the past, you will be charged for the publication at the "additional copies" price listed on page 438. All library copies will be sent by surface mail unless otherwise indicated in your request. Please consult the price list for airmail charges.

Journal Paper Reprints

JP 1 Mackenzie, D. R., L. Ho, T. D. Liu, Henry B. F. Wu, and E. B. Oyer. 1975. Photoperiodism of mung bean and four related species. HortScience 10(5):486-487.

JP 3 Wu, Henry B. F., T. T. Yu, and T. D. Liou. 1974. Physiological and biochemical comparisons of sweet potato varieties sensitive (Tai-Lung 57) and insensitive (Red-Tuber-Tail) to chilling temperatures. Bulletin 12, The Royal Society of New Zealand, pp. 483-486.

JP 7 Mew, T. W., W. C. Ho, and L. Chu. 1976. Infectivity and survival of soft-rot bacteria in Chinese cabbage. Phytopathology 66:1325-1327.

JP 9 Mew, T. W. and W. C. Ho. 1977. Effect of soil temperature on resistance of tomato cultivars to bacterial wilt. Phytopathology 67:909-911.

JP 13 Opeña, R. T. and S. H. Lo. 1978. Derivation of matroclinal diploids in Chinese cabbage and evaluation of their significance in breeding. J. Amer. Soc. Hort. Sci. 103(6):820-823.

JP 15 Shanmugasundaram, S. and Samson C. S. Tsou. 1978. Photoperiod and critical duration for flower induction in soybean. Crop Science 18: 598-601.

JP 17 Kuo, C. G. and J. S. Tsay. 1977. Propagating Chinese cabbage by axillary bud culture. HortScience, 12(5):456-457.

JP 20 Talekar, N. S., L. T. Sun, E. M. Lee, J. S. Chen, T. M. Lee, and L. Lu. 1977. Residual behavior of several insecticides on Chinese cabbage. J. Econ. Entomol. 70(6): 689-692.

JP 29 Lim, W. L., S. H. Wang, and O. C. Ng. 1978. Resistance in Chinese cabbage to turnip mosaic virus. Plant Dis. Reptr. 62:660-662.

JP 38 Ho, Leonard. 1976. Some aspects of seed production and distribution in Asia. Seed Technology in the Tropics 179-205.

JP 39 Villareal R. L., S. K. Lin, and S. H. Lai. 1979. Variations in the yielding ability of sweet potato under drought stress and minimum input conditions. HortScience 14(1):31-32.

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JP 42 Cowell, R. L. and C. L. Luh. 1978. International research in agriculture. Span 21(3)104-106.

JP 45 Opeña, R. T. and S. H. Lo. 1979. Genetics of heat tolerance in heading Chinese cabbage. HortScience 14(1):33-34.

JP 46 Shanmugasundaram, S. 1979. Variation in the photoperiodic response of several characters in soybean, Glycine max (L.) Merrill. Euphytica 28:495-507.

JP 48 Riley, James J. and Merle R. Menegay. 1978. Intensive agricultural practices in Asia. J. Food Proc. and Pres. 2:197-203.

JP 49 Villareal, R. L., S. K. Lin, L. S. Chang, and S. H. Lai. 1979. Use of sweet potato (Ipomoea batatas) leaf tips as vegetables. Expl. Agric. 15:113-116.

JP 50 Hubbell, John N., Jr. 1980. The germplasm accession information system at the Asian Vegetable Research and Development Center (AVRDC). HortScience, 15(1):17-21.

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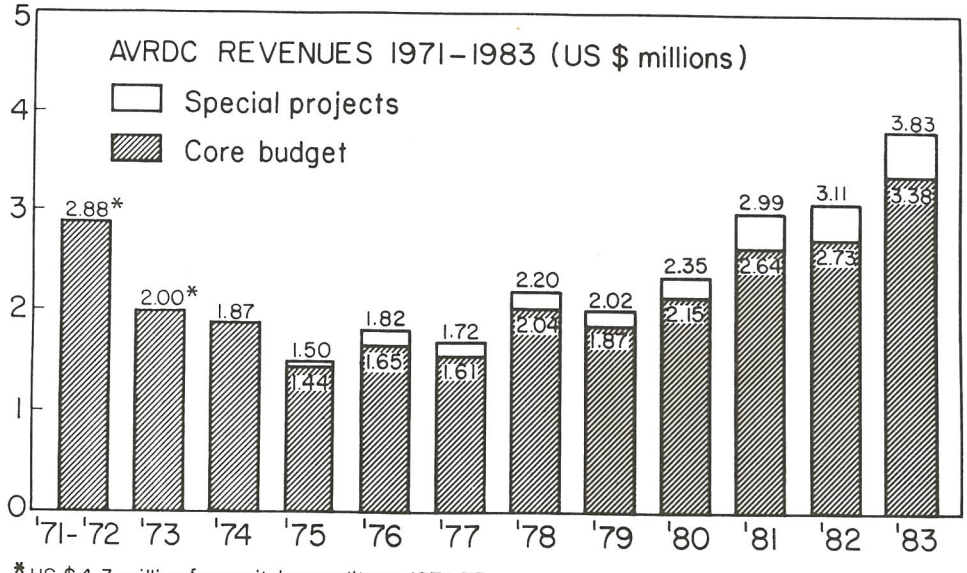

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