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Foreword

This publication provides a detailed record of the research conducted at the Asian Vegetable Research and Development Center (AVRDC) during the 1982 calendar year. It is intended to serve as a reference for scientists, agricultural development personnel, students of agriculture, and others interested in the development of tropical legumes and horticultural crops.

Due to the expense of producing the report, it is being distributed in limited numbers, primarily to libraries. Complimentary reprints of specific sections are available from AVRDC's Office of Information Services. Readers who would like more general information about AVRDC research are invited to request a copy of the Center's 1982 Progress Report Summaries, which contains abstracts of all the reports in this publication, as well as information on AVRDC training programs, bilateral projects, and other general interest topics.

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Contents

Horticultural Crops Program

Tomato Breeding

Crossing Program and Segregating Populations

Through tropical tomato breeding at AVRDC, good levels of heat tolerance and bacterial wilt (BW) resistance have already been achieved. AVRDC lines have been released for commercial production in 13 tropical countries. Fruit sizes of the advanced lines are generally small, however, and in a number of situations are deemed below commercial standards. Moreover, they lack resistance to other diseases besides BW, e.g., mosaic virus, nematode, gray leafspot, etc. Readily discernible fruit qualities such as firmness, crack resistance, and good red color have not yet been combined with the most advanced lines.

Crosses were made in 1982 to combine a number of the above traits with heat tolerance and BW resistance (Table 1). Diallel crosses to develop populations with enhanced levels of heat tolerance or BW resistance have also been made. In several cases, the heat tolerant, BW resistant parents used in the new crosses were the best breeding lines available. Segregating populations are currently being advanced rapidly by the bulk method (without selection) or by a modified bulk method (with selection for simply inherited traits, e.g. ToMV or nematode resistance). Techniques such as close spacing and pruning of shoots after fruit set in the first or second cluster have been adopted to accelerate the turnover in generation time. Consequently, fruits are harvestable about 2 to 2.5 months after transplanting. Pruning, when plants are grown in small pots (9 cm diameter) reduces the seed-to-seed cycle of crosses advanced via the single-seed descent method (SSD) to about 2.5 months. Testable lines from the SSD method can conceivably be available within two years. This rapid turnover in generation time is certainly an improvement over the 4.5 month period previously needed for field-grown bulk populations or the three to four month period needed for SSD-advanced materials.

Apart from one set of F_5 and F_6 lines screened for BW resistance, no lines or populations in earlier generations were carried in 1982 because of the severely low selection rate after BW inoculation in previous years. The previous selection scheme has now been altered; instead of imposing selection pressure for BW resistance in the early bulk generations when genotypes are still present as single plant entities, selection is now delayed until genotypes become relatively homozygous lines or families. This technique should suit the genetic complexity of both BW resistance and heat tolerance. Selections in early generations are restricted to those for simply inherited traits such as tomato mosaic virus (ToMV) or nematode resistance. Concomitant selection for desirable horticultural traits will also be practiced to enhance the potential for commercial acceptability of future lines.

Table 1. Number and nature of crosses made in 1982.

Doses in pedigree HT	Doses in pedigree BW	Other traits of interest[z]	Number of crosses
1	1	Tm1,Tm2a,large fruit,Mi,firmness,pat, GLS,BLR,Ve,F	54
2	1	Tm2a,large fruit,flood tolerance,BLR,Crk	27
1	2	Tm1,Tm2a,large fruit,Mi,firmness,pat, GLS,BLR,Crk	63
2	2	Tm1,Tm2a,large fruit,firmness,GLS,BLR,Crk	38
0	0;1;2;3	Tm1,Tm2a,large fruit,Mi,GLS,firmness, DGS,Ve,F	38
Total			220

[z] Characters underscored are those that are definitely carried in crosses, in various combinations with the other traits listed. Those not underscored are probable, based on donors' information about stocks. Mi = nematode resistance; pat = parthenocarpy; GLS = gray leafspot resistance; Crk = crack resistance; BLR = blotchy ripening resistance; Ve = Verticillium wilt resistance; F = Fusarium wilt resistance; DGS = dark green shoulder.

Evaluation of Germplasm for Heat Tolerance

Introduction

Germplasm collection is a continuing activity aimed at broadening the genetic base for breeding purposes. New accessions routinely pass through evaluation for heat tolerance, disease resistance, and other

important horticultural traits. Two heat tolerance trials of previously untested accessions were conducted in summer, 1982.

Materials and Methods

The first trial consisted of 48 entries and two check lines (CL 143-0-10-3-0-1-10 and CL 1131-0-0-38-4-0). This trial was sown June 24 and transplanted July 22 in single-row plots, each 4.8 m long, with 1.5 m between rows and 0.4 m between hills. The design was a randomized complete block with two replications. The second trial had the same number of entries evaluated against the same checks. This experiment was sown June 30 and transplanted July 26. The design and plot size of the first trial was used. Heat tolerance was evaluated using the fruit setting score system.

Results

Table 2 shows the five accessions that had fruit setting scores comparable to the check lines . Only two of the five, namely L 4841 (VC 11-3-1-8) and L 4964 (PI 427151), compared favorably with the higher fruit setting check. None of the 48 accessions in the second trial proved as heat tolerant as the checks.

Conclusions

The five promising accessions will be tested more thoroughly in 1983.

Table 2. Fruit setting scores of promising accessions and heat tolerant checks, AVRDC, 1982 summer season.

Accession or line number	Variety or code	Mean fruit setting score[z]
L 4841	VC 11-3-1-8	3.2
L 4912	PI 414171	3.0
L 4924	PI 419012	3.0
L 4964	PI 427151	4.5
L 4977	PI 432913	3.0
-	CL 143-0-10-3-0-1-10 (check)	3.8
-	CL 1131-0-0-38-4-0 (check)	4.0
LSD (0.05)		0.8
CV (%)		28.9

[z] Mean of two replicates, based on a scale of 1 to 5, 1 = no fruit or light set, 5 = very heavy set.

Yield Trials of Tropical Breeding Lines

Introduction

Breeding lines that have been selected previously for heat tolerance and bacterial wilt (BW) resistance are entered in successive hot season trials to compare their performance against the best check lines. The outstanding entries from these trials constitute the bulk of the germplasm distributed to other countries for further evaluation, release, and/or use in national breeding programs.

Materials and Methods

In 1982, six advanced tests were conducted with new lines selected from previous years tests. Some of these had ah-Tm2a genes in their pedigrees and were therefore also evaluated for tomato mosaic virus (ToMV) and BW resistance in separate nurseries through artificial inoculation methods. Three of the six trials were severely damaged by typhoon and heavy flooding. The three that survived the adverse elements were: advanced yield trial II (AYT-II), sown April 16 and transplanted May 13; AYT-IV, sown June 9 and transplanted July 5; and AYT-VI, sown July 18 and transplanted August 17. In all trials, the design was a randomized complete block with four replications. Each plot consisted of three rows, each 4.8 m long with rows and plants within rows spaced 1.5 m and 0.4 m apart, respectively. Thirteen breeding lines were compared against three common checks.

Results

In AYT-II, only one line, CL 1131-0-0-43-8-1, significantly outyielded the highest yielding check, CL 143-0-10-3-0-1-10 (Table 3). But this breeding line, which gave 14.5 t/ha marketable yield in 63 days, does not carry ToMV resistance even though one of its original parents was ah-Tm2a. Two other lines that carry ToMV resistance (gene Tm2a), CL 1131-0-0-13-0-6 and CL 1131-0-0-7-2-0, gave yields comparable to the highest yielding line although insignificantly different from that of the check. Of the two, CL 1131-0-0-7-2-0 appears more promising because of its ToMV resistance and its relatively large fruit size. Moreover, this line performed consistently well in all three tests (Tables 4 and 5).

In AYT-IV, CL 1131-0-0-7-2-0 gave the best yield and was the only line that significantly outyielded CL 143 (Table 4). It also matured

earlier although its fruit size was no better than the check's.

Table 3. Yield and other horticultural characters of promising entries from the advanced yield trial (AYT-II) of tropical breeding lines; AVRDC, summer, 1982.[z]

Entry	Yield (t/ha)		Days to maturity[x] (DAT)	Fruit set (%)	Fruit size (g)	Diseases[y]		
	Total	Marketable				SB (%)	ToMV	BW (%)
CL 1131-0-0-43-8-1	16.7 a	14.5 a	63 c	48 ab	28 c-e	14 b-f	+	13
CL 1131-0-0-13-0-6	16.1 a	13.6 ab	63 c	35 c-e	35 a-c	6 ef	Tm2a	11
CL 1131-0-0-7-2-0	13.7 a-d	12.2 a-c	64 bc	44 a-d	33 a-d	7 ef	Tm2a	15
CL 143-0-10-3-0-1-10 (check)[w]	11.9 b-d	10.2 bc	68 a	28 ef	22 e-g	30 ab	+	8
Mean of 16 entries	10.7	9.2	64	33	30	17	-	-
CV (%)	27.0	27.5	3	22	15	65	-	-

[z] Means followed by the same letters are not significantly different at P = 0.05 by Duncan's multiple range test.
[y] Based on natural disease incidence for southern blight (SB) and artificial inoculations for ToMV (strain 1) and BW (mixed strains).
[x] Maturity measured from DAT (days after transplanting).
[w] Best yielding among three check lines.

Table 4. Yield and other horticultural characters of a promising entry from the advanced yield trial (AYT-IV) of tropical breeding lines; AVRDC, summer, 1982.

Entry	Yield (t/ha)		Days to maturity (DAT)	Fruit size (g)	Diseases[z]		
	Total	Marketable			GLS?	ToMV	BW (%)
CL 1131-0-0-7-2-0	46.7 a	39.8 a	91 b	21	3 d	Tm2a	15
CL 143-0-10-3-0-1-10 (check)[y]	35.7 b	31.6 ah	98 a	24	5 c	+	8
Mean of 16 entries	27.6	23.9	95	24	4	-	-
CV (%)	25.3	26.5	1	14	16	-	-

[z] Based on natural infection for gray leafspot (GLS?) and artificial inoculations for ToMV (strain 1) and BW (mixed strain); GLS rating scale from 1 = none to 9 = severe (almost defoliated).
[y] Best yielding among three check lines.

In the late summer planting (AYT-VI), no breeding line significantly outyielded the checks (Table 5). However, CL 1131-0-0-7-2-0 and CL 1104-0-0-69-1-1 gave comparable yields. The former matured much earlier than the others.

Across the three trials, yields tended to be higher as the summer season progressed towards the cool, dry period. The fruit qualities of some entries, if not all, also improved significantly with delayed summer planting (Table 6), and compared favorably with the average figures for TK 70 grown in the cool season.

Stepwise regression analyses of variables contributing to variation in total yield (plot basis) in the above trials further reveal that

Table 5. Yield and other horticultural characters of promising entries from the advanced yield trial (AYT-VI) of tropical breeding lines; AVRDC, summer, 1982.

Entry	Yield (t/ha)		Days to maturity (DAT)	Fruit size (g)	Diseases[z]		
	Total	Marketable			GLS?	ToMV	BW (%)
CL 1131-0-0-38-4-0 (check)	55.2 a	47.4 a	73 ab	28	7.0 a	Tm2a	15
CL 1131-0-0-7-2-0	52.9 ab	45.6 ab	60 c	28	7.2 a	Tm2a	15
CL 143-0-10-3-0-1-10 (check)	52.2 ab	44.5 ab	75 a	30	2.5 c	+	8
CL 1104-0-0-69-1-1	50.3 ab	39.1 bc	75 a	25	5.2 b	Tm2a/+	10
Mean of 16 entries	43.2	36.8	66	31	3.5	-	-
CV (%)	11.8	12.2	4	10	25.9	-	-

[z] Based on natural disease incidence for gray leafspot (GLS?) and artificial inoculations for ToMV (strain 1) and BW (mixed strains).

Table 6. Quality characteristics of promising entries from advanced yield trials of tropical breeding lines; AVRDC, summer, 1982.

Entry	Hunter color	pH	°Brix	Titratable acidity	Cracking	Blotchy ripening	Blossom end rot
AYT-II							
CL 1131-0-0-43-8-1	1.4 f-h[z]	4.3 bc	5.2 e	0.46 ih	+[y]	+	+
CL 1131-0-0-13-0-6	1.4 f-h	4.2 c-e	5.2 e	0.54 d-f	+	+	+
CL 1131-0-0-7-2-0	1.7 c-e	4.0 f	4.7 g	0.65 ab	+	+	+
CL 143-0-10-3-0-1-10 (check)	1.9 a-c	4.3 bc	5.5 de	0.52 e-g	+	+	+
AYT-IV							
CL 1131-0-0-7-2-0	2.0	4.1	5.2	0.72	+	+	+
CL 143-0-10-3-0-1-10 (check)	2.4	4.2	5.6	0.50	+	+	+
AYT-VI							
CL 1131-0-0-38-4-0 (check)	1.7 f	4.1 f-i	4.4 d	0.48 b-d	+	+	+
CL 1131-0-0-7-2-0	2.4 bc	4.0 i	4.5 d	0.55 a	+	+	+
CL 143-0-10-3-0-1-10 (check)	2.2 cd	4.2 c-h	5.2 c	0.48 b-d	+	+	+
CL 1104-0-0-69-1-1	2.0 de	4.2 c-h	5.4 bc	0.38 gh	+	+	+
Cool season (TK 70)[x]	2.5	4.1	4.9	0.40			

[z] Significant difference evaluated separately for each trial.
[y] "+" means the disorder is present but intensity was not recorded.
[x] Derived from 1982 advanced yield trial of processing lines.

trials planted in late summer are of little value in screening for high temperature fruit set (Table 7). Of five variables regressed against total yield, fruit setting rate and plant stand contributed the most to total yield variation in AYT-II. R^2 for five variables was 0.53 or 53%, of which 41% was due to fruit set and 8% to stand. The variation in stand was due mainly to southern blight (r = -0.86**). In AYT-IV, R^2 for five variables was .34 or 34% of the total yield variation. Of this, 21% is due to fruit set and 8% to stand. In AYT-VI, R^2 for the

Table 7. Multiple regression of total yield with different variables in the advanced yield trials of tropical breeding lines; AVRDC, summer, 1982.

Trial[z]	R^2(%) (5 var)	Contribution (%) to variation in total yield (Y)			Regression equation[y]
		Fruit set (X_1)	Stand (X_2)	Maturity (X_3)	
AYT-II	53	41	8	nil	$Y = -3.55+.21X_1+.28X_2$
AYT-IV	34	21	8	nil	$Y = -.68+.79X_1+.86X_2$
AYT-VI	36	7	10	13	$Y = -25.05+.29X_1+1.37X_2+.36X_3$

[z] AYT-II sown 4/16, transplanted 5/13, and harvested from 7/8 to 7/29.
AYT-IV sown 6/9, transplanted 7/5, and harvested from 9/21 to 10/20.
AYT-VI sown 7/18, transplanted 8/17, and harvested from 10/19 to 11/16.
[y] Includes only the best 2- or 3- variable model.

same variables, plus one additional variable, was 0.36 or 36%. Fruit setting accounted for only 7% of the total yield variation. Stand (as affected by southern blight with r = -0.94**) and days to maturity contributed slightly more, 10% and 13%, respectively.

Conclusions

Based on the results, future trials of tropical breeding lines should not be transplanted later than July. Consideration of the most appropriate trial (AYT-II) shows that at least two lines, CL 1131-0-0-13-0-6 and CL 1131-0-0-7-2-0, may have good potential for tropical areas. These lines are now included in sets distributed to cooperators. They have also been channeled back to the breeding program to incorporate resistance to other diseases and to further improve their fruit characteristics, e.g. size, firmness, cracking, etc.

Cool Season Trials (Processing Lines)

Introduction

The cool season trial project has been an integral part of the tomato program for many years and has as its aim the search for and/or development of cultivars suitable for use by the processing tomato industry in relatively cool subtropical areas or tropical highlands.

Materials and Methods

Three sets of trials were conducted in 1982: An observational yield trial (OYT) of 47 entries compared with three leading checks; a preliminary yield trial (PYT) of 18 entries compared with two checks; and an advanced yield trial (AYT) of eight breeding lines compared with two checks. The OYT was sown in single-row plots on August 25, 1981, transplanted September 20, and harvested from December 23 to February 2,

1982. The PYT was sown in double-row plots on August 25, 1981, transplanted September 25, and harvested December 21 to January 15, 1982. The AYT was sown in four-row plots on September 11, 1981, transplanted October 8, and harvested from December 23 to February 3, 1982. In all trials, rows were 4.8 m long and spaced 1.5 m apart while hills within rows were spaced 40 cm apart. Design in all trials was randomized complete block, but the entries in the AYT were replicated three times, while the PYT and OYT were replicated twice.

Results

None of the advanced lines in the AYT significantly outperformed the checks, L 124 (TK 70) or CL 1561-6-0-5-1-3-1. CL 2749-2-2-1-1-1-0 had the highest marketable yield (84.6 t/ha) and produced significantly larger fruits (115 g/fruit) than TK 70 (70 g/fruit). It also had the lowest fruit setting rate (56%) indicating again that fruit set during the cool season is not very important in relation to yield. Because of the poor firmness of the relatively high yielding lines, none were selected for further testing.

In the PYT, no significant yield differences were observed. The three lines in Table 8 were singled out, however, for their superior firmness and/or fruit size comparable to that of the soft but large-fruited check (TK 70). Total yield was influenced mainly by stand and fruit size ($r = 0.38^{**}$ and 0.61^{**}, respectively). Again, fruit setting rate had no influence on yield.

The OYT also did not reveal any entry more outstanding than the check lines or cultivars. Some lines produced significantly larger fruits than TK 70 but fruit size variation in this trial was not important for yield. These lines also lacked fruit firmness and were eliminated accordingly.

Table 8. Yield and quality characteristics of selected entries from preliminary yield trial (PYT) of processing breeding lines; AVRDC, 1981-82 fall/winter season.

Entry	Yield (t/ha)		Size	Firmness	Quality			
	Total	Marketable	(g)		Hunter color	pH	°Brix	Titratable acidity
CL 1591-0-1-2-0	61.2	59.2	59 b	soft	2.5 b	4.1	4.4 a-c	.42 a
CL 2815-1-2-8-0	57.4	56.5	57 b	very firm	2.6 b	4.2	3.5 c	.25 f
CL 2815-1-2-3-4-0	52.8	51.1	67 a	moderately firm	2.7 b	4.1	3.9 bc	.28 ef
CL 1561-6-0-5-1-3-1 (check)	58.1	56.5	58 b	firm	2.9 a	4.2	3.9 bc	.27 ef
TK 70 (check)	56.5	53.9	63 a	soft	2.6 b	4.2	4.6 ab	.32 b-e
Mean of 20 entries	49.8	48.5	48	-	2.5	4.1	4.2	0.31
CV (%)	8	8	4	-	3	1	9	9

Conclusions

Three firm-fruited lines from the PYT and five entries from the OYT have been advanced for further evaluation.

Cool Season Trials (Fresh Market Lines)

Introduction

One AVRDC project aims to identify or develop suitable staked-type fresh market tomato lines for subtropical areas. This project was slightly expanded in 1982 to cover the tropical highlands, but does not necessarily conflict with the lowland tropics project. In terms of quality and production, the highlands are still the major tomato production areas for most tropical countries and AVRDC, as the principal vegetable research center for the tropics, has a great deal to contribute to these areas.

Materials and Methods

Nineteen entries were compared with KY 301, a fresh market hybrid commonly grown in Taiwan, in an observational trial. The entries were sown in a randomized complete block design with two replications on September 3, 1981, transplanted October 8, and harvested from December 10 to January 22, 1982. Each plot consisted of two 4.8 m long rows spaced 75 cm apart, with hills within rows spaced 40 cm apart.

Results

Two entries, CL 4805 and CL 4802, significantly outyielded KY 301 (Table 9). CL 4805 also produced fruits as large (189 g/fruit) as those of KY 301 (182 g/fruit). Fruit cracking and light green shoulder are

Table 9. Yield and other horticultural characters of selected entries from the observational yield trial of fresh market lines; AVRDC, 1981-82 fall/winter season.

Entry	Yield (t/ha)		Days to Maturity (DAT)	Fruit set (%)	Fruit size (g)	Fruit ripening[z]	Cracking
	Total	Marketable					
CL 4805	97.6 a	97.6 a	84	59	189 a	LGS	+
CL 4802	97.3 a	97.0 a	84	58	158 bc	LGS	-
KY 301 (check)	75.4 b-g	75.4 b-f	84	63	182 ab	DGS	-
Mean of 20 entries	80.8	80.7	81	72	115		
CV (%)	10	10	2	8	12		

[z] LGS = light green shoulder; DGS = dark green shoulder.

drawbacks of the high yielding entries, however. Dark green shoulder is preferred in Taiwan.

Conclusions

No entry from this trial can be considered particularly outstanding for local fresh market production.

Reaction of Tomato Mosaic Virus Resistant Genotypes to High Summer Temperatures

Introduction

In a separate experiment conducted by the AVRDC plant pathology unit, heterozygous types for $Tm2^a$ and Tm2 genes that were inoculated with tomato mosaic virus strain 1, (ToMV-1) and incubated at high temperature (32-26°C) and at lower temperature (26°C) developed mosaic symptoms.

A study was undertaken to test the behavior of ToMV resistant genotypes under natural high temperature conditions. The stabilization of ToMV resistance genes and a screening method for two-gene, (Tm/Tm2) or ($Tm/Tm2^a$), resistance type plants were sought.

Materials and Methods

F_1 seeds, which had previously been treated with trisodiumphosphate to eliminate possible seed-borne virus, were sown July 13 and seedlings were transplanted to the field on August 30 in two plots. One plot was inoculated with ToMV-1 on September 2; the other was not inoculated. ToMV symptoms were observed from September 20 and ToMV detection tests were performed four times (October 4, 10; November 9, 29).

During this trial, the maximum daytime air temperature was 35°C and the minimum was 28°C.

Results

Mosaic symptoms were observed under both inoculated and non-inoculated conditions only on plants of the susceptible line, CL 143-0-10-3-1 (Table 10). Systemic necrosis after inoculation with strain 1 was observed only on plants of the $Tm2^a/+$ and $Tm2^a/Tm2^a$ genotypes. In the detection tests, clear local lesions were observed on the leaves of Nicotiana sylvestris inoculated with leaf samples of (Tm/+.+/+), (Tm/Tm.+/+), (+/+.$Tm2^a$/+), (+/+.$Tm2^a/Tm2^a$), and (+/+.+/+) from the inoculated plot and (Tm/+.+/+), (Tm/Tm.+/+), and (+/+.+/+) from the non-inoculated plot.

Yield of ToMV infected lines in the inoculated plot was about half the yield of the same lines in the non-inoculated plot.

Table 10. Reaction of different ToMV genotypes under summer field conditions; AVRDC, 1982.[z]

Parental combination	Genotype		Inoculation		Without inoculation	
			30[y]	69	30	69
CL 143-0-10-3-1 x GCR237	Tm/+	+/+	93	93	0	89
CL 143-0-10-3-1 x Moperou	+/+	Tm2/+	0	0[N]	0	0
CL 143-0-10-3-1 x Momor	+/+	$Tm2^a$/+	53[N]	60[N]	0	0
GCR237	Tm/Tm	+/+	0	73	0	56
Moperou	+/+	Tm2/Tm2	0	0	0	0
Momor x Moperou	+/+	Tm2/$Tm2^a$	0	0[N]	0	0
Momor	+/+	$Tm2^a$/$Tm2^a$	7[N]	7[N]	0	0
GCR237 x Moperou	Tm/+	Tm2/+	0	0	0	0
GCR237 x Momor	Tm/+	$Tm2^a$/+	0	0	0	0
CSTMV-18 x GCR254	Tm/Tm	Tm2/+	0	0	0	0
GCR 237 x Mocimor	Tm/Tm	$Tm2^a$/+	-	-	-	-
IRB301-30 x GCR254	Tm/+	Tm2/Tm2	0	0	0	0
Sonatine x GCR254	Tm/+	Tm2/$Tm2^a$	0	0	0	0
Momor x Mocimor	Tm/+	$Tm2^a$/$Tm2^a$	0	0	0	0
GCR254	Tm/Tm	Tm2/Tm2	0	0	0	0
Mocimor x GCR254	Tm/Tm	Tm2/$Tm2^a$	0	0	0	0
Mocimor	Tm/Tm	Tm2/$Tm2^a$	0	0	0	0
CL 143-0-10-3-1	+/+	+/+	100[M]	100[M]	21[M]	90[M]

[z] Percent ToMV infected plants obtained via detection tests unless specified as N = necrosis and M = mosaic; both field symptoms also confirmed by detection tests.

[y] Days after inoculation with ToMV-1.

Conclusions

Field soil at AVRDC is infected with ToMV strains 0 and 1 because tomatoes have been grown successively for ten years. Crop rotation with other vegetables or paddy rice has not been effective in eliminating virus particles from the soil.

The Tm gene cannot prevent ToMV infection under Taiwan conditions. Tm2, $Tm2^a$, or two resistance genes (Tm/Tm2 or Tm/$Tm2^a$) need to be incorporated into promising AVRDC lines.

$Tm2^a$/+ and $Tm2^a$/$Tm2^a$ plants inoculated with ToMV-1 developed necrosis. This indicates that under high temperature conditions a high concentration of ToMV can induce necrosis on plants with a $Tm2^a$ resistance gene. The reaction of heterozygous $Tm2^a$ at high temperature can be utilized to screen for two-gene resistance (Tm/$Tm2^a$). The necessary condition for occurence of necrosis is temperature above 28°C and below 35°C.

Pure Line Selection for Tomato Mosaic Virus Resistance Among AVRDC Lines

Introduction

Some AVRDC lines originate from crosses with ah-$Tm2^a$ stock. However, no selection for tomato mosaic virus (ToMV) resistance was done during the breeding period. Resistant plants can be found in the population of these AVRDC lines. For example, when a ToMV inoculation test was conducted in March 1982, some plants showed no mosaic symptoms. If ToMV resistance can be fixed among these promising lines, breeding work can be shortened.

Materials and Methods

Thirteen promising lines, 50 to 100 seeds per line, were sown on November 24, 1982, in wooden flats filled with sterilized soil. Seedlings were inoculated with ToMV strain 1 (ToMV-1) on November 14, when the first true leaves had fully expanded. Symptoms were observed 15 days after inoculation.

Results

ToMV resistant plants were found in almost all of the AVRDC lines except CL 9-0-0-1-3-0 (Table 11).

No CL 1131-0-0-38-4-0 seedlings showed any mosaic or shoe string symptoms. All seedlings of this line had green stems, which are the expression of an anthocyaninless gene, linked closely with the $Tm2^a$ gene.

CL 1104-0-0-71-4-3-0 also included resistant plants. Sixty-seven percent of the seedlings showed no symptoms and 63% had green stems (anthocyaninless). None of the ah types showed mosaic symptoms.

Almost all of the nine sister lines of CL 1104-0-0-71-4-3-0 were found still segregating for resistance. No homozygous lines were found among the progenies of CL 1104-0-0-71-4-3-0. Two kinds of resistant plants were observed: Green stemmed (anthocyaninless) plants which carry the $Tm2^a/Tm2^a$ gene, and purple stemmed plants, which carry the $Tm2^a/+$ gene.

Forty-two percent of the CL 143-0-10-3-1 seedlings showed ToMV resistance. The source of resistance may be the parent VC 48-1GS or Tamu Chico III. The genotype is probably $Tm2^a$, because plants showed

resistance to ToMV-1, and the Tm2 gene was not common in the preceding breeding project.

CL 9-0-0-1-3-0 is completely susceptible to ToMV-1. Its parents, VC 11-1-2-1B and Saturn, do not carry ToMV resistance.

Conclusions

CL 1131-0-0-38-4-0 was recognized to be ToMV resistant, carrying the $Tm2^a$ gene which is closely linked with the ah (anthocyaninless) gene. Resistance was also found among the seedlings of CL 143-0-10-3-1. The probable gene for resistance is $Tm2^a$. CL 1104-0-0-71-4-3-0 and the nine related lines segregated for resistance, but ToMV resistance can be fixed among segregating lines in the next generation. CL 9-0-0-1-3-0 is susceptible to ToMV-1.

Table 11. Response of advanced breeding lines to ToMV strain 1 screening test.

AVRDC line	Parents	Mosaic or shoe string		Symptom-less (SL)		% SL
		ah+	ah	ah+	ah	
CL 9-0-0-1-3-0	(VC 11-1-2-1B/Saturn)	65	0	0	0	0
CL 143-0-10-3-1	(V 48-1GS/Tamu Chico III)	21	0	15	0	42
CL 1131-0-0-38-4-0	(VC 48-1GS/Tamu Chico III //ah-$Tm2^a$/VC 11-1UG)	0	0	0	78	100
CL 1104-0-0-71-4-3-0	(VC 9-1UG/Saturn// ah-$Tm2^a$/VC 11-1UG)	19	0	14	24	67
CL 1104-0-0-71-4-3-0-1[z]	(VC 9-1UG/Saturn//	35	0	9	10	35
" 5	ah-$Tm2^a$/VC 11-1UG)	19	0	11	3	42
" 7		14	0	14	7	60
" 9		16	0	13	14	63

[z] The seeds of lines CL 1104-0-0-71-4-3-0-(1 to 9), all included in this test, were produced from the CL 1104-0-0-71-4-3-0 plants that escaped infection in the March, 1982, screening.

Introduction of Tomato Mosaic Virus Resistance Genes into Promising AVRDC Lines

Introduction

Tomatoes are infected by many kinds of viruses, such as tobacco mosaic virus, cucumber mosaic virus, and potato virus X. Reduction in yield due to mosaic diseases can be as high as 20 to 30% in the tropics. Tomato mosaic virus (ToMV) is a major constraint.

Four strains of ToMV have been found throughout the world with qualitative pathogenicity varying from strain to strain. Dr. S. K. Green detected 58% strain 0 (ToMV-0) and 42% ToMV-1 in 223 field samples

from Taiwan in 1982. Strains 2 and 2^a have not yet been found in Taiwan.

To solve the ToMV problem in the tropics, cultivars should carry ToMV resistance genes (Tm, Tm2, and $Tm2^a$). The resistance breeding project aims to incorporate ToMV resistance genes into heat tolerant and bacterial wilt resistant tropical breeding lines and to supply new crosses or new inbred lines to other tomato breeding projects.

Materials and Methods

Over 100 ToMV resistant accessions were collected in 1981. The collection contains 18 varieties of the Tm/Tm genotype, nine varieties of the Tm2/Tm2 genotype, 15 varieties of the $Tm2^a/Tm2^a$ genotype, and three varieties of the $Tm/Tm2^a$ genotype.

This project used as recurrent parents four AVRDC tropical tomato lines and four processing tomato lines. ToMV resistance donors were:

Tm/Tm genotype	: Mobaci, GCR 237, Italian-c, 1017, CSTMV-18
Tm2/Tm2 genotype	: Moperou, IRB301-30, GCR 236, 68/41, Italian-d
$Tm2^a/Tm2^a$ genotype	: Momor, GCR 267, MR12, MR13, Italian-b, Sonatine (F_1), Delisa (F_1), 2939, L127
Tm/Tm, $Tm2^a/Tm2^a$	: Mocimor
Tm/+, $Tm2^a$/+	: Tanit (F_1), 79W177 (F_1)

AVRDC lines were crossed with ToMV resistant parents as males and F_1s and subsequent progenies were repeatedly backcrossed to the AVRDC lines. Schemes for one- and two-gene resistance breeding are shown in Figures 1 and 2. In each backcross generation, seedlings were tested by ToMV inoculation. Only symptomless seedlings were selected and planted in the field.

Screening for ToMV resistance followed the method used at AVRDC in 1981. In brief, seeds and soil were sterilized; seedlings were inoculated with ToMV strain 1 at the first true leaf stage using 0.5 ml inoculum per plant applied with cotton and carborundum; and 10 to 14 days after inoculation symptoms were observed and resistant plants were selected.

Results

A total of 113 crosses (F_1s) between AVRDC lines and ToMV resistant stocks were made in 1982 (Table 12).

Table 13. Selected F_1 combinations for the backcross program.

Recurrent parent	Donor		
	Tm2/Tm2	$Tm2^a/Tm2^a$	$Tm/Tm2^a$
CL 143-0-10-3-1	2	2	2
CL 1104-0-0-71-4-3-0	2	2	2
CL 1131-0-0-38-4-0	2	2	2
CL 1561-6-0-5-1-3	2	2	2
CL 1591-5-0-1-2-0	2	2	2

Table 14. Combining ability for mean fruit weight of F_1s between AVRDC lines and ToMV resistant stocks (g/fruit).

Female parent AVRDC lines \ Male parent ToMVR stocks		+/+ Tm2/Tm2 IRB301	Moperou	+/+ $Tm2^a/Tm2^a$ Momor	Delisa	Tm/Tm $Tm2^a/Tm2^a$ Mocimor	Tm/+ $Tm2^a/+$ Tanit
	Parent mean	57.8	79.2	60.1	71.3	56.6	-
CL 143-0-10-3-1	32.9	54.8	71.5	55.7	80.7	70.3	86.4
CL 1104-0-0-71-4-3-0	46.4	54.9	73.2	71.9	86.8	58.5	-
CL 1131-0-0-38-4-0	-	35.3	53.2	50.0	78.9	46.5	57.7
					MR12	79W177	
CL 1561-6-0-51-3	62.5	98.1	104.9	84.4	125.5	103.2	107.1
CL 1591-5-0-1-2-0	86.9	90.7	88.9	78.7	92.6	-	91.2

F_1s between AVRDC lines and Moperou (Tm2/Tm2), Momor ($Tm2^a/Tm2^a$), and Mocimor (Tm/Tm, $Tm2^a/Tm2^a$) showed hybrid vigor and better horticultural traits in the field trial (Table 14).

Only 20 backcrosses were selected from the last backcross and their seedlings were evaluated for mosaic symptoms by inoculation with ToMV strain 1. The results are presented in Table 15. Yellow mosaic symptom was observed on leaves of susceptible plants during the warm period (until November) but many shoe string and stunting symptoms were noted in the winter.

Three kinds of resistant genotypes are expected from B_1 populations. Tm2/+ will segregate from the B_1 of (AVRDC line x Moperou), $Tm2^a/+$ from the B_1 of (AVRDC line x Momor), and $Tm/Tm2^a$ from the B_1 of (AVRDC line x Mocimor).

Backcrosses with CL 143, CL 1561, and CL 1591 showed over 50% susceptibility but B_1s with CL 1104 and CL 1131 showed very low susceptibility. This was expected since, as seen in earlier inoculation tests, these lines carry the $Tm2^a$ gene.

Although CL 1104 and CL 1131 have the $Tm2^a$ gene, Tm2, $Tm2^a$, and Tm/Tm2 genes will still be introduced into them because some disadvantageous traits are associated with the ah gene.

Conclusions

For the introduction of Tm2, $Tm2^a$, Tm/Tm2 and $Tm/Tm2^a$ genes into AVRDC promising lines, only a few crosses were selected, such as AVRDC line x Moperou (Tm2/+), AVRDC line x Momor ($Tm2^a/+$), AVRDC line x Mocimor (Tm/+, $Tm2^a/+$), and GCR237 x Moperou x AVRDC line (Tm/+, Tm2/+). Resistant B_1 plants were planted in the field and B_2s are now being produced.

B_1s of CL 1104-0-0-71-4-3-0 and CL 1131-0-0-38-4-0 showed high resistance to ToMV and it was clear that both lines carried a $Tm2^a$ gene linked with an ah (anthocyaninless) gene.

Selection of Tm/Tm2 (or $Tm/Tm2^a$) resistant plants is still difficult. The occurence of necrosis on the Tm2/+ genotype is not stable. A temperature- and light-controlled facility is necessary.

Table 15. Results of screening test for resistance to ToMV strain 1 among B_1 families.

	Combination	Expected genotype and ratio				Observed ratio		Chi square test	Probability
		Tm/Tm2 (or $Tm2^a$)	Tm/+	+/Tm2 (or $Tm2^a$)	+/+	Mosaic	Symptomless		
I.	AVRDC line x F_1 Tanit	1	1	1	1	64	36	18.1	0.001
	AVRDC line x F_1 79W177	1	1	1	1	69	31	50.2	0.001
II.	B_1 (CL 143 x Moperou)	0	0	1	1	49	51	0.01	0.9
	B_1 (CL 143 x Momor)	0	0	1	1	64	36	6.5	0.01-0.001
	B_1 (CL 143 x Mocimor)	1	1	1	1	62	38	5.5	0.02-0.01
	B_1 (CL 1104 x Moperou)	0	0	1	1	23	77	24.6	0.001
	B_1 (CL 1104 x Momor)	0	0	1	1	37	63	4.9	0.05-0.02
	B_1 (CL 1104 x Mocimor)	1	1	1	1	18	82	33.8	0.001
	B_1 (CL 1561 x Moperou)	0	0	1	1	57	43	2.0	0.2-0.1
	B_1 (CL 1561 x Momor)	0	0	1	1	60	40	1.7	0.2-0.1
	B_1 (CL 1591 x Moperou)	0	0	1	1	66	34	9.0	0.01-0.001
	B_1 (CL 1591 x Momor)	0	0	1	1	94	6	70.5	0.001
III.	GCR237/Moperou/CL 143	1	1	1	1	52	48	0.06	0.9-0.8
	GCR237/Moperou/CL 1104	1	1	1	1	61	39	4.1	0.05-0.02
	GCR237/Moperou/CL 1561	1	1	1	1	12	88	18.9	0.001
	GCR237/Moperou/CL 1591	1	1	1	1	46	54	0.2	0.7-0.5
IV.	B_1 (CL 1131 x Moporou)	0	0	1	0	1	99	0.01	0.9
	B_1 (CL 1131 x Momor)	0	0	1	0	2	98	0.04	0.9-0.8
	B_1 (CL 1131 x Mocimor)	1	0	1	0	0	100	0.00	0.9

Heat Tolerance and the Effect of Hormones on Tomato Mosaic Virus Resistant F_1s and Their Parents

Introduction

In this trial, the heat tolerance and other horticultural traits of ToMV resistant F_1s were observed in the hot summer season.

AVRDC tropical tomato lines set many fruits during the hot season. Unfortunately, productivity is depressed by their small size. At present, an exceptionally high yielding, heat tolerant, wilt resistant variety has not yet been bred. For the time being, utilization of plant hormones can be considered for increasing fruit set and size under high temperature conditions. The effect of plant hormones on fruit setting was accordingly studied and the practicality of their use was considered.

Materials and Methods

Twenty F_1 crosses between AVRDC lines (tropical lines CL 143, CL 1104 and CL 1131 and processing lines CL 1561 and CL 1591) and ToMV resistant materials (Tm2/Tm2: IRB 301-30 and Moperou; $Tm2^a/Tm2^a$: Momor, Delisa, and MR12; and Tm/Tm, $Tm2^a/Tm2^a$: Mocimor) were compared with their parental stocks for fruit set and other horticultural traits.

Seeds were sown on June 20 and the seedlings were transplanted to the field on July 22.

Tomatotone (5% P-chlorophenoxyacetic acid, diluted 100 times) was applied to clusters when 60% of the flowers in the cluster had bloomed. Two plants of each line or F_1 were treated with Tomatotone and four plants were left untreated. Tomatotone was sprayed every three to four days from August 2 until the middle of September. A total of five clusters per plant were treated.

Results

Tropical tomatoes CL 143 and CL 1131 set many fruits under high temperature. Processing tomatoes and ToMV resistant materials showed very poor fruit setting. The F_1s of tropical lines and ToMV resistant stocks showed higher fruit setting than other F_1s or their parents.

The fruit size of tropical tomatoes was small (30 to 40 g) while the fruit size of ToMV resistant materials and processing tomatoes was larger (60-90 g). The fruit size of F_1s of tropical lines crossed with ToMV resistant stocks was moderate (40-65 g). On the other hand, F_1s of

ToMV resistant stocks crossed with processing lines had the largest fruits (90-100 g).

The Tomatotone treatment was observed to have an appreciable effect on the number and weight of fruits of all lines except CL 143 (Tables 16 and 17). Generally, average fruit weight was increased 10 to 40% by the hormone treatment. The increase was pronounced among heat sensitive lines and their F_1s. In general, the F_1s of CL 143 and ToMV resistant materials showed better performance than other F_1s.

Table 16. Effect of Tomatotone on fruit weight (g/plant) of F_1s and parents.

			Male parents						F_1
			IRB301-30	Moperou	Momor	Mocimor	Delisa	MR12	Mean
Female parents	Without (W) or with (T) Tomatotone	Line \ Line mean	58	173	136	183	800	0	(137.5)
		mean	843	1583	1622	2150	2210	248	(1549.5)
CL 143	W	1415	970	337	385	768	185	-	615.0
	T	1795	1945	3325	2340	2110	2180	-	2430.0
CL 1104	W	327	70	298	400	260	100	-	257.0
	T	2065	1565	1940	1330	1725	1650	-	1640.0
CL 1131	W	-	50	428	268	395	145	-	285.3
	T	-	1770	820	950	1860	710	-	1350.0
						Tanit			
CL 1561	W	0	50	160	125	260	-	70	148.8
	T	3680	1570	2465	1688	1660	-	1438	1846.0
						Tanit			
CL 1591	W	150	168	0	168	23	-	0	89.8
	T	2780	2450	1555	1770	2370	-	880	2036.0
F1 mean	W	(470.5)	261.6	244.6	269.2	341.2	143.0	35.0	
	T	(2580.0)	1860.0	2021.0	1616.0	1945.0	1513.3	1159.0	

Corresponding F_1 means are enclosed by broken lines.

Table 17. Effect of Tomatotone on the number of fruits per plant of F_1s and parents.

	Male parent		IRB301-30	Moperou	Momor	Mocimor	Delisa	MR12	F_1 mean
Female parents	Without (W) or with (T) Tomatotone	Line \ Line mean	1.0	3.0	2.0	3.0	11.0	0	(2.3)
		mean	15.0	20.0	27.0	38.0	31.0	2.0	(25.0)
CL 143	W	50.3	17.3	6.0	5.3	15.8	2.5	-	11.1
	T	54.5	35.5	46.5	42.0	30.0	27.0	-	38.5
CL 1104	W	9.0	1.3	6.0	6.0	4.6	1.7	-	4.5
	T	44.5	28.5	26.5	18.5	29.5	19.0	-	25.8
CL 1131	W	-	1.5	8.8	5.0	12.3	3.0	-	6.9
	T	-	32.0	15.5	19.0	40.0	9.0	-	21.3
						Tanit			
CL 1561	W	0	1.0	1.5	1.0	5.0	-	0.7	2.1
	T	59.0	16.0	23.5	20.0	15.5	-	11.5	18.8
						Tanit			
CL 1591	W	2.4	1.7	0	2.0	0.3	-	0	1.0
		32.0	27.0	17.5	22.5	26.0	-	9.5	23.3
F_1 mean	W	15.4	4.6	4.5	3.9	7.6	2.4	0.4	
	T	47.5	27.8	25.9	24.4	28.2	18.3	10.5	

Conclusions

F_1s of crosses between tropical tomatoes and ToMV resistant stocks set more fruits than the ToMV resistant and heat sensitive parents, but these fruits had little commercial value because of their small size. Tomatotone treatment accelerated fruit setting and increased yield remarkably. The F_1 crosses with CL 143 performed especially well under this treatment. Tomatotone appears highly efficient for yield enhancement of good F_1 combinations with disease resistance, heat tolerance, and hybrid vigor.

Evaluation of AVRDC and Introduced Processing Tomato Lines

Introduction

A new project was begun in fall, 1982, to develop processing tomato cultivars. This project, which will be funded by the ROC Government from July 1, 1982 to June 30, 1985, is aimed at incorporating resistance to diseases such as tomato mosaic virus (ToMV), nematode, and bacterial wilt into AVRDC or local processing cultivars, developing firm fruited and uniformly maturing cultivars, and extending the production seasons by developing cultivars that have some degree of heat resistance.

For fast progress, the development of F_1 hybrids is necessary. Trials were conducted in fall, 1982 to identify elite inbred lines for use as parental materials. Large and firm fruit, early and uniform maturity, superior yield, and compact plant type were sought. Trials were also aimed at evaluating current AVRDC and introduced processing tomato cultivars. The Center already has materials for ToMV, bacterial wilt, and heat resistance, and some of these can be used in the hybridization program without further improvement. A third goal of the trials was to purify AVRDC parental stocks.

Materials and Methods

Three separate trials were conducted.

AVRDC selections: Nine advanced and 23 preliminary AVRDC selections were transferred to the processing tomato program and were evaluated against the local check, TK 70, in observational trials from September 17 to December 20, 1982. All lines were inoculated with bacterial wilt at the seedling stage to reevaluate their resistance.

Introduced processing cultivars: Forty-seven cultivars or breeding lines newly introduced from the USA, New Zealand, South America, and Europe were divided into five groups and evaluated from October 8, 1982 to January, 1983 in a replicated trial.

Parental lines: Another 55 potential parental lines were selected from the Center's germplasm collection based on the specific characteristics needed in the hybridization program. These materials were evaluated in a non-replicated trial in the cool season. All of the off-type plants were rogued in order to purify parental stocks. Fruits were harvested in three pickings at 10 to 14 day intervals. The marketable fruit ratio could be used as an indication of the plants' retention of fruit. Reactions to ToMV and nematode were recorded based on field observations without artificial inoculation, while bacterial wilt resistance was evaluated by the clipping method at the seedling stage.

Results

AVRDC selections: Of the advanced lines, CL 2728-0-3-2-2 was identified as the best of all entries in terms of marketable yield, fruit size, and reaction to bacterial wilt (Table 18). Two other lines, CL 2736-0-2-1-6 and CL 2816-2-2-1-1-0-9, also appeared satisfactory, but their fruits were small.

Of the preliminary lines, CI 2729-1-1-5-5-0-4 exhibited the best yield, resistance, and fruit set. Fruits of this line were too small, however, and also too soft.

Introduced cultivars: In the first group of elite lines, Kagome's TK-10 and TK-11, Known-you's KY 209, and AVRDC's CL 1561-1 (recently released as processing cultivar Tainan Selection No. 2 in Taiwan) provided good yield and acceptable firmness (Table 19). All are susceptible to ToMV. CL 1561-1 is a good source for large fruit and firmness. KY 209 has small to medium fruit but because of its small stem scar it is suitable for whole-peel tomato processing. CL 1561-1 is probably not suitable for intercropping because of its large plant size.

In the second group, Goldsmith cultivar GS 12 gave the highest yield. Ben Sheffer also had good yield, with large, firm fruit and good fruit set. Hypeel 229 had small fruits but excellent fruit set and uniform maturity. Castle Rock is a good source of firmness and large fruit, although its fruit set was not good. Castle Long and Euromech

are good sources of firmness and uniform maturity, although the former gave low yield and was very susceptible to diseases. Goldsmith's GS 372, a fresh market cultivar, is the only one of these cultivars that exhibited resistance to ToMV.

In the fourth group, all UC lines can be good sources of firmness. UC 134-1-2 was noted for its high market ratio.

In the fifth group, CIAR-5 stands out for its very large fruits and high market ratio. It will likewise be a good source of firmness and early maturity.

Conclusions

AVRDC selections carry some degree of bacterial wilt resistance but the fruit size, plant type, and firmness of all except CL 1561-1 must be improved. Some selections also require improvement for plant vigor.

Most of the introduced and AVRDC cultivars do not carry ToMV and nematode resistance. These characteristics can be incorporated by producing F_1 cultivars.

Elite parental lines were selected for improving the horticultural traits of the AVRDC lines that will be used as resistance sources. Hybridization and combining ability tests will be conducted in 1983.

Table 18. Performance of advanced AVRDC processing tomato selections.[z]

AVRDC selection or accession no.	Marketable yield (t/ha)	Fruit size (g)	Marketable ratio	Firmness[y]	Reaction to bacterial wilt[x] (% wilt)
CL 2797-1-1-5-5-0-9	47.8 a	57.9 ab	0.906 ab	S-M	41.6
CL 2728-0-3-2-2	43.3 a	67.3 ab	0.881 ab	S	1.0
CL 2736-0-2-1-6	42.5 a	52.2 ab	0.846 ab	S	31.2
CL 2816-2-2-1-1-0-1	42.0 a	73.4 ab	0.914 ab	S-M	39.6
CL 2816-2-2-1-1-0-9	39.9 a	53.7 ab	0.933 a	M	39.6
CL 2797-1-1-5-5-0-4	36.4 a	74.7 ab	0.809 ab	F	36.4
CL 1561-6-0-5-1-3-2	34.3 a	49.1 b	0.780 b	F	70.8
CL 2736-0-2-1-5	32.0 a	79.2 ab	0.908 ab	S	30.2
CL 2787-3-2-3-5	31.3 a	50.1 ab	0.770 b	M	62.5
L 124 (TK 70)	38.0 a	82.9 a	0.787 ab	S	58.3

[z] Transplanted on September 21, 1982 and harvested from December 13, 1982 to January 12, 1983, replicated twice.
[y] S = soft, M = moderately firm, F = firm.
[x] Inoculated on September 10, 1982, in seedling flats.

Table 19. Performance of introduced processing tomato lines, AVRDC, 1983.[z]

Cultivar or accession no.	Marketable yield (t/ha)	Fruit size (g)	Marketable ratio	Firmness[y]
GROUP I				
TK 10	46.9 a	90.8 a	0.843 ab	S-F
TK 11	44.4 a	90.5 a	0.853 ab	S-F
Known You 209	43.4 a	55.5 c	0.784 ab	S-F
CL 156-2	42.2 a	68.0 cb	0.644 c	S-F
CL 1561-1	39.9 a	78.1 ab	0.629 c	F
Wei Chen #1 CL 1561-6-0-8-3-4	37.6 a	64.1 cb	0.855 a	S
Yeng Mei #3 CL 1591-5-0-1-7-6	36.9 a	81.1 ab	0.807 ab	S-F
TK 70 (check)	39.5 a	88.3 a	0.758 b	S
GROUP II				
GS 28	48.5 a	90.2 d	0.810 abc	F
Ben Sheffer	46.3 ab	114.4 c	0.786 abcd	F
Hypeel 229	42.6 ab	53.9 e	0.900 ab	F
GS 12	42.1 ab	114.0 c	0.908 ab	F
Castle Rock	41.9 ab	118.1 c	0.789 abcd	F
Euromech	35.9 abc	69.7 e	0.872 ab	F
GS 372	35.0 abc	213.2 a	0.506 e	S-F
GS 393	34.3 abc	193.4 b	0.694 abcd	F
Andino	26.8 bc	82.4 d	0.557 ecd	F
Castle Long	26.4 dbc	55.8 e	0.954 a	F
Early pak 7	21.3 dc	122.4 c	0.638 bcd	S-F
BSI-80	6.3 d	185.1 b	0.276 e	S-F
TK 70 (check)	37.5 abc	80.7 d	0.802 abc	S
GROUP IV				
VF 315	56.5 a	82.9 ab	0.769 ab	F
UC 134-61-D	54.7 ab	76.0 abc	0.759 ab	F
Keystone No. 3032	51.4 ab	72.3 bc	0.690 b	F
UC 134-1-2	46.1 abc	71.0 bc	0.844 ab	F
145B-7879K-3	42.9 abc	84.4 ab	0.673 b	F
VF 198	42.4 abc	69.7 dbc	0.677 b	F
UC 82-B	40.5 abc	66.3 dbc	0.702 b	F
Keystone AV x 5715	38.1 abc	63.8 dc	0.740 ab	F
Murrieta	37.9 abc	75.7 abc	0.700 b	F
Triumph	36.2 bc	67.8 dbc	0.895 a	F
Keystone No. 6203	27.8 c	52.4 d	0.899 a	F
TK 70 (check)	45.7 abc	92.3 a	0.849 ab	S
GROUP V				
Early Stone	47.3 a	89.7 b	0.833 abc	F
Napoli-VF	46.6 ab	48.8 d	0.676 d	F
CIAR-3	41.3 abc	74.7 bc	0.822 abc	F
CIAR-5	39.6 abc	113.1 a	0.947 a	F
Peloro	37.0 abc	51.3 d	0.695 dc	F
Titano-M	30.7 bc	55.7 dc	0.704 dc	F
Deneb	30.5 bc	38.0 d	0.679 d	F
Bull	30.1 c	50.0 d	0.925 ab	F
TK 70 (check)	49.1 a	82.3 b	0.790 dbc	S

[z] Transplanted on October 8, 1982 and harvested from December 30, 1982 to January 1983, replicated two times.

[y] S = soft, F = firm.

Selection and Evaluation of Parthenocarpic Tomatoes

Introduction

The use of naturally occuring parthenocarpy is a new approach in developing tomato cultivars for use under adverse conditions. For example, this simply inherited trait has recently been used in Europe to overcome low temperature constraints. An experiment was conducted at AVRDC during the 1981-82 cool and warm seasons to verify the potential for the use of parthenocarpy in tropical areas.

Materials and Methods

Seven parthenocarpic breeding lines and cultivars plus a seeded (non-parthenocarpic) check, VC 134-1-2, were planted without replication on October 19, 1981, for cool season observation, and 14 parthenocarpic tomato lines plus an AVRDC heat tolerant check, CL 1131-0-0-38-4-0, were planted from May 28 to July 27, 1982, for hot season observation.

Sixty-two F_1, F_2, and F_3 families derived from two parthenocarpic sources (pat and pat-2) were planted first on May 28 and then on September 20, 1982, for single plant selection and generation advance.

Results

Cool season trials: The amount of seedless fruits ranged from 30.7 to 74.1% in all parthenocarpic materials, whereas 7.2% of the control's fruits were seedless (Table 20). There was no significant correlation between the total fruit number and the degree of seedlessness; i.e., seedlessness neither increased nor decreased the fruit set of these tomatoes under favorable conditions.

Although there were differences in the degree of seedlessness in these lines, none of the lines were 100% seedless. It may therefore be possible to multiply genetic parthenocarpic materials in Taiwan's cool season.

Hot season trials: The parthenocarpic lines had fruit set as high as or higher than the check cultivar in the hot season trials (Table 21). The higher fruit set in seedless lines was probably due to better tolerance to rain, as these lines set fruit without requiring pollination.

Seven lines in this trial were 100% seedless, illustrating the difficulties in selecting heat tolerant materials with parthenocarpic

traits, as the only way to propagate these materials is to take vegetative cuttings.

Single plant selections: Elite single plants were selected from the F_2 and F_3 populations and were advanced to the F_3 or F_4 generation in the 1982 cool season.

Conclusions

Parthenocarpy can probably be used to increase the degree of heat tolerance in tropical tomatoes. Parthenocarpic lines set a comparable or higher number of fruits under AVRDC summer conditions, especially higher than other lines during rainy periods.

Several problems should be solved in order to utilize this particular trait in the tomato breeding program. First, poor vigor is associated with parthenocarpic set. It will be difficult to select seedless indeterminate-type tomatoes. Also, the expression of parthenocarpy under different environments must be studied. The most adequate environments must be found for multiplication and for selection for heat tolerance. More studies should be conducted to better understand the mechanism of parthenocarpic fruit set under favorable and unfavorable conditions. It must be found how and to what degree parthenocarpy could contribute to fruit set in order to utilize these genes in AVRDC tomato breeding programs.

Table 20. Total fruit number and percent seedless fruit of parthenocarpic tomato lines planted in the cool season.[z]

Variety	Total fruit no.	Seedless fruit (%)
Oregon Cherry F_4	29.1 a	74.1 a
Oregon Cherry F_4 (selected)	30.0 a	71.9 a
S 4-0-0	28.9 a	71.1 a
Ventura	29.0 a	56.0 ab
Severianin	23.6 b	55.8 b
pat-ps-c	30.0 a	48.9 bc
pat-ps	24.0 b	30.7 c
UC 134-1-2 (check)	30.0 a	7.2 d

[z] Transplanted at AVRDC on October 19, 1981.

Table 21. Total fruit number, percent fruit set, and percent seedless fruit of parthenocarpic tomato lines planted in the hot season.[z]

Variety	Fruit set (%)	Total fruit no.	Seedless fruit (%)
(S x Red Cherry) F_5 (A)	58.6 a	13.1 abcd	100.0 a
(S x Tiny Tim) F_5	54.5 ab	2.8 de	100.0 a
(S x Red Cherry) F_5 (B)	47.9 abc	8.0 bcde	100.0 a
(*pat* x *pat-2*)-2 F_3	47.6 abc	12.0 abcde	100.0 a
(*pat* x *pat-2*)-3 F_3	11.2 e	2.3 e	100.0 ab
S 4-0-0-0-0-0 (A)	39.6 abc	6.6 cde	98.9 ab
S 4-0-0-0-0-0 (B)	43.5 abc	10.9 abcde	97.5 ab
Oregon Cherry Select	12.4 de	16.7 ab	88.2 ab
(*pat* x *pat-2*) F_2	29.2 cde	4.8 cde	83.3 ab
(*pat* x *pat-2*)-1 F_3	25.5 cde	4.7 cde	62.5 bc
(*pat* x *pat-2*)-12 F_3	34.9 bcd	4.2 de	50.3 c
Ventura	45.6 abc	6.0 cde	38.4 dc
(*pat* x *pat-2*)-7 F_3	25.1 cde	4.1 de	31.3 cde
CL 1131-0-0-38-4-0 (check)	30.5 bcde	17.7 a	12.3 de
Oregon Cherry	40.2 abc	14.0 abc	10.1 e

[z] Transplanted at AVRDC on May 28, 1982.

Tomato Pathology

Tomato Mosaic Virus Strain Detection in Tomato and Other Solanaceous Crops in Taiwan

Introduction

A survey for strains of tomato mosaic virus (ToMV) was initiated in fall 1980 with the aim of using naturally occurring ToMV strains for resistance screening. The survey was continued through 1982.

Materials and Methods

In 1982, 295 tomato leaf samples were collected from Taiwan's major tomato growing areas. In addition, 21 leaf samples were collected from sweet pepper and chili pepper and one sample from black nightshade (Solanum nigrum). ToMV was isolated from field samples according to the scheme outlined in Figure 1.

Strain typing of ToMV isolates was carried out according to Rast's method, using the differential host reaction on Lycopersicon esculentum cultivars GCR (+/+), CSTMW-18 (Tm-1/Tm-1), Perou 2 (Tm-2/Tm-2), and Delisa ($Tm\text{-}2^2/Tm\text{-}2^2$).

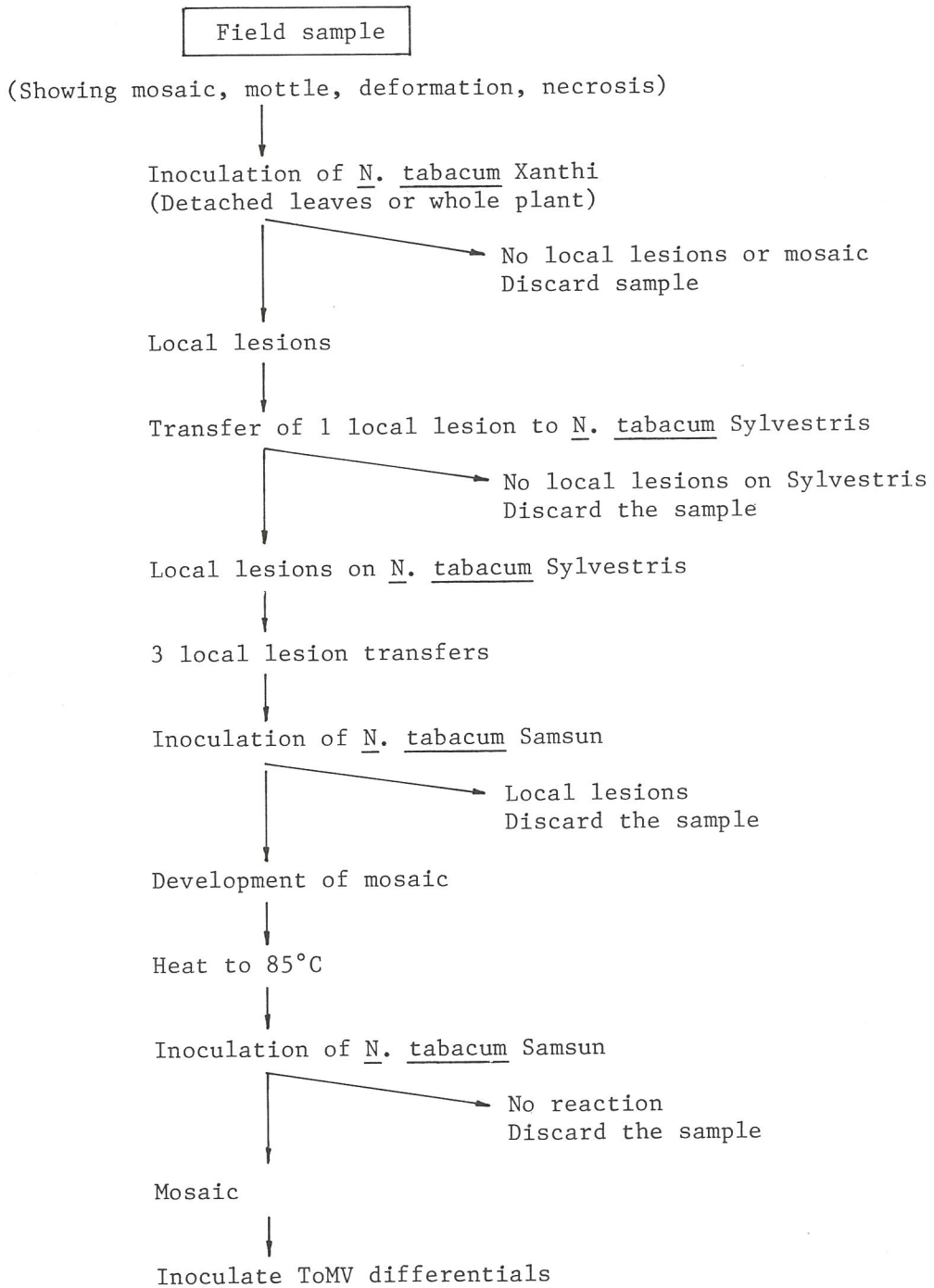
Results

The results are presented in Table 1. The five isolates suspected to be strain ToMV-2^2 in 1981 were retested and were found to be ToMV-1. The symptoms on Delisa (stunt, mosaic necrosis, excessive proliferation) are presumed to have been caused by ToMV-1 infecting a few odd Delisa plants that were heterozygous for $Tm\text{-}2^a$ instead of homozygous ($Tm\text{-}2^a/Tm\text{-}2^a$).

In 1981 ToMV-1 was found more frequently than ToMV-0. When a larger sample size had been processed by the end of 1982, however, it was found that ToMV-1 and ToMV-0 were present in almost equal proportions, meaning that ToMV-0 and ToMV-1 are the two most common ToMV strains on tomato in Taiwan. ToMV strain 2^a was not detected.

Three isolates produced mild mosaic on L. esculentum Perou 2 (genotype Tm-2/Tm-2) and yellowing, mosaic, and leafcurl on Moperou

Figure 1. Isolation of tomato mosaic virus (ToMV) from field samples.



(genotype Tm-2/Tm-2). These isolates originated from tomato field samples suspected to be infected with both ToMV and leafcurl. The samples were grafted on ToMV-0 and ToMV-1 resistant Delisa (genotype $Tm2^2/Tm2^2$), Perou, and Moperou (both of genotype Tm2/Tm2) to obtain

Table 1. Survey for naturally occurring tomato mosaic virus (ToMV) on tomato in Taiwan (1981-82).

	1981	1982	1981+1982
Counties surveyed	10	10	10
Counties where ToMV was detected (on fresh leaf samples)	10	10	10
Leaf samples collected (fresh market and processing tomatoes)	467	295	762
Samples tested for ToMV (local lesion formation on N. tabacum Sylvestris)	345	242	587
Samples containing ToMV	158/345	85/242	243/587 (41%)
Samples strain typed	138/345	85/242	223/587 (38%)
Samples containing ToMV-0	59/138	53/85	112/223 (50%)
Samples containing ToMV-1	74/138	29/85	108/223 (48.5%)
Samples containing ToMV-2_2	0/138	3/85	3/223 (1.5%)
Samples containing ToMV-2^2	(5)[z]/138	0/85	0/223 (0%)

[z] The five ToMV isolates identified as ToMV-2^2 in 1981 on the basis of necrosis producted on L. esculentum Delisa were retested in 1982 and found to be ToMV-1.

plants with leafcurl only. However, all Perou and Moperou plants developed mosaic. These grafts were then processed according to the scheme outlined in Figure 1. Final inoculation of the four ToMV differentials after three local lesion transfers on Nicotiana tabacum Sylvestris and subsequent heating to 85°C gave evidence of the presence of ToMV-2 in the original field samples. This finding was confirmed by Dr. B. Rast of the Glasshouse Crops Research Institute in Naaldwijk, Holland.

ToMV was also found in four of the 21 sweet pepper and chili pepper samples. Three samples contained ToMV-1 and one contained ToMV-0. ToMV-0 was also detected in Solanum nigrum.

Conclusions

So far ToMV strains 0, 1, and 2 have been detected on tomato in Taiwan. ToMV-0 and ToMV-1 are the two most common strains. ToMV-2 is present also, but apparently in such low concentrations that it can only be detected by passage through tomato hosts possessing the Tm-2/Tm-2

gene. All strains are now being maintained and propagated for screening purposes.

When breeding for stable resistance to ToMV in tomato under tropical and subtropical conditions, the Tm-2 and $Tm-2^2$ genes for resistance should be incorporated into breeding materials together with Tm-1 in the homozygous condition.

Detection of Tomato Mosaic Virus in Tomato Seeds

Introduction

Since tomato mosaic virus (ToMV) is a seed transmitted virus, infected seed was suspected to be one of the sources contributing to high incidence of this disease in tomato plantings. In this study seeds from several commercial seed companies and AVRDC were checked for the presence of ToMV.

Materials and Methods

Seed samples of 23 tomato cultivars were collected from four of the major commercial seed companies and AVRDC. From each cultivar 4 x 100 seeds were ground in 10 ml 0.1 M phosphate buffer pH 7.2. Two half-leaves of Nicotiana tabacum Xanthi were inoculated with the homogenate of each 100-seed sample. Local lesion formation was an indication of the presence of ToMV.

One local lesion from each seed sample was transferred to N. tabacum Sylvestris and strain typed by Rast's method.

Results

The results are shown in Table 2. ToMV was found in 19 of 23 samples. Seven cultivars produced more than 50 local lesions on each of the inoculated half-leaves of N. tabacum Xanthi, indicating strong contamination with ToMV. Strain typing of 19 ToMV single local lesions revealed ToMV-0 in 11 and ToMV-1 in eight of the samples.

Seed Treatments to Eliminate Seed Borne Tomato Mosaic Virus and the Long-Term Effect of Heat Treatment on Germination

Introduction

In this study, two seed treatments that did not reduce germination in a 1981 study (78°C dry heat for two days and 12.5% trisodium

Table 2. Occurrence of ToMV on commercial and AVRDC seeds.

Seed source	Cultivar	No. of local lesions produced on half-leaves of of N. tabacum Xanthi							
		Seed sample[z] 1		Seed sample 2		Seed sample 3		Seed sample 4	
A	1	++[y]	++	11	13	13	8	++	++
	2	++	++	++	++	++	++	++	++
	3	-	-	6	11	8	7	1	2
	4	43	36	2	35	++	++	++	++
	5	++	++	++	++	++	++	21	11
	6	1	8	24	21	16	6	7	2
	7	-	-	-	-	-	2	-	1
	8	++	++	++	++	++	++	++	++
B	1	1	-	2	4	1	2	2	6
	2	5	4	-	-	-	1	-	-
	3	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-
	5	-	-	11	-	-	-	-	-
C	1	19	6	8	8	28	39	23	35
	2	4	1	++	12	++	++	22	10
	3	7	6	28	15	27	19	36	++
D	1	-	1	-	-	-	-	-	1
	2	-	1	1	-	-	-	1	1
	3	1	9	1	1	1	2	-	-
E	1	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	1
	3	-	-	-	-	-	-	-	-
	4	2	6	1	-	2	-	17	5

[z] One seed sample consisted of 100 seeds.
[y] More than 50 local lesions produced on one half-leaf of N. tabacum Xanthi.

phosphate soak for 20 minutes) were compared for their ability to eliminate seed borne tomato mosaic virus. Also, the germination rate of the heat-treated seeds was tested at various intervals up to 48 weeks after the treatment.

Materials and Methods

Three tomato cultivars - varieties one, two, and eight of seed source A - that had been found heavily infected with ToMV in a previous test were chosen. Four 100-seed lots of each variety were soaked for 20 minutes in 12.5% trisodium phosphate and rinsed thoroughly in sterile distilled water. Four other seed lots were brought to a moisture content of 5-6% and heated at 78°C (dry heat) for two days.

Following the treatments, each 100-seed lot was ground up in 10 ml

phosphate buffer pH 7.0 and inoculated to two leaves of Nicotiana tabacum Xanthi. Local lesion formation indicated the presence of ToMV.

To test the long-term germination rate of heat-treated tomato seeds, seeds of variety TK-70 were brought to a moisture content of 5-6% and heated at 78°C for two days. Following the heat treatment the seeds were cooled to room temperature for three days and sealed in small foil packets of 200 seeds each. The germination rate was measured at various intervals in a petri dish and/or in the soil. The germination rate in the petri dish was measured by the standard ISTA germination test (30°C moist chamber, observation for 21 days).

Results

The results are shown in Tables 3 and 4.

Conclusions

Heat treatment (78°C dry heat for two days) eliminates ToMV on tomato seeds but soaking in 12.5% trisodium phosphate for twenty minutes is ineffective.

Heat treatment of 78°C dry heat for two days does not significantly reduce the germination rate of tomato seeds in a petri dish, even when the seeds are stored for 48 weeks following the treatment.

When heat treating a large amount of seeds, two points should be carefully observed: The seeds should have a moisture content of 5-6% or less, and they should be placed in the oven in a thin layer not deeper than 1 cm to ensure even heating and to prevent buildup of moisture.

Table 3. Efficency of seed treatments for the elimination of seed borne ToMV on tomato seeds.

	No. of local lesions on N. tabacum Xanthi			
	Seed lot A (100 seeds)	Seed lot B (100 seeds)	Seed lot C (100 seeds)	Seed lot D (100 seeds)
Na_3PO_4 for 20 minutes				
Variety 1	50[z]	2	0	0
Variety 2	12	50	1	0
Variety 8	0	0	0	0
Dry heat (78°C) for two days				
Variety 1	0	0	0	0
Variety 2	0	0	0	0
Variety 8	0	0	0	0

[z] Mean of two inoculated leaves of N. tabacum Xanthi.

Table 4. Effect of heat treatment (78°C/2 days) on the long-term germination rate of three tomato cultivars.

Time[y]	Germination rate[z]					
	CL 1131-0-0-52-3		CL 2729-0-2-1-6		TK-70	
	heat	no heat	heat	no heat	heat	no heat
1 P	92 ab[x]	93 ab	97 abc	97 a	82 bcde	82 cb
4 P	91 ab	91 bc	99 abc	98 a	86 abc	87 b
8 P	92 ab**	96 a	100 a	99 a	90 a	94 a
12 P	91 abc	97 a	100 a	99 a	88 ab	87 b
20 P	95 a	93 ab	99 ab	96 a	85 abcd	85 cb
S	89 abc	81 fe	89 de	81 d	67 g	69 e
28 P	92 ab	88 cd	97 abc	97 a	81 cde	83 bc
S	85 cd	83 de	94 bcd*	81 d	77 ef	73 de
40 P	89 abc	86 cd	97 abc	96 a	97 def	79 cd
S	82 d	78 f	91 de*	85 cd	78 def	77 cd
48 P	87 bcd	87 cd	93 cd	91 b	78 ef	79 cd
S	88 bc**	67 g	88 e	88 bc	72 fg	68 e

[z] Mean % germination of 4 x 100 seeds, measured by ISTA recommended germination test (30°C, moist chamber, observation for 21 days).

[y] Weeks after heat treatment.
P = germination rate measured in petri dish.
S = germination rate measured in soil.

[x] Means in each column followed by the same letter are not significantly different (P = 0.05) by DMRT. * and ** significance is relative to the no heat treatment.

Detection of Tomato Mosaic Virus in Agricultural Soils

Introduction

Tomato mosaic virus (ToMV) is known to survive for a long time in the soil on infected plant debris. Most soil survival studies have been conducted in Europe and the United States, which have different climatic patterns and crop successions than Taiwan. The purpose of this investigation was to see how many months after the tomato harvest ToMV could still be detected in agricultural soils in Taiwan.

Materials and Methods

Soil samples were taken from 41 fields at various locations in Tainan County where tomatoes were either growing at the time of sampling or had been grown at various times prior to sampling. From each field, soil was collected at three to five randomly selected sites, depending on the size of the field. At each site five subsamples were taken up to a depth of 20 cm. Each subsample was crushed, shaken vigorously in 0.1 M phosphate buffer pH 7.2, and inoculated on two half-leaves of Nicotiana tabacum Xanthi. Local lesion formation indicated the presence of ToMV. From five samples, two local lesions were further processed

for strain identification according to Rast's method, using the four differential Lycopersicon esculentum cultivars.

Results

The results are shown in Table 5. ToMV was detected in sixteen fields where tomatoes were either growing at the time of sampling or had been harvested up to five months prior to sampling. ToMV could also be detected in the soil when the tomato crop had been followed by a rice crop. The five samples processed for strain identification were found to contain either ToMV strain 1 or strain 0 or both.

Conclusions

Infestation of agricultural soils with ToMV seems common. It was surprising, however, to find ToMV even in those fields where a tomato crop had been followed by rice. To reduce soil borne ToMV infection, two tomato crops should not be planted consecutively. Possibly two crop cycles of a non-solanaceous crop should be grown between tomato crops for a period of at least six months.

Table 5. Survival of ToMV in the soil at cropping time and after the tomato harvest.

Total number of fields surveyed	41
Number of fields where ToMV was detected	
- at cropping time	7/8
- 1 month after harvest	2/3
- 2 months after harvest	1/3
- 3 months after harvest	3/6
- 4 months after harvest	2*/6[z]
- 5 months after harvest	1*/9
- 6 months after harvest	0/4
- 9 months after harvest	0/1
- 12 months after harvest	0/4
Total number of fields where ToMV was detected	16/41

[z] * = tomato crop followed by one rice crop.

Survival of Tomato Mosaic Virus in Artificially Flooded Soil

Introduction

In previous investigations it was shown that 1) tomato mosaic virus (ToMV) could survive in agricultural soils up to five months after a tomato harvest, even when the tomato crop was followed by a rice crop, and 2) flooding of a field for one week after the tomato harvest did not

eliminate or reduce soil borne ToMV. A study was conducted to determine the effect of a rice crop on the survival of ToMV in the soil if fields are flooded for an extended period of time.

Materials and Methods

Soil was collected from a field where tomatoes had just been harvested. The soil (207,900 cm^3) was packed into four boxes and amended with 8,100 cm^3 debris of tomato plants that had been artificially inoculated with ToMV. Two boxes were flooded with well water to a level approximately 5-10 cm above the soil surface. Twice a week the soil in the boxes was stirred slightly. At monthly intervals five 20 g soil samples were taken from each box and assayed by the method described previously for the presence of ToMV.

Results

The results are shown in Table 6. ToMV was detected in the flooded soil for six months and in the unflooded soil for five months. Up to three months, large amounts of ToMV were found in both flooded and unflooded soils. A sharp decline in ToMV occurred after the fourth month in both soils. After seven months no ToMV could be detected in flooded or unflooded soils.

Conclusions

This study supports previous evidence that flooding of the soil has no measurable effect on ToMV survival in the soil. It also supports the evidence that six to seven months after a tomato harvest the presence of ToMV is either nil or so minimal that it cannot be detected with the method applied in this study. From this and other studies it appears that to avoid ToMV infection from the soil a tomato crop should not be planted less than six months after the harvest of a previous tomato crop even if the first tomato crop is followed by rice.

Table 6. Survival of ToMV in soil amended with virus infected plant debris.

Sampling date (months after soil amendment)[z]	Local lesions per leaf (*N. tabacum* Xanthi)	
	non-flooded soil	flooded soil
1	> 100[y]	> 100
2	> 100	> 100
3	> 50	> 50
4	3.2	3.7
5	0.7	0.9
6	0	0.01
7	0	0

[z] Soil amendment January 7.
[y] Means of two replications and five 20 g soil samples.

Survival of Tomato Mosaic Virus in Soil from Fields with Different Cropping Patterns

Introduction

In a previous survey of agricultural soils in Tainan County, Taiwan, tomato mosaic virus (ToMV) was detected up to five months after a tomato harvest, even when the tomato crop was followed by a rice crop. In this investigation the presence of ToMV in the soil of four fields at AVRDC was monitored monthly to study the survival of soil borne ToMV in fields with different cropping patterns.

Materials and Methods

Four fields with different crop sequences after a tomato harvest were chosen for the study. One field (No. 111) was flooded for ten days after the tomato harvest. At monthly intervals, five soil subsamples were collected from each of five randomly selected sites in each field, to a depth of 20 cm. Each subsample was crushed, shaken vigorously in 0.1 M phosphate buffer pH 7.2, and inoculated to two half-leaves of Nicotiana tabacum Xanthi. Local lesion formation indicated the presence of ToMV.

Results

The results of this study are shown in Figure 2. ToMV began to

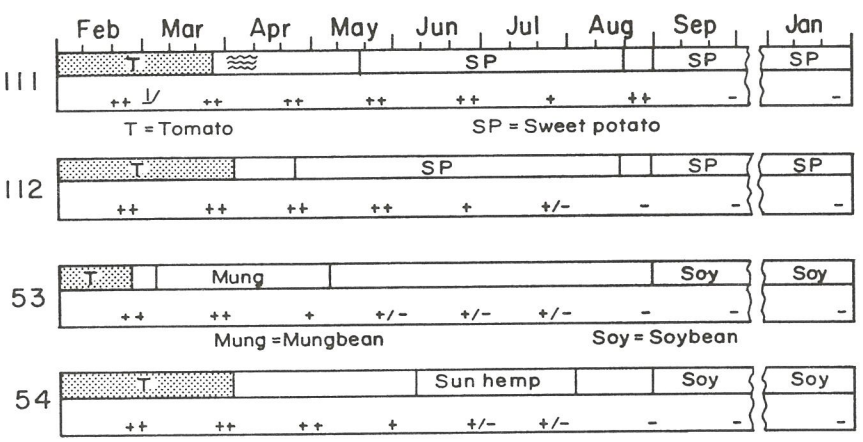


Figure 2. Survival of TMV in the soil after tomato harvest.[z]

[z] ++ : an average of 50 local lesions produced on half-leaves of N. tabacum Xanthi.
+ : an average of 10 to 50 local lesions.
+/- : an average of 1 to 10 local lesions.
- : no local lesions.

decline two to four months after the tomato harvest but could still be detected at five months. In all fields ToMV was no longer detectable six months after the tomato harvest. Flooding of a field after the tomato harvest had no adverse effect on the survival of ToMV in the soil.

Conclusions

The results are in agreement with those of a field survey conducted previously, where ToMV was detected in agricultural soils up to five months after the tomato harvest.

Transmission of Tomato Mosaic Virus to Tomato Seedlings from Infected Soil

Introduction

An experiment was conducted to study the rate of movement of tomato mosaic virus (ToMV) into tomato plants from ToMV infected soil and to establish whether any difference exists between the rate of movement into transplanted and direct seeded plants.

Materials and Methods

Seeds of the ToMV susceptible tomato cultivar TK-70 were treated with dry heat (78°C) for three days to eliminate all seed borne ToMV. Half of the seeds were sown directly into 30 pots (two seeds/pot, later thinned to one seedling) containing soil contaminated with ToMV infected plant debris. The remaining seeds were sown into flats containing autoclaved soil and were transplanted five weeks later into pots (one plant/pot) containing ToMV infected soil. The pots were arranged outdoors, 110 cm apart to prevent contact between plants. Extreme care was also taken to avoid contamination during handling. The controls consisted of plants seeded directly or transplanted into non-contaminated compost.

Leaves from both top and bottom of the emerging plants were collected every seven to 14 days until harvest. The leaves were homogenized in 0.1 M phosphate buffer and inoculated to Nicotiana tabacum Xanthi. ToMV infected plants were immediately removed to minimize the possibility of infection through plant-to-plant contact.

Results

The results are shown in Figure 3. In plants grown from seeds sown directly, ToMV first appeared in the sixth week. In transplanted

seedlings, ToMV was first detected in the fifth week after transplanting to ToMV infected soil. At harvest, 50% of the direct seeded plants were found to be infected with ToMV, compared to 33% of the transplanted plants. None of the control plants exhibited ToMV infection at harvest. Both transplanted and direct seeded plants reached maturity at the same time.

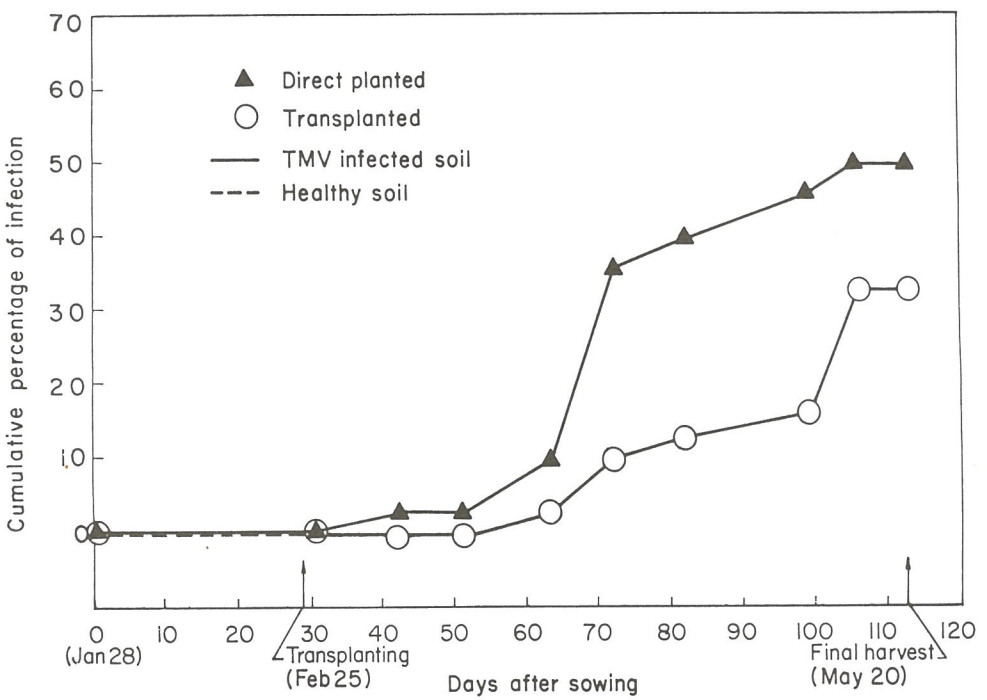


Figure 3. Transmission of TMV from the soil to direct seeded and transplanted tomato plants.

Conclusions

The rate of movement of ToMV from soil into tomato seedlings appears to be lower when tomato seeds are first seeded in autoclaved compost soil and then transplanted into ToMV infected soil than when seeds are planted directly in infected soil. This preliminary experiment will be repeated to ascertain whether the results are consistent.

Investigation of Tomato Leafcurl Disease

Introduction

In the fall season of 1981 a few tomato plants were observed in Tainan County, Taiwan, that showed symptoms that could not be attributed to any of the mechanically transmitted tomato viruses. These symptoms included stunting of the plant and dwarfing, yellowing, and curling of the leaves. Often many lateral branches were produced, giving the plants a bushy appearance. All samples collected were shown to be infected with ToMV and a gemini-type virus particle similar to that of tomato yellow leafcurl virus and tomato yellow dwarf virus. ToMV was recently eliminated from those samples and investigations are now being conducted to further characterize the disease and the disease agent.

Materials and Methods

Transmission: All mechanical inoculations consisted of crude extracts obtained by grinding systemically infected leaf tissue in 0.01 M phosphate buffer pH 7.2. This extract was inoculated to carbon dusted tomato leaves (Lycopersicon esculentum TK-70).

Graft transmissions consisted either of scions of healthy plants (L. esculentum AVRDC Acc. 213 and IITA LIT 123 and Solanum nigrum) cleft-grafted onto virus infected tomato plants, or of diseased tomato scions cleft-grafted onto the healthy plants.

For whitefly transmission tests, 100 healthy whiteflies were placed on a virus infected tomato plant for 30 hours. After the acquisition access feeding they were placed on healthy plants to feed for four days. The plants were then placed in the greenhouse for symptom observation.

Electron microscopy: Leaf dip preparations were prepared by the standard method. Phosphotungstic acid (2% in water, pH 6.5) was used as a negative stain. The leaf dip preparations were prepared and examined electron microscopically by Drs. Lesemann and Vetten of the Biologische Bundesanstalt (BBA), Braunschweig, Federal Republic of Germany.

Serology: Agar gel double-diffusion: 1 ml agar solution (0.8% agarose, 0.85% Nacl, 0.2% sodiumazide in distilled water) was poured evenly onto a microscope slide. Six peripheral wells surrounding a central well were cut out with a 5mm diameter gel cutter. Each peripheral well was located 5 mm from the central well. A small piece (approximately 1 x 1 cm) of virus infected leaf was homogenized in a few

droplets of 24% NaCl solution. The homogenates of infected tissues were placed in the peripheral wells. Antiserum against tobacco leafcurl virus (TLCV) (prepared by Dr. Inoyue of Osaka University, Japan) was placed in the center well. The reactions were viewed 24-48 hours later.

Immunoabsorbent electron microscopy (ISEM): ISEM tests, using the Derrick method and antisera to five different gemini viruses (TLCV German isolate, bean golden mosaic virus, wheat dwarf virus, maize streak virus, and cassava latent virus) were conducted by Drs. Lesemann and Vetten of the BBA.

Results

The results are shown in Table 7. The virus could be transmitted by grafting and by whiteflies, but not by mechanical means.

In leaf dip preparations, gemini-type virus particles were found in infected leaf tissues.

In serological tests the virus reacted positively only with antiserum prepared against a Japanese isolate of TLCV.

Table 7. Investigation of tomato leafcurl virus.

Transmission	
Transmission by sap to	
Lycopersicon esculentum Acc. L 213	0/40
Transmission by white flies to	
L. esculentum Acc. L 213	25/30
Datura stramonium	3/5
Transmission by grafting to	
L. esculentum Acc. L 213	64/64
L. esculentum LIT 123 (TLCV resistant line from IITA)	22/35
Datura stramonium	2/4
Electron microscopy	
Detection of gemini-type particles	21/29
Serology	
A) Agar gel double-diffusion	
Reaction with tobacco leaf curl antiserum (from Japanese TLCV isolate)	+
B) ISEM	
Reaction with tobacco leafcurl antiserum (from German TLCV isolate)	-
Bean golden mosaic antiserum	-
Wheat dwarf antiserum	-
Maize streak antiserum	-
Cassava latent antiserum	-

Conclusions

The agent causing stunting, leafcurling, and yellowing of tomatoes in Tainan County has been identified as a gemini-type virus. In agar gel double-diffusion tests a positive reaction was obtained with antiserum to a tobacco leafcurl virus isolate from Japan, which is also known to react positively with the Japanese tomato yellow dwarf virus. Further tests, in particular whitefly transmission tests, are needed to determine if the virus found in Taiwan is similar to tomato yellow dwarf virus or to tomato yellow leafcurl virus, which is endemic in the Near East and Africa.

Cucumber Mosaic Virus Strain Detection

Introduction

Cucumber mosaic virus (CMV) is one of the most serious viruses affecting tomato in Taiwan and elsewhere. Fields with more than 50% infection have been found in Taiwan. If young plants are infected, they will bear only few and very small, unmarketable fruits. A survey was initiated in 1982 to detect the strains of CMV that infect tomato in Taiwan for possible use in resistance screening.

Materials and Methods

From the major tomato production areas, 152 leaf samples were collected from plants exhibiting symptoms typical of CMV (mottle and deformation, stunting and reduction of leaf size, shoestring, and mosaic). The leaf material was triturated in 0.02 M phosphate buffer pH 7.2 (with 0.3% Na-thioglycollate and 0.1% Na-diethyldithiocarbamate added as stabilizing agents) and inoculated to two Cucumis sativus cv. National Pickling plants. When mosaic symptoms developed, the sample was processed as outlined in Figure 4. Strain differentiation was performed following the method of Marrou et al. using 20 differential hosts.

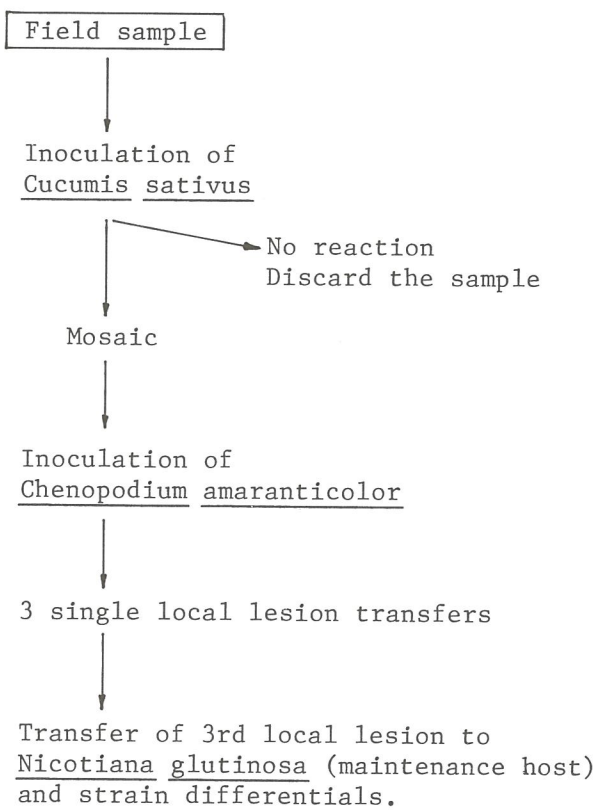
Results

Of 152 samples collected, 25 contained CMV. Twelve isolates were strain typed. Based on their ability to infect Physalis floridana systemically, all are classified in group C.

Conclusions

Since none of the twelve isolates infected Vigna unguiculata systemically, they belong to subgroups C-1, C-2, and C-3, which include seven strains. One strain appears to be strain TN, because of its ability to produce mosaic on Beta vulgaris. The other 11 isolates cannot be classified as strains with certainty because the reactions on the test plants were not conclusive. More test plants of each differential host are presently being inoculated to further separate the CMV isolates.

Figure 4. Isolation of CMV from tomato field samples.



Tomato Entomology

Study of Fruitworm Resistance in Tomato Segregating Materials

Introduction

Two polyphagous insects, Heliothis armigera and Spodoptera exigua, are important pests of tomato in Southeast Asia. Both insects attack foliage in early larval instars and fruits in later instars. The major damage comes from their feeding on the fruits. In 1980 two Lycopersicon hirsutum f. glabratum accessions which had shown resistance to other lepidopterous pests at North Carolina State University were found resistant to these two insects at AVRDC. Since these accessions are not cultivated types and have poor horticultural characteristics, the Center's plant breeder has crossed them with cultivated tomato to breed high yielding tomato cultivars with fruitworm resistance. In 1982 the backcross progenies were tested along with the parents to study the inheritance of resistance and select resistant entries with good horticultural characters.

Materials and Methods

Seedlings were transplanted in the field in November, 1981 on 1.5 m wide beds with 1 m between plants in each row. Plants were left exposed to infestation by the ambient population of H. armigera in December and January and S. exigua in February and March, the normal times for tomato infestation by these pests. Twice during the growing period the damaged and healthy fruits were counted to evaluate fruitworm damage.

In October, 1982, advanced generation breeding materials were planted in a similar manner. The natural insect population was augmented by frequent release of the two insect species reared in the laboratory on artificial diets. These materials were evaluated twice in 1982 and will be observed two more times in 1983.

Results

In the first screening several entries were free of fruitworm damage. However, only 13 resistant entries had the characteristics of

cultivated tomato. All fruits of each of these entries were harvested for multiplication. Seven of these 13 were free of virus infestation.

Fifty plants of each of the 13 entries with fruitworm resistance and cultivated type characteristics were evaluated in the fall trials. Based on the first two observations, entries with no damaged fruits and good horticultural characters were selected for backcrossing to cultivated parents. The progenies will be evaluated during 1983.

Conclusions

Screening of breeding materials must be continued, as many segregating materials show characters of L. esculentum f. glabratum parents. It has recently been found that plants grown under a long photoperiod show better levels of resistance than those grown under a shorter photoperiod. Starting in 1983, therefore, progenies will be screened during late spring and summer, and additional sources of resistance will be sought for practical use in the fall and winter seasons as well.

Evaluation of Insecticides for Fruitworm Control

Introduction

Besides resistance breeding, AVRDC also has a small program for the evaluation of insecticides for fruitworm control. One screening is conducted per year to select the compounds most effective in fruitworm control. Since insect pests develop resistance to insecticides quickly in the tropics, screening makes possible the identification of new effective treatments before the target pest becomes resistant to those in current use. In 1982 one insecticide screening trial was conducted to select chemicals effective against H. armigera and S. exigua.

Materials and Methods

The experimental procedure was as described in the AVRDC publication "Vegetable Pest Control: Insecticide Evaluation Tests." The selection of chemicals was based on their efficacy on the target pests or related species elsewhere. Efforts were made to include chemicals with non-traditional modes of action. The details of the experimental conditions are listed as footnotes to the table summarizing the test results.

Results

The results are presented in Table 1. Four synthetic pyrethroids - fenvalerate, permethrin, decamethrin, and cypermethrin - sprayed at weekly intervals from the first fruit set until one week before harvest, controlled tomato fruitworm better than other chemicals.

Conclusions

Synthetic pyrethroids fenvalerate, permethrin, decamethrin, and cypermethrin sprayed at weekly intervals from the first fruit set until one week before harvest give good control of tomato fruitworm and beet armyworm on tomato. The first three of these synthetic pyrethroids, along with methomyl, had given good control of the two pests in the previous year's trials as well.

Table 1. Evaluation of insecticides for the control of fruitworm on tomato.[z-u]

Insecticides	Rate (kg ai/ha)	Damaged fruits (%)
Fenvalerate 20EC	0.10	0.9 c
Permethrin 10EC	0.05	1.3 bc
Decamethrin 2.8EC	0.025	1.1 bc
Cypermethrin 5EC	0.05	1.1 bc
MIPC 50WP	0.8	10.1 a
BPMC 50EC	0.8	9.5 a
MIPC + malathion	0.4+0.5	4.9 b
BPMC + malathion	0.4+0.5	4.3 bc
Malathion 50EC	1.0	4.2 bc
Check	-	9.6 a

[z] Cultivar: CL 1591-0-1-7-6.
[y] Transplanting date: 9/9/81.
[x] Insecticides applied: 11/17, 11/25, 12/2, 12/10, 12/17, 12/24, and 12/31/81 and 1/7, 1/14, 1/21, and 1/28/82.
[w] Sampling (harvest) dates: 12/28/81, 1/18/82 and 2/9/82.
[v] Data shown is mean of four replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[u] Plot size: 15 m^2.

Tomato Physiology

Evaluation of Heat Tolerance in Parthenocarpic Tomato Lines

Introduction

The heat tolerance of normal tomato depends on the ability of several component factors of the fruit setting and development processes (e.g. viable pollen production, pollination, fertilization, etc.) to overcome heat stress. Parthenocarpic tomatoes bypass some of these factors to set and develop fruits. However, the heat tolerance of parthenocarpic tomatoes is not fully known. An experiment was conducted to evaluate the fruit setting and development of parthenocarpic tomatoes at high temperatures.

Materials and Methods

Seven parthenocarpic and non-parthenocarpic entries including a heat tolerant breeding line, CL 1131-0-0-38-4-0 and a local cultivar, White Skin (L 387) were raised in ID 25 cm clay pots in the greenhouse, one plant/pot, three plants/replicate in three replicates. Mean maximum and minimum temperatures from first flowering through the duration of the experiment were 35.3 ± 2.6 and 25.6 ± 0.8^{o}C, respectively. Plants were maintained as double stems. Flowers of the second to fourth clusters were observed for fruit setting rate (%), antheral cone splitting (%), stigma exsertion (%), pollen production, fruit yield/three clusters, fruit number/three clusters, fruit size, and parthenocarpic fruit rate (%). Shoot dry weight was determined at the termination of the experiment.

Results

Path coefficient analysis revealed that fruit number and average fruit weight determined more than 74% of fruit yield. Among the seven entries, CL 1131-0-0-38-4-0, Line 31, and Ventura produced the highest fruit yields. CL 1131-0-0-38-4-0 produced larger quantity but smaller sized fruits, whereas Line 31 and Ventura gave fewer, slightly bigger fruits (Table 1). Although yields of Family 12 and Severianin were low,

their fruits were the largest. No clear relationship was found between reproductive growth and shoot dry matter. Family 12, Oregon cherry, and Severianin had the highest rates of parthenocarpic fruit setting (Table 2).

Table 1. Fruit set, yield, yield components, and shoot dry weight of parthenocarpic and non-parthenocarpic tomatoes grown at high temperature.[z]

Variety	Fruit yield (g/3 clusters) Y	Fruit setting (%)	Fruit no./ 3 clusters X_1	Fruit wt. (g/fruit) X_2	Shoot dry wt. (g/ plant)	$Y=a+bX_1+cX_2$
CL 1131-0-0-38-4-0	125 a[y]	35 a	7.0 a	19 d	52 b	$12.7X_1+6.5X_2-86.0$
L 387	19 c	9 c	1.0 b	26 cd	153 a	$11.4X_1+1.3X_2-14.7$
Line 31	120 ab	23 b	3.2 b	37 bc	41 b	$34.1X_1+2.8X_2-95.4$
Family 12	59 bc	14 bc	1.8 b	42 ab	44 b	$34.6X_1+1.1X_2-33.8$
Oregon cherry	14 c	19 bc	6.0 a	2 e	33 b	$0.9X_1+5.6X_2-6.2$
Severianin	56 c	9 c	1.3 b	51 a	24 b	$42.8X_1+1.5X_2-72.6$
Ventura	69 abc	18 bc	3.1 b	26 cd	35 b	$19.9X_1+3.5X_2-75.1$

[z] Seeds were planted on June 8 and harvested on September 1, 1982.
[y] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Fruit setting rate and its component factors, and parthenocarpic fruit rate of second to fourth clusters of tomato plants.

Entries	Fruit set (%)			Stigma exsert (%)	Antheral cone split (%)	Partheno-carpy (%)	Seed no./fruit
	2nd	3rd	4th				
CL 1131-0-0-38-4-0	35.1 a[z]	34.5 a	35.1 a	0.5 d	2.2 d	5.0 e	25.9 a
L 387	14.4 b	5.8 d	3.5 d	99.1 a	29.9 bcd	39.6 cd	10.0 c
Line 31	19.9 b	28.0 ab	17.3 b	24.1 cd	34.8 abc	24.2 de	17.4 b
Family 12	16.0 b	13.0 bc	15.8 bc	44.6 bc	50.1 ab	94.4 a	0.1 d
Oregon cherry	19.7 b	12.9 bc	16.5 bc	92.2 a	12.3 cd	91.4 ab	1.1 d
Severianin	10.5 b	8.7 c	6.9 cd	34.4 bc	65.7 a	88.3 ab	1.4 d
Ventura	20.5 b	14.1 bc	15.3 bc	57.2 b	59.9 ab	61.8 bc	3.8 d

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Previous studies revealed that the fruit setting rate depends on various factors such as antheral cone splitting, stigma exsertion, pollen production, pollen and ovule viability, etc. In this experiment, according to a multiple regression, the fruit setting rate (%) of all seven entries = 31.8 - 0.15 (stigma exsertion rate) - 0.23 (antheral

cone splitting rate) + 0.29 (pollen viability). Furthermore, path coefficient analysis revealed that stigma exsertion, antheral cone splitting, and pollen viability contributed 31.2, 31.2 and 0.3% respectively toward the reduction of fruit setting. The low effect of pollen viability on fruit setting was probably observed because not enough pollens could be collected in each investigation. Other component factors contributed 37.3% to the low fruit setting rate.

CL 1131-0-0-38-4-0 had the highest fruiting rate among the seven entries (Table 2). This entry had the lowest rates of stigma exsertion and antheral cone splitting. L 387 and Oregon cherry had the highest rates of stigma exsertion. Ovaries of Severianin started to develop before or during anthesis which might have caused the high stigma exsertion rate and antheral cone splitting. Moreover, styles did not abscise but in some cases swelled and remained on the fruits. Abnormal flowers were also found in Ventura. Its flowers and sepals were bigger, and in some cases two or three flowers were combined. Although antheral cone splitting and stigma exsertion were previously shown to reduce fruit setting of non-parthenocarpic tomatoes at high temperature, they did not reduce the yield of Line 31 and Ventura. If CL 1131-0-0-38-4-0 and L 387 are excluded from the multiple regression and path coefficient analyses, fruit setting rate of the other five entries = 24.1 - 0.05 (stigma exsertion rate) - 0.17 (antheral cone splitting) + 0.27 (pollen viability) with 62.9% residual effect of other factors.

Conclusions

In terms of fruit yield, Line 31 and Ventura had the same level of heat tolerance as CL 1131-0-0-38-4-0. Ventura was sometimes parthenocarpic. Parthenocarpic Family 12 and Severianin had moderate yields and produced few but large fruits, whereas Line 31 had medium-sized fruit and CL 1131-0-0-38-4-0 had the smallest. Although intermediate parthenocarpic Ventura produced yields comparable to CL 1131-0-0-38-4-0, it had higher rates of antheral cone splitting and stigma exsertion and lower fruit setting rate. It is likely that parthenocarpic Family 12 and Severianin, but not Oregon cherry, had high sink strength to bypass pollination and fertilization and proceed toward large fruit growth at high temperatures. However, this did not result in high fruit yield because fewer fruits were set. The promise of parthenocarpic tomatoes for heat tolerance must still be verified.

Effect of New Growth Regulators On Tomato Fruit Setting

Introduction

CPA (4-chlorophenoxyacetic acid) is a synthetic growth regulator commonly used to improve fruit set and yield of summer fresh market tomatoes in Taiwan. However, this growth regulator often causes abnormal, seedless, and dry fruits. An experiment was conducted to evalute the effect of two newly released growth regulators, Cytex and Pix, and other conventional growth regulators on tomato fruit set and yield in the summer.

Materials and Methods

In an outdoor pot experiment the following treatments were applied to the first two clusters of CL 9-0-0-1 plants, five plants per treatment: CPA at 10, 20, 40 mg/l; Cytex (from Atlantic & Pacific) at 25, 50, 100 times dilutions; Pix (from BASF) at 500, 1000, 2000 mg/l; Kinetin at 50, 100, 200 mg/l; GA_3 (Gibberellin A_3) at 50, 100, 200 mg/l; ABA (abscisic acid) at 5, 10, 20 mg/l; and water control. The rest of the buds were pruned after application. Maximum and minimum temperatures from anthesis to observation of fruit setting were 31.0 and 24.0°C,respectively. Fruit set and fruit yields were investigated at two and three weeks after application.

In a field experiment, whole newly flowered second to sixth clusters of CL 9-0-0-1 were dipped into solutions of CPA (20, 100 mg/l), Cytex (10, 100 x), Pix (50, 250 mg/l), and GA_3 (100, 400 mg/l) once a week for four weeks. Plot size was 1.0 x 5.0 m single row with 40 cm between hills. A randomized complete block design with three replicates was employed. Plants were maintained for double stems. Maximum and minimum temperatures from first anthesis of the second cluster through termination of the experiment were 31.4 and 24.4°C, respectively.

Results

In the preliminary pot experiment, CPA (10, 20, 40 mg/l) and GA_3 (50, 100 mg/l) increased fruit setting rate in the first two clusters. ABA, Cytex, Kinetin, and Pix had no effect. In the field, Cytex had no effect on fruit setting rate and yield, whereas Pix (50 mg/l) increased fruit setting rate only in the third cluster (Table 3). CPA (20, 100 mg/l) increased fruit setting rates of the third to fifth clusters, and CPA (100 mg/l) increased fruit setting rate of the second cluster.

GA_3 (100, 400 mg/l) increased fruit setting rates of the third to sixth clusters, and the 400 mg/l application likewise affected the second cluster. Although both CPA and GA_3 increased fruit setting rates, only CPA increased fruit yield. Both CPA and GA_3 induced seedless fruits.

Conclusions

Newly released growth regulators Cytex and Pix did not increase fruit setting rates in either the pot or field experiments. ABA and Kinetin also showed no effect at the concentrations used. Both CPA and GA_3 increased fruit setting rate at high temperatures in the field, but only CPA increased fruit yield. Both CPA and GA_3 induced parthenocarpic fruit setting. Further study is needed to examine the potential of growth regulators to increase the yield of seeded fruit at high temperatures.

Table 3. Effect of growth regulators on fruit setting, fruit weight, and seed number of CL 9-0-0-1.[z]

Treatment	Fruit setting(%) of cluster					Fruit wt. (g/5 clusters)	Seed no./ Fruit
	2nd	3rd	4th	5th	6th		
CPA (20 mg/l)	45 b[y]	42 b	33 bc	20 c	9 c	253 ab	5 b
CPA (100 mg/l)	72 a	64 a	41 b	24 bc	13 bc	355 a	3 b
Cytex (10 x)	26 b	17 d	7 d	6 d	0 c	168 b	22 a
Cytex (100 x)	36 b	34 bcd	13 d	7 d	1 c	211 b	21 a
GA_3 (100 mg/l)	45 b	52 ab	46 ab	40 a	34 a	161 b	5 b
GA_3 (400 mg/l)	73 a	69 a	62 a	36 ab	24 ab	149 b	3 b
Pix (50 mg/l)	46 b	37 bc	16 cd	6 d	1 c	215 b	27 a
Pix (250 mg/l)	42 b	20 cd	4 d	1 d	1 c	192 b	25 a
Control	41 b	16 d	10 d	3 d	2 c	182 b	26 a

[z] The seedlings were planted in the field on May 14 and harvested on July 8, 1982.
[y] Mean separation in columns by Duncan's multiple range test, 5% level.

Effect of High Temperature on Auxins and Gibberellins in Tomato Reproductive Organs

Introduction

Studies have shown that tomato fruit development is accompanied by an increase in endogenous auxin content. Moreover, exogenous application of an auxin-type growth regulator on unpollinated flowers

usually results in better fruit set at high temperature. This study investigated the effect of high temperature on endogenous auxin and gibberellin levels during the initiation of the fruit setting process.

Materials and Methods

Test cultivars were seedlings of L 387 and CL 11d-0-2-2-0-3, three replicates per cultivar and five plants per replicate. As soon as the second inflorescence became macroscopic, seedlings were subjected to 38°C for five hours. Flower buds (expected to open two to four days later), open flowers, and flowers with small developing fruits were harvested at 0, 8, 24, 48, and 72 hours after the completion of the heat treatment. Untreated seedlings were also sampled. Reproductive organs were ground with 90% cold methanol, filtered, and evaporated to the aqueous phase. The aqueous phase was later adjusted to pH 3.0 and separated with ethyl acetate to obtain acidic organic compounds. The acidic ethyl acetate fraction was dried and chromatogrammed with a thin layer of silical gel. The chromatogram was divided into 15 fractions and bioassayed for auxin-like and gibberellin-like compounds by the oat coleoptile straight growth method and the dwarf rice method, respectively. Each fraction with hormonal activity was calculated into IAA or GA_3 equivalent in µg/g fresh tissue. Total values of auxin- and gibberellin-like equivalents for each cultivar were combined and plotted.

Results

Heat treatment significantly reduced the level of auxin activity for all three reproductive organs (Figure 1). In both cultivars, reduction occurred at 8 and 24 hours after heat treatment, but showed a trend of recovery after 24 hours. Untreated reproductive organs, of the same physiological age as the others immediately after heat treatment, had the highest level of auxin-like substances. A similar decrease of endogenous GA-like substances after high temperature treatment was observed in L 387. The level of endogenous GA-like substances in general is much lower than the level of auxin-like substances, especially in cultivar CL 11d-0-2-2-0-3 (Figure 2).

Conclusions

Auxins have been suggested as the predominant hormonal factor controlling fruit set, and the low auxin level in heated reproductive organs may reflect the influence of high temperature. Both flower buds

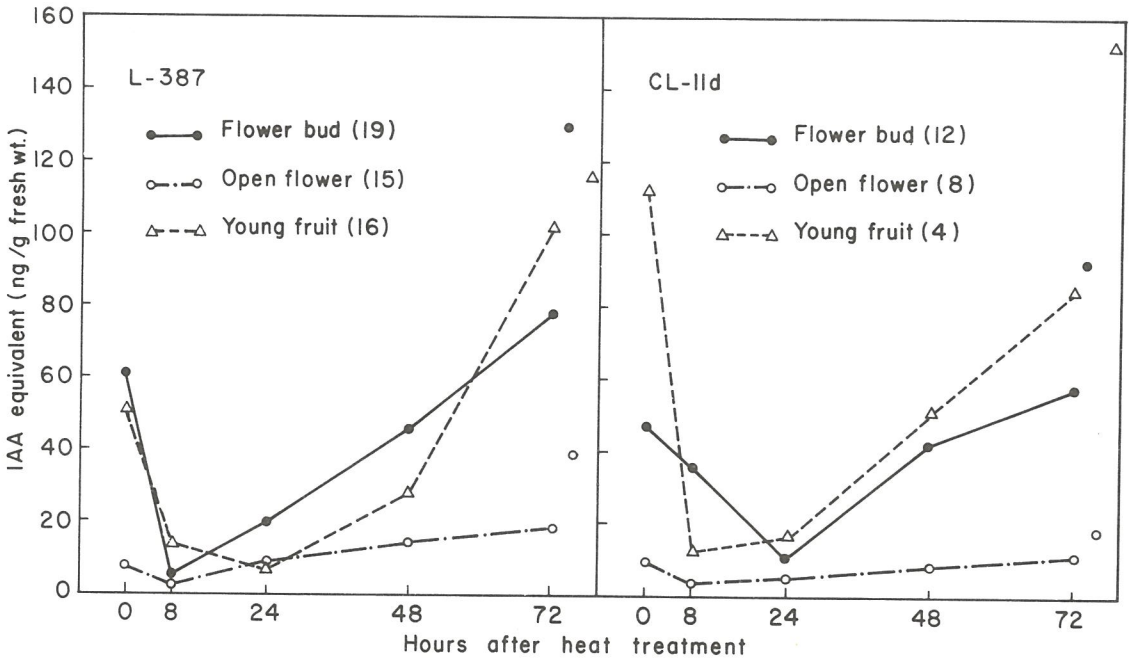


Figure 1. Quantitative changes in auxin-like activity of heated tomato reproductive organs during the initiation of fruit-setting. Unconnected points represent the unheated control. The least significant difference at the 5% level is in parentheses.

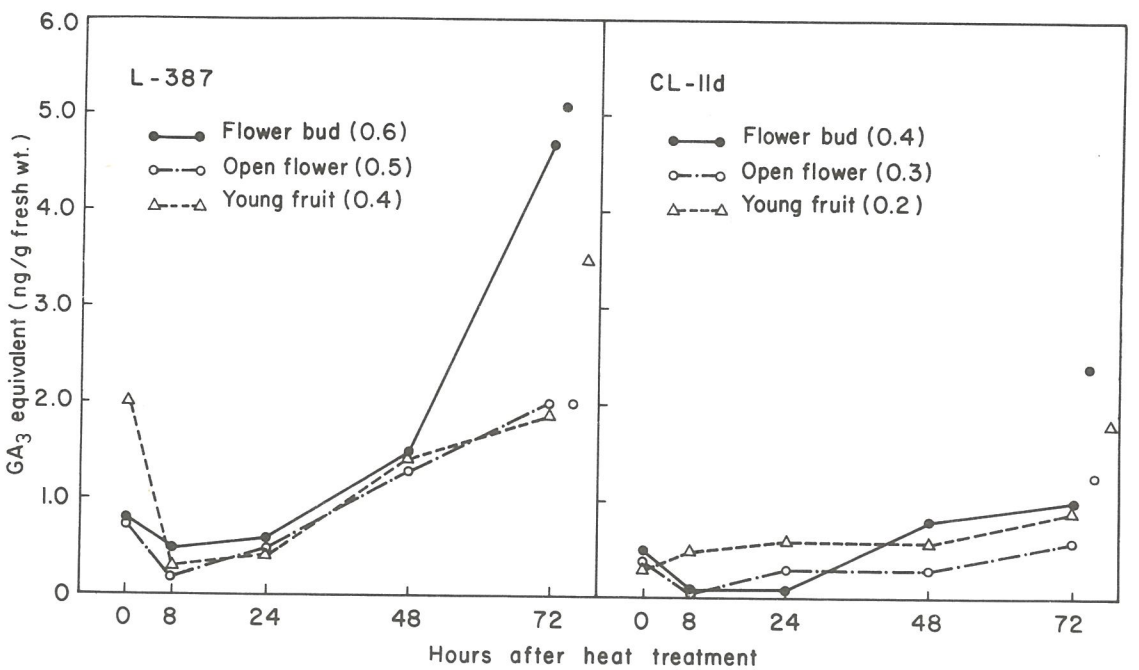


Figure 2. Quantitative changes in giberellin-like activity of heated tomato reproductive organs during the initiation of fruit-setting. Unconnected points are the unheated control. The least significant difference at the 5% level is in parentheses.

and young fruits had higher auxin levels than open flowers, perhaps because they were just developing. Although GAs are also implicated in the control of fruit setting, their exact role in terms of high temperature effect is still not clear. Endogenous GA levels in all three reproductive organs were low in both cultivars. It is conceivable that the presence of both auxins and GAs in the reproductive organs is important for fruit set at high temperatures; however, other plant hormones may be interacting with these hormones to control fruit set.

Evaluation of Heat Tolerance of Fruit Setting Processes in Heat Tolerant Accessions

Introduction

Fruit set at high temperature is the most important physiological process necessary for heat tolerance in tomato. This process depends, however, on the ability of its component factors (e.g. pollen production, style exsertion, antheral cone splitting, pollen and ovule viability, etc.) to overcome heat stress. The enhancement of heat tolerance depends on the best combinations of heat resistant component factors.

Nearly 40 of AVRDC's tomato germplasm accessions have been previously identified as heat tolerant. Most of these ratings were based on visual observation of fruiting loads at high temperatures in the field. To better pinpoint the source of tolerance, fruit setting and its component factors were examined at high temperatures in the field.

Materials and Methods

Thirty-nine accessions and a breeding line, CL 1131-0-0-38-4-0, were sown April 28, May 26, June 23, and August 4, 1982. Rainfall and temperature for the period are shown in Figure 3. One-month-old seedlings were transplanted to 1.5 x 4.0 m plots, two rows per plot, 60 cm between rows and 40 cm within rows. A randomized complete block design with three replicates was employed. Six randomly selected plants from each replicate were investigated for first flowering, number of flowers and fruits of second to fourth clusters, stigma exsertion, antheral cone splitting, and dry weight. Fruit setting rates were later calculated.

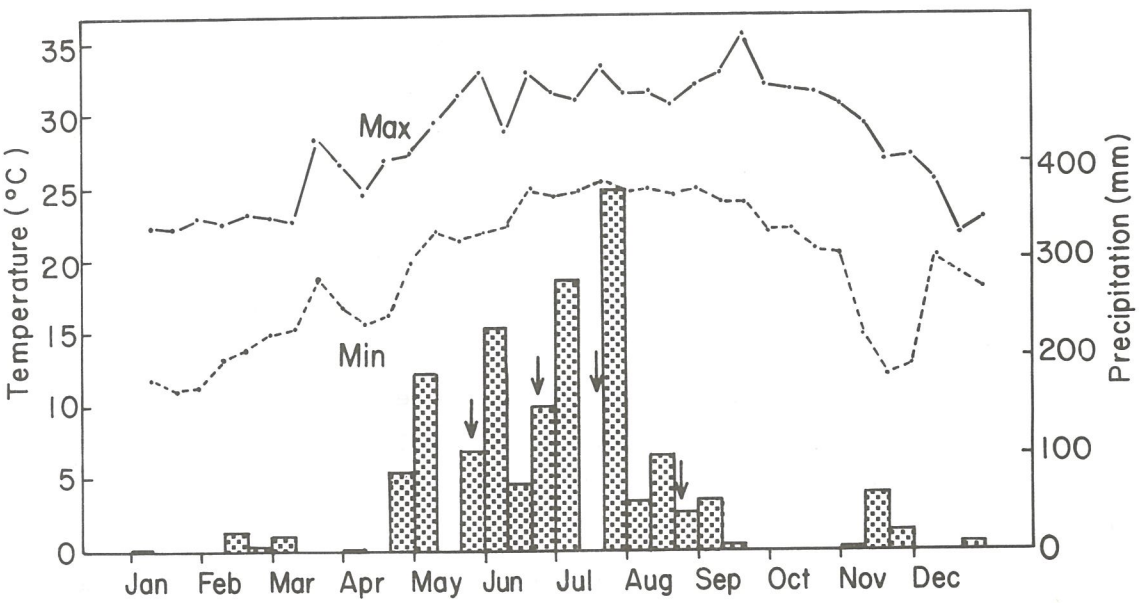


Figure 3. Maximum and minimum temperature and precipitation at AVRDC, 1982.

Results

Average fruit setting rates for the April 28, May 26, and June 23 plantings were lower than for the August 4 planting. Physiological conditions that are known to reduce fruit setting (i.e. antheral cone splitting and stigma exsertion) were higher in the first three plantings, excluding stigma exsertion investigated at seven weeks after sowing. Plants of both the May 26 and June 23 plantings were exposed to typhoon; therefore, dry weights were reduced. Comparison of April 28 and August 4 plantings revealed that plant vegetative growth did not hold the key for the difference in fruit setting rates (Table 4).

Table 4. Comparison of overall first flowering, stigma exsertion, fruit setting, antheral cone splitting, and dry weight of 40 tomato accessions and breeding lines.

Sowing date	Flowering (days from sowing)	5 weeks after sowing				7 weeks after sowing			
		Stigma exsert (%)	Antheral cone split (%)	Fruit set (%)	Dry wt (g/ plant)	Stigma exsert (%)	Antheral cone split (%)	Fruit set (%)	Dry wt (g/ plant)
April 28	45 c[z]	26 b	41 a	13 b	52 a	10	20 a	16 b	72 a
May 26	49 b	41 a	23 b	9 b	35 c	-[x]	-	-	-
June 23	61 a[y]	-	-	-	-	15	11 b	19 b	44 c
August 4	48 b	14 c	8 c	41 a	40 b	11	8 b	40 a	63 b

[z] Mean separation in columns by Duncan's multiple range test, 5% level.
[y] Flowered late due to typhoon.
[x] Plants were damaged by typhoon.

Stigma exsertion and antheral cone splitting rates were lower at seven weeks than at five weeks after sowing; apparently reproductive organs of larger plants were more resistant to high temperature. Heat tolerant accessions had lower stigma exsertion but higher fruit setting rate during the hot, wet season, and the difference between heat tolerant and sensitive lines became smaller when the temperature and precipitation decreased. Among the 40 entries, only L 3690 had both high stigma exsertion and high fruit setting rate. There were no significant differences in antheral cone splitting among heat tolerant and sensitive accessions, but there was a tendency that the lower the temperature also the lower the antheral cone splitting (Table 5).

Conclusions

The high fruit setting rate of heat tolerant accessions during the hot, wet season may be due to stable and low stigma exsertion rates. The only exception was L 3690, which had high fruit setting rate in spite of high stigma exsertion. There was no relationship between plant vegetative growth and fruit setting rates. The reproductive organs of larger plants were more resistant to high temperature. There were some other factors (e.g. pollen production, pollen and ovule viability, etc.) affecting fruit setting rates. However, antheral cone splitting had no noticeable effect.

Table 5. Comparison of stigma exsertion, antheral cone splitting, and fruit setting of heat tolerant tomato accessions.

Entry	Stigma exsert (%)			Antheral cone split (%)			Fruit set (%)		
	I[z]	II	III	I	II	III	I	II	III
L 3690	62 a[y]	28 b	22 b	9	0	12	29 abc	46 a	60
L 492	10 b	1 c	9 b	8	0	5	39 ab	44 a	51
L 2972	0 b	4 c	0 b	16	9	12	22 bc	43 ab	52
L 1488	1 b	1 c	0 b	26	11	4	31 ab	39 ab	54
L 232	2 b	7 c	1 b	20	10	4	28 abc	35 ab	49
L 229	0 b	0 c	0 b	7	12	3	41 a	30 ab	58
L 387(check)	17 b	58 a	47 a	21	11	6	17 c	5 b	41
Mean of all entries (40)	10	15	11	20	11	8	16	19	40
Range	0-74	0-94	0-50	4-53	0-31	3-31	1-41	0-46	10-60
CV (%)	111	79	107	91	91	142	57	71	30

[z] Sowing dates, I: April 38, II: June 23, III: August 4, 1982. Investigation seven weeks after transplanting.
[y] Mean separation in columns by Duncan's multiple range test, 5% level.

Chinese Cabbage Breeding

Hybridization Program

The search for heat tolerant combinations superior to earlier AVRDC hybrids in traits such as yield, earliness, and disease resistance was continued among crosses between early generation inbred lines as well as crosses with advanced lines. One hundred fourteen new combinations were made in the 1981-82 cool season and subsequently evaluated in 1982 summer season combining ability trials. In addition, a number of backcross programs were begun or continued to incorporate resistance to diseases such as downy mildew, turnip mosaic virus (TuMV), and soft rot into heat tolerant genetic backgrounds and to transfer cytoplasmic male sterility (CMS) derived from mustard (*Brassica juncea*) and radish (*Raphanus sativus*) (Table 1).

Table 1. Backcross breeding schemes in the Chinese cabbage program.[z]

Trait(s) under transfer	Source	Recipient	Current generation
Downy mildew resistance	B 742	7 HT inbreds	F_1
Downy mildew and soft rot resistance	Hakuran (B 639)	1 HT OP; 3HT, TuMVR inbreds	BC_2F_1; F_1
TuMV resistance	B 141	1 HT inbred	BC_3F_1; BC_2F_2
Cytoplasmic male sterility	*R. sativus*	1 HT OP; 1 HT inbred (SF)	BC_1F_1
Cytoplasmic male sterility	*R. sativus*	1 HT OP	B8P/6A
Cytoplasmic male sterility	*R. sativus*	1 HT inbred (SF)	B5P/3A-B7P/3A
Cytoplasmic male sterility	*B. juncea*	1 HT OP; 2 HT inbreds (SF)	BC_1F_1; F_1

[z] HT = heat tolerant; SF = self-fertile; OP = open-pollinated.

Evaluation of Germplasm for Heat Tolerance

Introduction

Twenty-four new accessions received in 1982 were evaluated with other untested accessions to broaden the genetic base for the breeding program.

Materials and Methods

In summer 1982, 43 accessions were evaluated for heat tolerance in a randomized complete block design with two replications. AVRDC Hybrid 62 served as the heat tolerant check. Each plot consisted of a double-row bed, with 4.0 m long rows spaced 50 cm apart within beds and plants within rows spaced 40 cm apart. This trial, sown on June 30 and transplanted on July 19, was destroyed by heavy rain and flooding. A subsequent resowing was made on August 6 with seedlings transplanted on August 25. Evaluation for heat tolerance was based on yield of compact heads. Since the trial was planted late, the heat tolerance evaluation was considered very preliminary.

Results

Six new accessions, B 763, B 775, B 792, B 794, B 795, and B 801, yielded firm heads and are tentatively considered heat tolerant.

Conclusions

The six entries considered heat tolerant will be reevaluated in the 1983 mid-summer season to confirm their heat tolerance.

Advanced Yield Trials

Introduction

Five hot season trials were conducted in 1982 to evaluate the performance of ten new heat tolerant entries selected from 1981 trials.

Materials and Methods

The experimental design in all five trials was a randomized complete block with four replications. Each plot consisted of four 4 m long rows; rows within double-row beds and plants within rows were spaced 50 cm and 40 cm apart, respectively. AVRDC 62 and Wen Wu (WWCC) served as checks in all trials.

Of the five trials, two were damaged by heavy rain and floods. Those that survived were the advanced yield trial II (AYT-II), sown on

May 14 and transplanted on June 2; AYT-IV, sown on July 15 and transplanted on August 5; and AYT-V, sown on August 16 and transplanted on September 3.

Results

Two entries (80-6 and 80-32) significantly outyielded the check cultivars in AYT-II (Table 2). Two other entries performed as well as the best entries but not significantly better than AVRDC 62. In general, all AVRDC entries produced significantly more compact heads and had better heading efficiency (ratio of head weight to non-wrapper leaf weight) than Wen Wu (WWCC). The high yielders were also the early maturing types with relatively low incidence of soft rot infection.

No entry significantly outyielded the check varieties in AYT-IV but performances were comparable to the checks (Table 3). In this trial, soft rot infection, and consequently harvest rate, did not differ among entries and the advantages of early maturing combinations such as 80-6 and 80-32 were not expressed. Heading efficiency and heading rate among AVRDC entries were generally higher than Wen Wu's.

In AYT-V, none of the entries performed significantly better than the check varieties (Table 4). However, three entries, 81-29, 80-32, and 80-37, matured earlier and had higher harvest rates than Wen Wu. Yields of new entries were comparable to the checks'. In this trial, soft rot infection again did not notably affect yield.

Table 2. Yield and other horticultural characters of some entries from the advanced yield trial (AYT-II) of heat tolerant Chinese cabbage entries; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Head rate (%)	Harvest rate (%)	Soft rot (%)
80-6	17.0 a	33 f	566 bc	542 e	98 a	83 a	5 d
80-32	16.9 a	34 ef	626 ab	778 ab	98 a	73 ab	17 c
80-37	15.6 ab	35 c-e	634 ab	726 a-d	98 a	66 b-d	21 a-c
81-29	15.9 ab	34 ef	676 a	681 b-d	96 a-c	62 b-c	21 a-c
AVRDC 62 (check)	12.3 bc	36 cd	580 a-c	683 b-d	98 a	56 b-c	26 a-c
WWCC (check)	7.6 d	40 a	568 bc	825 a	74 b	30 f	26 a-c
Mean of 12 entries	13.2	35	585	714	96	60	15
CV (%)	19	3	11	9	6	14	27

Table 3. Yield and other horticultural characters of some entries from the advanced yield trial (AYT-IV) of heat tolerant Chinese cabbage entries; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Heading rate (%)
81-44	26.2 a	38 bc	803 ab	914 b-d	100 a
80-37	24.9 a	37 cd	792 ab	808 de	100 a
81-29	23.7 ab	38 bc	779 ab	845 b-e	100 a
AVRDC 62 (check)	22.2 a-c	38 bc	716 bc	872 b-e	100 a
WWCC (check)	26.2 a	43 a	888 a	1066 a	93 b
80-32	21.3 a-c	35 d	662 bc	763 ef	100 a
80-6	19.1 bc	35 d	557 c	540 g	100 a
Mean of 12 entries	22.4	37	722	824	99
CV (%)	14	4	12	9	3

Table 4. Yield and other horticultural characters of some entries from the advanced yield trial (AYT-V) of heat tolerant Chinese cabbage entries; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Harvest rate (%)
81-29	22.2 a	34 b	667 a	584 bc	100 a
80-32	21.2 ab	34 b	641 ab	668 ab	100 a
80-37	20.8 ab	34 b	630 ab	667 ab	100 a
AVRDC 62 (check)	20.3 a-c	35 ab	620 a-c	664 ab	98 a
WWCC (check)	18.3 a-c	38 a	612 a-c	766 a	85 b
80-6	17.8 b-c	34 b	535 bc	441 d	100 a
Mean of 12 entries	19.3	35	590	630	99
CV (%)	16	5	15	18	11

Conclusions

Across the three trials, three entries, 80-32, 80-37, and 81-29, performed consistently well compared to the check varieties and other entries. They either matured comparably to or earlier than AVRDC 62. During early-middle summer when much of the year's rainfall occurs, the early maturity of these entries is certainly an important attribute. The qualities of these cultivars will be confirmed further in summer 1983.

Combining Ability Trials

Introduction

Six combining ability trials were carried out in the 1982 summer season to identify superior heat tolerant combinations. Four of these (CAT-I, -II, -III, and -VI) involved the evaluation of new combinations among inbred lines compared with the best hybrid, AVRDC 62. The other two trials tested combinations between a local variety, B 129, and selected inbred lines (CAT-IV) or other selected local open-pollinated cultivars (CAT-V). AVRDC 62 also served as check in these trials. The main objective of CAT-IV and -V was to find additional male parents (inbred or open-pollinated) to match with cytoplasmic male sterile (CMS) B 129 once it becomes available from the CMS backcross program.

Materials and Methods

All trials used randomized complete block design with two replications. Plots consisted of two rows, each 4 m long, with rows within double-row beds and plants within rows spaced 50 cm and 40 cm apart, respectively.

Results

None of the 30 new entries in CAT-I, sown May 17 and transplanted June 8, performed better than AVRDC 62 in terms of yield, earliness, and disease resistance.

In CAT-II, four new combinations were selected for further comparison with AVRDC 62 in summer, 1983, because although their yield advantages over the latter were insignificant, they showed no soft rot infection and, in general, had a much better overall appearance (Table 5).

Again, no significant yield differences were noted when the best entries were compared with AVRDC 62 in CAT-III. The two entries listed in Table 6 were selected for summer, 1983 tests because of their lack of soft rot infection and good overall appearance.

In CAT-VI one entry, 82-159, yielded better than AVRDC 62 (Table 7). This combination matured as early as AVRDC 62 although head weight was significantly lower.

Entries 82-101 and 82-115 (combinations of B 129 with advanced inbred lines) performed comparably to the check in CAT-IV (Table 8).

Head weights of these entries were generally lower but maturity, heading rates, and harvest rates were comparable to those of AVRDC 62.

Table 5. Yield and other horticultural characters of some entries from the second combining ability trial (CAT-II); AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Heading rate (%)	Harvest rate (%)
82-60	22.9 a	36 ab	688	692 c-e	100	100
82-43	22.8 a	39 a	684	740 b-e	100	100
82-56	21.6 a	36 ab	648	868 ab	100	100
82-50	21.1 a	36 ab	632	618 e-g	100	100
AVRDC 62 (check)	20.8 ab	34 b	646	746 b-e	100	97
Mean of 23 entries	19.6	36	619	686	99	96
CV (%)	12	5	11	10	10	13

Trial sown August 6, transplanted August 24, 1982 (June trial with the same entries was destroyed by flood).

Table 6. Yield and other horticultural characters of some entries from CAT-III; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Heading rate (%)	Harvest rate (%)
82-74	25.2	36 cd	758	1024 ab	100	100
82-79	26.4	36 cd	818	903 cd	100	100
AVRDC 62 (check)	27.4	33 e	822	728 d-g	100	100
Mean of 25 entries	20.2	36	624	821	99.7	98
CV (%)	14	3	13	6	8	13

Trial sown June 30, transplanted July 11, 1982.

Table 7. Yield and other horticultural characters of some entries from CAT-VI; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Heading rate (%)	Harvest rate (%)
82-159	20.6 a	35	500 b	682	100	100
AVRDC 62 (check)	16.7 b	35	582 a	738	98	83
Mean of 20 entries	13.9	36	429	609	99	99
CV (%)	12	5	11	11	6	11

Trial sown August 2, transplanted August 23, 1982.

In CAT-V, the best two combinations of B 129 with other heat tolerant cultivars were generally inferior to AVRDC 62 in terms of yield and head weight (Table 9). Maturity, heading rates, and harvest rates were comparable.

Conclusions

While no entry dramatically outperformed AVRDC 62 in the combining ability trials, seven new combinations among inbred lines (Tables 5, 6, and 7) merit further study in view of their low soft rot infection rates and good appearance. The selected inbred and open-pollinated combinations with B 129 (Tables 8 and 9) will also be further evaluated in conjunction with the CMS backcross program as possible inbred/variety or variety/variety hybrids.

Table 8. Yield and other horticultural characters of some entries from CAT-IV; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	Heading rate (%)	Harvest rate (%)
82-101	18.2 a-c	35	602 ab	95	83
82-115	18.0 a-d	35	558 b-d	100	97
AVRDC 62 (check)	20.4 a	35	702 a	100	77
Mean of 22 entries	15.8	35	509	98	93
CV (%)	12	5	10	10	12

Trial sown August 2, transplanted August 23, 1982.

Table 9. Yield and other horticultural characters of some entries from CAT-V; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	Heading rate (%)	Harvest rate (%)
82-134	18.5 b	36	574 b	100	97
82-137	18.4 b	35	571 bc	98	97
AVRDC 62 (check)	23.5 a	36	704 a	100	100
Mean of 11 entries	16.5	35	519	99	94
CV (%)	11	7	9	13	17

Trial sown August 2, transplanted August 23, 1982.

Further Improvements of AVRDC Hybrids 58, 59, and 62

Introduction

The search for better combinations with the inbred parents of Hybrids 58, 59, and 62 was continued in 1982. The male parents of these hybrids, only in the S_4 inbred generation, still exhibited a certain degree of heterogeneity that, with further selection, could give the new combinations an advantage (in terms of yield, early maturity, etc.) over the original hybrids.

Materials and Methods

Six combinations selected from the 1981 trial were compared with the original Hybrid 58, and eight and nine combinations were evaluated against Hybrids 59 and 62, respectively. In all trials, plots consisted of four rows, each 4 m long with rows 50 cm apart within double-row beds and plants spaced 40 cm apart within rows. The experimental design was a randomized complete block with three replications.

Results

No advanced combinations of Hybrid 58 significantly outperformed the original hybrid. However, 58-19 was selected for further evaluation against Hybrid 58 to confirm the evidently large differences in yield and harvest rate (Table 10). Coefficients of variation for these traits were rather large in this trial and definitely affected the sensitivity of the test. Combination 58-19 gave 7 t/ha more yield, matured about one week earlier, and had a higher harvest rate than the original Hybrid 58.

Combination 81639 consistently outperformed the original Hybrid 59 (Tables 11 and 12). Differences between the two in yield, maturity, and harvest rate were statistically significant in the early summer trial (partially damaged by flood) but only maturity and non-wrapper leaf weight were significantly different in the late summer trial. Generally, 81639 matured four to six days earlier and had a lower non-wrapper leaf weight and consequently a higher heading efficiency than the original Hybrid 59.

No advanced combination of Hybrid 62 outperformed the original hybrid.

Conclusions

Combinations such as 58-19 and 81639 will be analyzed in more

detail in summer, 1983, and will later replace the original hybrids if the advantages are found to be significant.

Table 10. Comparative performance of an advanced combination of Hybrid 58 against the original hybrid, AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)
58-19	20.0	36	97
Hybrid 58 (check)	12.8	44	71
Mean of 7 entries	16	40	84
CV (%)	32	10	29

Trial sown May 31, transplanted June 17, 1982.

Table 11. Comparative performance of an advanced combination of Hybrid 59 against the original hybrid; AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Soft rot (%)
81639	18.4 a	39 b	92 a	3
Hybrid 59 (check)	8.1 c	45 a	48 c	9
Mean of 9 entries	12.2	42	69	7
CV (%)	30	6	21	35

Trial sown May 31, transplanted June 17, 1982

Table 12. Comparative performance of an advanced combination of Hybrid 59 against the original hybrid (repeat trial); AVRDC, summer 1982.

Entry	Yield (t/ha)	Maturity (DAT)	Head weight (g)	NWL weight (g)	Heading rate (%)
81639	25.0	37 b	801	774 c	100
Hybrid 59 (check)	22.8	41 a	706	1023 a	98
Mean of 7 entries	23.1	40	741	898	99.8
CV (%)	10	3	10	3	6

Trial sown August 6, transplanted August 24.

Cytosterility Backcross Program

Introduction

The cytoplasmic male sterility (CMS) backcross program was designed to replace self-incompatibility (SI) as a mechanism of hybrid production for Chinese cabbage. CMS is more stable than the SI system with respect to environmental fluctuation. Moreover, it is a considerably simpler technology to transfer to cooperating countries.

The most advanced generation, B 8P/6A, of substitution crosses to transfer CMS derived from radish (Raphanus sativus) into the heat tolerant background were made in the 1981-82 cool season. Selections were made from these and other backcross families.

Abnormalities such as poor vigor, chlorosis, vestigial nectaries, etc. have already been reported to accompany CMS derived from radish. Selection for normal forms of these traits (except for functional nectary) has been made in every backcross generation since the inception of the backcross program. A detailed analysis of the defective traits among various backcross generations was conducted to determine if there were appreciable responses to selection.

In view of the abnormal traits in the advanced generations, a new backcross program was begun in 1981 using vigorous CMS lines from the University of Wisconsin, and this program was continued in 1982. In addition, a backcross program begun in 1981 using CMS Brassica juncea (expected to be a better CMS source than radish because of its genetic proximity to Chinese cabbage) was also continued.

Materials and Methods

The advanced B 8P/6A generation includes eight straight crosses with B. pekinensis of which six were made specifically to AVRDC accession B 129. One hundred fifty plants each of four families from an August 24 sowing were transplanted on September 29 along with the recurrent parent for further selection based on general vigor and heading characteristics.

Another four backcross families (generations B 5P/3A to B 7P/3A) with a self-fertile inbred line (7252-1) as recurrent parent were sown and transplanted on the same dates as above for selection purposes. The recurrent parent was included for comparison.

To determine backcross response to selection for normal traits, CMS progenies of the B 5P/3A to B 8P/6A generations were planted on seed flats, after pregermination on petri plates, in a completely randomized design with an unequal number of replications. The recurrent parent, B 129, was included as check. Chlorosis (%) and vigor (expressed as fresh weight in grams per plant of five-plant samples at three sampling dates) were compared among generations and against B 129. Nectary development in different generations was also monitored.

The new program of backcrosses begun in 1981 used CMS lines that had been preselected at the University of Wisconsin for vigor, normal (non-chlorotic) leaf color, and functional nectary. The recurrent parents were two AVRDC heat tolerant inbred lines of poor self-incompatibility but good combining ability. Progenies from 12 families of these crosses were selected for vigor and normal leaf color and are now being monitored for nectary development prior to making additional backcrosses.

In the program of backcrosses with B. juncea, eight BC_1 families of crosses with a line from B 129 were developed in 1981 and 28 selections with normal green leaves are currently undergoing further backcrosses. These vigorous selections were derived from seven families.

Results

The B 8P/6A families expressed overall similarities with the recurrent parent, B 129, although B 8P/6A seedlings were weaker. Generally, all CMS progenies were heading types. Fifteen good heading, vigorous selections were derived from three families for further studies.

The derivatives from backcrosses with recurrent parent 7252-1 were largely similar to the recurrent parent in general appearance but the range of heading was wider. A number of progenies exhibited better vigor than the recurrent parent. A total of eight vigorous heading selections were derived from three families for further backcrosses.

From the selection response study, Figure 1 and Table 13 show the comparative growth rate and degree of chlorosis among CMS backcross derivatives and recurrent parents. Excluding the exceptional behavior of B 6P/4A, an increasing trend of improving vigor (though insignificant among families) was apparent as the number of backcrosses increased. However, the CMS backcross derivatives were still generally weaker than

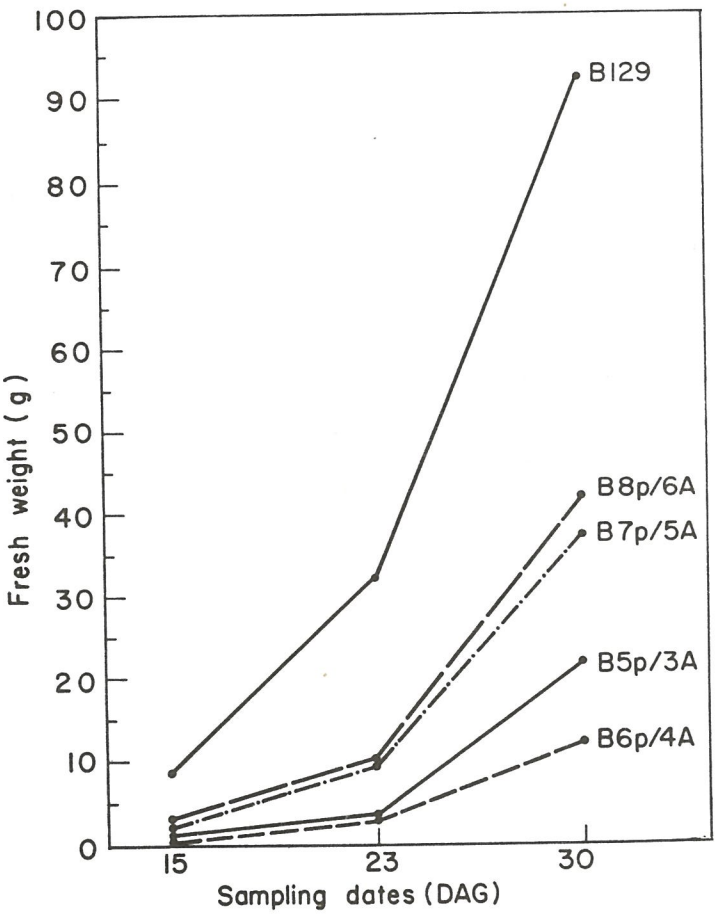


Figure 1. Comparison of the vigor (measured as mean fresh weight) of B 129 and various backcross generations.

Table 13. Comparison of the recurrent parent, B 129, and various backcross generations for chlorosis and vigor.[z]

Generation	Chlorosis (%)	Fresh weight[y] (g)
B 129	0 a	42.7 a
B 8P/6A	36.2 b	18.3 b
B 7P/5A	54.7 c	16.4 b
B 6P/4A	63.0 cd	5.2 b
B 5P/3A	65.2 d	9.0 b
CV (%)	12.1	34.6

[z] Means with different letters are significantly different at P = 0.05 by Duncan's multiple range Test.

[y] Mean of three sampling dates.

the normal recurrent parent. Chlorosis decreased significantly with more substitution crosses to B 129. Table 14 shows the flower size (measured in terms of petal size as a fraction of that of B 129) and number of nectar glands among backcross families. Flowers of CMS progenies were generally about one-third the size of normal B 129 flowers. The number of nectar glands increased substantially from generation B 5P/3A to B 6P/4A, but no apparent change occured thereafter. It must be noted that no previous selection pressure for functional nectary was applied on these families. Other developmental abnormalities such as multiple pistils, unusually swollen stigmas, multiple flowers arising from a single flower, and variation in the number of nectar glands between flowers from a single plant have also been observed.

Table 14. Comparison of petal size and number of nectar glands of flowers of various backcross generations.

Generation	Number of plants	Number of flowers examined	Petal size index[z]	Number of flowers with nectaries			Mean number of nectaries
				0	1	2	
B 5P/3A	8	160	0.32	118	29	13	0.34
B 6P/4A	8	160	0.28	38	47	75	1.23
B 7P/5A	16	320	0.29	96	114	110	1.04
B 8P/6A	19	380	0.35	127	93	160	1.09

[z] The petal size index is based on a value of 1 for B 129.

In the new backcross program, initial observations for vigor and green leaf color of the early generation families show that derivatives from this group may have better potential than those from the CMS sources used earlier. By and large, vigorous progenies with normal green leaves can easily be found. Bee visitations among selected plants are also more frequent than among previous CMS lines, indicating that nectary development is evidently improved.

In the B. juncea backcross program, although some weak plants were still seen in several families, vigorous progenies were readily selectable. Chlorosis (%) was minimal, the highest being 20% in one family. The best family had only 6% chlorotic plants. Among selections, nectary development was much better both in number and size

of nectar glands than in the most advanced CMS lines from radish. Moreover, the best selections showed nectar production, which was rarely seen in the radish-derived CMS families. Certain problems such as small flowers, light yellow petal color, small pods, and multiple pistils were still obvious but these may respond to selection pressure as the genetic background of Chinese cabbage is steadily recovered. Selection for desirable types is being applied on progenies to improve their overall merit.

Conclusions

The most advanced radish-derived CMS families do not appear suitable for further use because of poor vigor, chlorosis, and lack of functional nectaries. New CMS sources, such as those from B. juncea or from radish, preselected for vigor, normal leaf color, and functional nectaries, should prove more utilizable for the development of CMS Chinese cabbage.

Turnip Mosaic Virus Resistance Backcross Program

Introduction

Attempts have been underway to incorporate the turnip mosaic virus (TuMV) resistance of B 141 (Fung Lu) to one of AVRDC's good combining heat tolerant inbred lines (B 18). In 1982, 300 plants of one BC_3 family and 80 plants each of three BC_2S_1 families were grown along with the recurrent and donor parents to select early maturing, heat tolerant, TuMV resistant progenies.

Materials and Methods

Materials were sown on August 24 and transplanted on September 14. The progenies were artificially inoculated with TuMV.

Forty selections were derived from the BC_3 population and twenty-six from the three BC_2S_1 families (Table 15). Field selections were further assayed for TuMV after they started flowering in the greenhouse to insure that only resistant plants are used in further crosses.

Results

Of the 66 selections, only nine were found to be virus-free. Further crosses are now restricted to these plants.

Conclusions

Since the resistance of B 141 is specific only to TuMV strain C-1,

a new backcross program was begun in 1983 using as the resistant donor B 708 (PI 418957), which carries immunity to strains C-1 and C-3 and resistance to C-2 and C-4.

Table 15. Percent TuMV infection among backcross families.[z]

Family	Generation	TuMV (%)	Number of selections	Non-carrier
B 141/B 18	BC_3	85	40	0
B 141/B 18	BC_2S_1	80	13	5
B 141/B 18	BC_2S_1	88	9	3
B 141/B 18	BC_2S_1	82	4	1
B 141 (resistant donor)	-	55	-	-
B 18 (susceptible recipient)	-	100	-	-
B 40 (susceptible and check)	-	100	-	-
Total			66	9

[z] Inoculated on September 7, inoculation repeated on September 27, and symptoms surveyed by plant pathologists on October 8, 1982.

Downy Mildew and Soft Rot Resistance Backcross Program

Introduction

B 639, a Hakuran (*Brassica pekinensis* x *B. oleracea*) accession from Japan, has shown good levels of resistance to downy mildew and soft rot in past trials. This accession was crossed at AVRDC with a local heat tolerant cultivar to develop a heat tolerant population with resistance to these two diseases.

Materials and Methods

The BC_2 population was sown on August 24 and transplanted on September 14 in order to select heading progenies with resistance to both downy mildew and soft rot. Total population size was 500 plants. Soft rot and turnip mosaic virus were artificially inoculated while downy mildew infection was through natural means (no spraying against the disease). The screening for TuMV was only exploratory since the recurrent parent is generally susceptible *per se* but has yielded some resistant plants in screening tests (using strain C-1) at the University of Wisconsin.

A separate backcross program to transfer the downy mildew resistance of B 742 to heat tolerant inbred lines had also been initiated in 1981. Seven selected inbred lines serve as recurrent parents. The F_1 plants from these crosses are currently planted to develop the BC_1 generation. A duplicate field planting (without fungicide spray) was made in the downy mildew nursery to check the general reaction of the F_1 plants compared to the parents.

Results

Ten selections with soft rot resistance or soft rot/downy mildew resistance were taken from the BC_2 population for further backcrosses. Generally, the proportion of heading plants among the survivors after soft rot infection was already high (253/296 or 85%) even with only two backcrosses. The morphotype of Hakuran (very thick, smooth, dark green leaves with few stubby hairs) was observed in only 5% (15/296) of the population which means that the elimination of unpaired chromosomes (C genome type identical to B. oleracea) is likely occurring at a relatively rapid pace. TuMV infection of the BC_2 family was high (92%) indicating the futility of selecting for TuMV resistance among backcross progenies. The soft rot resistance levels of backcross progenies remain high (Table 16).

The intensity of downy mildew infection in this population was not recorded. However, a general impression of the population indicated that highly susceptible types were present in greater frequency than resistant types. Only five of the ten selections carried relatively high levels of downy mildew resistance.

A preliminary survey of the progenies from the downy mildew resistance program with B 742 shows dominance of resistance in some crosses. However, the reactions of some F_1 plants and parents do not conform to this observation. Further analysis of the results is necessary.

Table 16. Soft rot (SR) and TuMV infection levels on Hakuran backcross derivatives.[z]

Family	Generation	TuMV (%)	Soft rot (%)
B 639/B 129	BC_2	92	21
B 639 (SR resistant parent)	-	100	11
B 40 (TuMV susceptible check)	-	100	33
B 141 (SR susceptible check)	-	60	80

[z] Inoculated for TuMV on September 7 and surveyed October 8; inoculated for soft rot on October 15 and surveyed on October 29.

Chinese Cabbage Pathology

Turnip Mosaic Virus Strain Detection

Introduction

In the screening of AVRDC Chinese cabbage germplasm and breeding lines for resistance to turnip mosaic virus (TuMV), an apparent "loss of resistance" was noted (Table 1). The presence of field strains of TuMV other than the strain used in the screening tests was suspected. Therefore an island-wide survey was conducted to detect all possible strains of TuMV present on Chinese cabbage and other commonly grown cruciferous hosts in Taiwan.

Table 1. Reactions of some AVRDC Chinese cabbage accessions to artificial inoculation with TuMV.

Acc. no.	Origin	Type	Disease rating[z]	
			Before 1981	1981
64	Japan	F_1	R,R,R,R,R,R	S
141	Taiwan	F_1	I,I,R,R,R,MS	R,MR
181	USA	OP	R,R,R,R,MR	S
204	Korea	F_1	R,R,R,R,R,R,MR	MS
205	Korea	F_1	R,R,R,R,R,R,R,R,	MS
Hybrid 58	AVRDC	F_1	R,R	MR,S,S,MS,MR
Hybrid 68	AVRDC	F_1	R,R	R,S,S,MS,MR

[z] Ratings based on disease incidence:
I = immune.
R = resistant (0-20% plants infected).
MR= moderately resistant (21-40% plants infected).
MS= moderately susceptible (41-75% plants infected).
S = susceptible (more than 75% plants infected).

Materials and Methods

Isolation of TuMV from field samples: Leaf samples of Chinese cabbage, radish, and tendergreen mustard were collected from AVRDC and the major vegetable production areas of Taiwan. To separate TuMV from other viruses possibly present in the samples, leaf material was

triturated in 0.05 M phosphate buffer (pH 7.0) and rubbed on carborundum-dusted leaves of Nicotiana tabacum White Burley, a non-host for cabbage mosaic virus (CaMV), radish enation mosaic virus (REMV), and turnip crinkle virus. Local lesion formation was a strong indication that TuMV was present.

Those isolates found to be TuMV on the basis of differential host range reactions, serology, and electron microscopy were passed through three successive single local lesion transfers on Chenopodium amaranticolor and maintained on Brassica juncea.

Serology: Agar gel double-diffusion: Crude sap from systemically infected B. juncea plants was triturated in distilled water containing 3% sodiumdodecyl sulfate (SDS). The virus isolates were tested in SDS agar gel double-diffusion tests (0.8% agarose, 3% SDS) against antiserum derived from a Japanese isolate of TuMV (kindly provided by Dr. N. Sako, Saga University, Japan).

Immunoabsorbent electron microscopy (ISEM): Formvar coated carbon stabilized copper grids were floated for five minutes on a drop of antiserum diluted 1:100 in distilled water. The grids were rinsed with 20 drops of phosphate buffer and then floated for ten minutes on a drop of crude extracts from TuMV infected plants. The grids were washed with 40 drops of distilled water and subsequently stained with four drops of 2% uranylacetate in distilled water. The grids were then ready for examination in the electron microscope.

Electron microscopy: For leaf dip preparations, small pieces of virus-infected leaves were chopped with a razor blade in a droplet of 1% aqueous sodium phosphotungstate solution (pH 6.0) on a glass slide. A small quantity of liquid, free of plant debris, was taken up with a fine capillary pipette and placed on a formvar coated and carbon stabilized copper grid. The grids were air dried and examined in a JEM-7 electron microscope.

TuMV strain differentiation: Four of the nine Brassica campestris ssp. pekinensis cultivars used by Provvidenti for TuMV strain classification were chosen for their ability to differentiate TuMV strains (Table 2). Three plants of each cultivar were inoculated with each TuMV isolate. Both inoculated and non-inoculated leaves of symptomless plants were assayed on C. amaranticolor to determine symptomless infection.

Table 2. Reaction of Brassica campestris ssp. pekinensis differential cultivars to four strains of turnip mosaic virus (TuMV) (from Provvidenti, 1980).

Cultivar	Reaction of TuMV strains[z]			
	C-1	C-2	C-3	C-4
PI 418957	I	R	I	R
Tropical Delight	I	S	S	S
Crusader	S	R	S	S
PI 419105	S	R	R	S

[z] I = immune (plants are locally and systemically free of virus).
R = resistant (virus confined to the inoculated leaves).
S = susceptible (virus present in inoculated and non-inoculated leaves).

Results

Based on symptom reactions on the diagnostic host species (Table 3), serological tests, and particle shape (determined by electron microscopy), 56 isolates of TuMV were recovered from a total of 92 leaf samples collected from Chinese cabbage, radish, and tendergreen mustard. TuMV was present in all of the nine major vegetable production areas surveyed (Table 4). All four strains described by Provvidenti were detected (Tables 5 and 6). TuMV strain C-4 was recovered from seven of the nine areas surveyed (Table 6) and accounted for 19 out of 44 single lesion isolates, leading to the conclusion that this is the most prevalent and widespread strain of TuMV in Taiwan (Table 7). Ten of the 44 isolates were strain C-2 and nine isolates were typed C-3. Strain C-1 was detected only once (Table 7). In addition, a fifth strain of TuMV was isolated from Chinese cabbage and mustard (Table 5). It was recovered from five of the 44 single local lesion isolates (Table 7). This strain, tentatively named C-5, systemically infected B. campestris ssp. pekinensis PI 41857, which is immune or resistant to the four TuMV strains isolated and described by Provvidenti in New York State, USA.

Conclusions

TuMV strain C-4, which Provvidenti detected only once in New York, appears to be well established and widely distributed in Taiwan. It is possible that the tentatively named TuMV C-5 strain has differentiated from TuMV C-4.

In previous screenings for TuMV resistance, AVRDC accession B 141 (the Tropicana variety of the Takii Seed Co.) has been used as the resistant check cultivar. According to Provvidenti's scheme for strain differentiation, Tropicana is susceptible to TuMV C-4, tolerant to C-3, and resistant to C-2. It is suspected, therefore, that the strain used in previous screenings was either strain C-2 or strain C-1. The presence in AVRDC fields of TuMV C-3, C-4, and C-5 may explain the apparent loss of resistance of accessions and breeding lines resistant only to TuMV C-2 or C-1. In the future, the stability of the five strains of TuMV so far detected on cruciferous crops in Taiwan must be monitored, as it may be possible that other strains may derive (or may already be present) from the five strains detected so far in Taiwan.

Table 3. Differential host reactions of TuMV isolates recovered from Chinese cabbage, mustard, and radish on Taiwan.

Host plant	Symptoms caused by TuMV isolates[z]
Brassica juncea	-/M or -/M,N
B. napus	-/M
Chenopodium amaranticolor	cL/-
C. quinoa	cL/cL
Datura stramonium	-/-
Gomphrena globosa	nL/-
Nicotiana glutinosa	cS/- or -/M
N. tabacum Xanthi	nL/-
N. tabacum White Burley	nL/- or cL/-
Petunia hybrida	-/M or -/Mo,R
Phaseolus vulgaris Bountiful	-/-
Physalis floridana	cS/- or cS,M/M,Def
Spinacia oleracea	-/- or cL/M
Tetragonia expansa	cS/-
Vigna sinensis Blackeye	-/-
Zinnia elegans	-/M

[z] Symbols for symptoms:
- = symptomless, no virus detected by reinoculating *C. amaranticolor*.
cL = chlorotic lesions.
nL = necrotic lesions.
cS = chlorotic spots.
N = necrosis.
M = mosaic.
Mal = malformation.
Mo = mottle.
R = recovery.
Def = deformation.

Format for symptom symbols:
Reactions on inoculated leaves/reactions on non-inoculated leaves.

Table 4. Recovery of turnip mosaic virus (TuMV) isolates from Chinese cabbage, mustard, and radish field samples collected at nine locations in Taiwan.

Location	No. of samples collected	No. of samples containing TuMV
Yang-Ming-Shan	3	2
Lu-Chou	3	3
Chu-Pei	6	1
Chon-Lin	7	3
Chiu-Ho	8	5
Yon-Chin	6	5
Chia-Yi	4	4
Feng-Shan	1	1
Shanhua (AVRDC)	54	32
Total	92	56

Table 5. Reactions of four Chinese cabbage cultivars to strains of TuMV found on Taiwan.

Cultivar	Reaction[z]				
	T-46	T-37	T-40	T-91	T-42
PI 418957	-/-	(+)/-	-/-	(+)/-	(+)/M
Trop. Delight	-/-	(+)/M,N	(+)/M,N	(+)/M,N	(+)/M,N
PI 419105	-/(+)	(+)/-	(+)/-	(+)/M	(+)/M
Crusader	(+)/M	(+)/-	(+)/M	(+)/M,N	(+)/M

Format for symptom symbols:
Reaction on inoculated leaves/Reaction on non-inoculated leaves.
Symbols for symptoms:
- : no symptoms, no virus recovered by reinoculating C. amaranticolor.
(+): no symptoms, but virus was recovered by reinoculating C. amaranticolor.
M : mosaic.
N : necrosis.

Table 6. Recovery of turnip mosaic virus (TuMV) isolates from Chinese cabbage, mustard, and radish field samples and classification into strains.

Location	Strains of TuMV recovered				
	C-1	C-2	C-3	C-4	C-5
Yang-Ming-Shan			+	+	
Lu-Chou			+	+	
Chu-Pei				+	
Chon-Lin		+		+	
Chiu-Ho			+	+	
Yon-Chin		+	+	+	
Chia-Yi		+	+		
Feng-Shan	+				
Shanhua (AVRDC)		+	+	+	+

Table 7. Frequency of different TuMV strains recovered from 44 single lesion isolates collected in Taiwan.

TuMV strain	Frequency
C-1	1/44
C-2	10/44
C-3	9/44
C-4	19/44
C-5	5/44

Physical Properties, Purification, and Antiserum Production of Turnip Mosaic Virus Strain C-5

Introduction

A previously unreported strain of turnip mosaic virus, TuMV C-5, was detected on Chinese cabbage and mustard in Taiwan. Its physical properties were investigated for comparison with other known strains of TuMV, and purification of TuMV C-5 was attempted for the production of antiserum.

Materials and Methods

Physical properties: Thermal inactivation point, dilution end point, and in vitro longevity were examined from TuMV-infected crude sap (B. juncea) using standard procedures. Results were based upon local lesion development in C. amaranticolor plants.

Purification of TuMV C-5: Systemically infected leaves of B. juncea were used as a source of TuMV C-5. The virus was purified by PEG and Triton X precipitation followed by differential and sucrose gradient centrifugation (Figure 1). The resulting pellets were used for determination of shape, size, and UV absorption and for antiserum production.

Antiserum production: Rabbits were immunized by intramuscular injections of purified virus preparations emulsified with an equal volume of Freund's complete adjuvant. Four injections of 2 ml each were administered at 10-day intervals and antiserum was obtained from blood collected ten days after the final injection. The antiserum titer was determined by ring interface tests.

Results

The TIP, DEP, and LIV of the five strains are shown in Table 8. The partially purified TuMV preparation had a UV absorption curve

Figure 1. Purification scheme for TuMV[1].

Frozen infected leaves (at -21°C)

↓ Homogenize with 1-1.2 (w/v) 0.5 M phosphate buffer, pH 7.5, containing 0.01 M Na-EDTA and 0.1% thioglycollic acid
Filter through two layers of cheesecloth

Crude sap

↓ Centrifuge at 3,200 x g for 10 min

Supernatant

↓ Add 1% Triton X-100, 4% PEG and 1.0 M NaCl
Stir at room temperature for 2-3 hr
Centrifuge at 8,500 x g for 15 min

Pellet

↓ Resuspend in 0.5 M phosphate buffer, pH 7.5, containing 0.01 M $MgCl_2$
Centrifuge at 8,500 x g for 10 min

Supernatant

↓ Centrifuge at 65,900 x g for 90 min

Pellet

↓ Resuspend in 0.5 M phosphate buffer, pH 7.5, containing 0.01 M $MgCl_2$
Centrifuge at 8,500 x g for 10 min

Supernatant

↓ Layer on 10-40% sucrose density-gradient column
Centrifuge at 61,000 x g for 120 min

Viral zone

↓ Dilute with 0.01 M phosphate buffer, pH 7.0
Centrifuge at 69,600 x g for 90 min

Pellet

↓ Diffuse in 0.01 M phosphate buffer, pH 7.0
Centrifuge at 8,500 x g for 10 min

Supernatant (purified virus)

[1] Choi, et al. (1977). Ann. Phytopath. Soc. Japan 43:440-448.

typical for nucleoproteins. It showed a maximum absorption at 268 nm and a minimum absorption at 250 nm. The UV absorption rates $E_{280/260}$ and $E_{max/min}$ were 0.9 and 1.03 respectively (Figure 2).

Table 8. Determination of TIP, DEP, and LIV of five strains of TuMV.

	Local lesion formation on C. amaranticolor				
	C-1	C-2	C-3	C-4	C-5
TIP					
50°C	+[z]	+	+	+	+
55°C	+	+	+	+	+
60°C	+	+	+	+	+
65°C	−	+	−	+	−
70°C	−	−	−	−	−
DEP					
10^{-1}	+	+	+	+	+
10^{-2}	+	+	+	+	+
10^{-3}	+	+	+	+	+
10^{-4}	+	+	+	+	+
10^{-5}	+	+	−	−	−
10^{-6}	−	−	−	−	−
LIV					
1 Day	+	+	+	+	+
2 Days	+	+	+	+	+
3 Days	+	+	+	+	+
4 Days	+	+	+	+	+
5 Days	+	+	+	+	+
6 Days	+	−	−	−	+
7 Days	+	−	−	−	+
8 Days	+	−	−	−	−
9 Days	+	−	−	−	−
10 Days	−	−	−	−	−

[z] Local lesion formation on any of three inoculated leaves of C. amaranticolor.

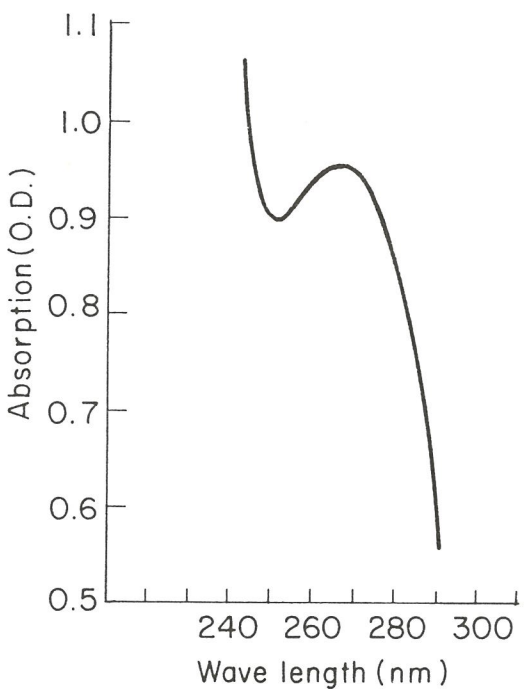


Figure 2.
Ultrabiolet absorption spectrum of partially purified TuMV.

Electron micrographs of negatively stained virus preparations revealed flexuous rods about 700-800 nm long, typical for TuMV.

Antisera with a titer of 1/512 in ring interface precipitin tests were obtained from partially purified TuMV C-5 (Table 9).

Conclusions

The five TuMV strains show some variation in their physical properties. This variation must be taken into consideration in the development of a reliable method for future screening of AVRDC germplasm and breeding lines for resistance to TuMV.

The antiserum produced has a high titer and will be very useful for the detection of TuMV in infected field samples using agar gel double-diffusion, ISEM, or ELISA.

Table 9. Determination of TuMV antiserum titer by ring interface test.

Antigen	Antiserum dilution[z]											
	1	1/2	1/4	1/8	1/16	1/32	1/64	1/128	1/256	1/512	1/1024	1/2048
TuMV infected crude sap	+	+	+	+	+	+	+	+	+	+	±	-
Healthy crude sap	+	+	+	+	±	-	-	-	-	-	-	-
	Normal serum dilution											
TuMV infected crude sap	-	-	-	-	-	-	-	-	-	-	-	-

[z] TuMV C-5 antiserum.

Screening of AVRDC Chinese Cabbage Germplasm for Resistance to Turnip Mosaic Virus

Introduction

Screening for resistance to turnip mosaic virus (TuMV) was discontinued in 1981 because an apparent "loss of resistance" was observed in lines rated resistant to TuMV in previous screenings. In a recent survey for naturally occurring strains of TuMV in Taiwan, five TuMV strains were recovered. Representative isolates of these strains are now being maintained and propagated. Before resuming screening for resistance on a large scale, a reliable method for screening must be established and susceptible and resistant check cultivars must be determined. In this study a small number of AVRDC Chinese cabbage accessions chosen from those previously rated resistant were inoculated with TuMV C-4 and the newly detected strain TuMV C-5, and their reactions were investigated.

Materials and Methods

Twenty plants of each accession were artificially inoculated at the seedling stage (four to six leaves) with sap from B. juncea plants infected with TuMV C-5 or C-4. The inoculum was prepared by grinding 1 g infected plant tissue in 5 ml 0.01 phosphate buffer (pH 7.0). The plants were kept in a growth room (26°C day, 16-20°C night, 9000 Lux) and observed for symptom development. Symptoms were recorded 21 days after inoculation.

Results

The results of the screening are shown in Table 10. No line with resistance to TuMV C-5 was identified. Four lines were resistant to TuMV C-4 but not to C-5, indicating that resistance to TuMV may be controlled by multiple genes.

Conclusions

Resistance to TuMV C-4 appears to be present in AVRDC germplasm. Stable resistance, however, can only be obtained when resistance to several strains of TuMV, especially TuMV C-5, is incorporated into the Center's breeding materials. Therefore the search for resistance to TuMV C-5 must be continued.

Table 10. Screening of Chinese cabbage accessions and breeding lines for resistance to TuMV strains C-4 and C-5.

Acc. no.	TuMV C-4[z]			TuMV C-5[y]		
	Infected plants/total	Percent diseased	rating[x]	Infected plants/total	Percent diseased	Rating[x]
34	12/23	52	MS	11/11	100	S
96 (SCK)	23/23	100	S	18/18	100	S
141	4/22	18	R	10/10	100	S
181	18/23	78	S	9/9	100	S
188	20/30	67	MS	17/17	100	S
521	7/23	33	MR	10/10	100	S
648	3/16	19	R	9/9	100	S
662	9/24	38	MR	3/3	100	S
676	15/21	71	MS	11/11	100	S
685	15/24	63	MS	8/8	100	S
687	9/10	90	S	5/5	100	S
732	13/23	57	MS	7/7	100	S
734	11/23	48	MS	8/8	100	S
738	9/18	50	MS	12/12	100	S
742	2/21	10	R	3/5	60	MS
743	2/14	14	R	3/3	100	S
744	8/24	33	MR	7/7	100	S
747	5/25	20	R	7/7	100	S
749	12/25	48	MS	8/8	100	S
Breeding line						
Hybrid 58R	5/22	23	MR	12/12	100	S
59R	13/22	59	MS	10/10	100	S
62R	14/23	61	MS	11/11	100	S
Pin Luh Sib 1	9/20	45	MS	5/5	100	S
Sib 2	21/23	91	S	9/9	100	S
76M(2)-20-26	12/24	50	MS	9/9	100	S
77M(2/3)-41B-33	16/21	76	S	8/8	100	S
-35	17/24	21	S	7/7	100	S
-36	11/24	46	MS	5/5	100	S
-43L-1-1-1	20/22	91	S	16/16	100	S
77M(3)-26	13/23	57	MS	5/5	100	S
-27	9/27	33	MR	11/11	100	S
77M(3)-27S-33-21	6/21	29	MR	9/9	100	S
-27B-16-2-21	19/22	86	S	7/7	100	S
77M(3)-35	12/23	52	MS	8/8	100	S
77M(3)-38	14/20	70	MS	7/7	100	S
77M(3)-38-11-2-21	14/24	58	MS	7/7	100	S
-38-35-5	9/18	50	MS	4/4	100	S
-38-36-2	20/22	91	S	13/13	100	S
9819-9(C-2-9-9)	9/21	43	MS	4/4	100	S
R-1-8-8-(31)	15/23	65	MS	6/6	100	S

[z] Sown: September 22 (greenhouse)
Inoculated: October 7, TuMV C-4 fresh leaves (1:3)
Symptom recording: October 28, 1982

[y] Sown: October 7 (greenhouse)
Inoculated: October 21, TuMV C-5 fresh leaves (1:3)
Symptom recording: November 26, 1982

[x] Rating is based on disease incidence:
R (Resistant): 0-20% plants infected
MR (Moderately Resistant): 21-40% plants infected
MS (Moderately Susceptible): 41-75% plants infected
S (Susceptible): more than 75% plants infected

Chinese Cabbage Entomology

Screening of Chemical and Biological Insecticides for Diamondback Moth, Cabbage Webworm, and Aphid Control

Introduction

Diamondback moth (Plutella xylostella), aphids (Myzus persicae and Lypaphis erisemi), and cabbage webworm (Hellula undalis) are important insect pests of Chinese cabbage in Southeast Asia. In the past eight years' research, a few promising accessions have been identified that contain some resistance to these pests. However, the low level of resistance and undesirable agronomic characters that seem to be closely associated with the resistance have precluded the use of these materials in AVRDC's breeding program. Moreover, all other control measures tend to be location specific. Research on cultural control of aphids and webworm has led to only limited success. Therefore, no classical entomological research on these insect pests took place during 1982. Rather, ongoing insecticide screening was continued to identify chemicals that, alone or in combination, will control these pests effectively with minimum cost. Since insect pests develop resistance to insecticides if one uses a particular chemical frequently, it is necessary to screen new compounds or their combinations to identify a suitable chemical before insects develop resistance to the ones being used. Described here are the results of three screenings conducted during 1982.

Materials and Methods

Screening procedures were identical to those described in the AVRDC publication "Vegetable Pest Control: Insecticide Evaluation Tests." The chemicals were selected based on their efficacy on the target pests or related species elsewhere. Efforts were made to include chemicals that have non-traditional modes of action. Two trials were conducted in the cool season for diamondback moth and aphid control, and one in the summer for cabbage webworm control. The details of the experimental

conditions are listed as footnotes accompanying the results of each test.

Results

Test 1: The results are summarized in Table 1. Among nine insecticides and their combination treatments, Bacillus thuringiensis and decamethrin gave better control of diamondback moth than other chemicals. At this time the aphid population was still low and the efficacy of the insecticide could not be ascertained reliably. All treatments, including untreated checks, gave good yields.

Test 2: The results are summarized in Table 2. Bacillus thuringiensis alone gave good control of diamondback moth, especially when the population was very high. Contrary to the previous test, the decamethrin spray alone or in combination with B. thuringiensis did not control diamondback moth.

Aphids were the dominant pests during this screening. Decamethrin alone at 0.025 kg ai/ha, at the same concentration in combination with B. thuringiensis, and the combination of diflubenzuron and triazophos gave fairly good control of aphids. In these three treatments alone the yields were significantly higher. Diflubenzuron alone did not control aphids.

Test 3: The results are summarized in Table 3. This test was conducted during the summer to control cabbage webworm which infests Chinese cabbage and other crucifers mainly during hot and humid weather. However, this year the webworm population was low. Therefore, laboratory reared diamondback moths were released. As in the preceeding tests, aphids were the dominant pests. The insecticides that gave best aphid control also gave better yields. Parathion gave the best control of aphids. Triazophos alone or triazophos + diflubenzuron also gave good control of aphids, although diflubenzuron alone was not effective. Because of the relatively low diamondback moth population, the results on the chemicals' effectiveness in controlling this pest were inconclusive. Servere aphid damage weakened plants seriously, thus the diamondback moth damage or population build-up was restricted.

Conclusions

Bacillus thuringiensis gave some control of diamondback moth. Its application must be adjusted for better results. Triazophos and parathion gave the best control of aphids.

In tropical Southeast Asia, diamondback moth is a severe insect pest of Chinese cabbage and other crucifers. This insect has developed resistance to many insecticides. In Taiwan, diamondback moth infestation is considerably reduced by severe aphid infestation. It is therefore not possible to get clearcut information on diamondback moth control in insecticide screening trials at AVRDC, as no insecticide exists that will selectively kill aphids only. Since the nature of diamondback moth damage is similar in Chinese cabbage and common cabbage, the latter, which is moderately resistant to aphid infestation, will be used in future insecticide screenings for diamondback moth control.

Table 1. Evaluation of insecticides for the control of diamondback moth and aphids on Chinese cabbage.[z-u]

Insecticides	Rate (kg ai/ha)	Diamondback moth larvae+pupae/10 plants		No. infested plants/10 with estimated number of aphids 3/1/82				Yield (t/ha)
		2/16/82	3/1/82	0-10	11-100	101-1000	1000+	
Cypermethrin 5EC	0.05	10.00ab	44.25bc	5.00b	2.25ab	0.25ab	2.50a	70.5
MIPC 50WP	0.8	11.75ab	75.25abc	4.50b	3.75ab	0.75ab	1.00ab	70.8
BPMC 50WP	0.8	15.25ab	103.00ab	5.25ab	4.50a	0.00b	0.25b	72.5
MIPC+malathion	0.4+0.5	14.50ab	123.50a	5.50ab	4.50a	0.00b	0.00b	65.7
BPMC+malathion	0.4+0.5	16.00ab	97.00abc	5.75ab	3.50ab	0.75ab	0.00b	69.9
Malathion 50EC	1.0	16.50a	94.00ab	4.75b	4.75a	0.50ab	0.00b	66.2
Bacillus thuringiensis (Bt)	0.5	2.25b	17.50c	8.25a	1.25b	0.25ab	0.25b	77.9
Decamethrin 2.8EC	0.025	16.75a	69.25abc	4.25b	2.75ab	1.00ab	1.75ab	72.9
Bt+Decamethrin	0.5+0.025	3.75ab	20.50c	6.75ab	1.75b	1.00ab	0.50ab	74.1
Control		14.75ab	91.00ab	3.50b	3.25ab	1.50a	1.75ab	63.7

[z] Cultivar: New King.
[y] Transplanting date: 12/30/81.
[x] Insecticides applied: 1/14/82, 1/21, 1/28, 2/4, 2/11, 2/18, 2/25.
[w] Harvest date: 3/2/82.
[v] Data shown are means of four replicates. Means in each column followed by the same letter are not significantly different at the 5% level.
[u] plot size: 15 m^2.

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

Insecticides	Rate (kg ai/ha)	Diamondback moth larvae+pupae/10 plants		No. infested plants/10 with estimated number of aphids			Harvestable heads (%)	Yield (t/ha)
		4/7/82	4/22/82	4/7/82				
				0-100	101-1000	1000+		
B. thuringiensis (Bt)	0.5	0.75b	13.50c	0.25	0.00	9.75a	19.50b	3.50c
Bt + Decamethrin 2.8EC	0.5+0.010	7.25ab	51.50bc	0.00	1.00	9.00ab	38.75b	10.10c
Bt + Decamethrin 2.8EC	0.5+0.025	13.00ab	49.00bc	0.00	2.00	8.00b	64.50a	22.70b
PH60-44 25WP	0.075	12.50ab	82.25b	0.00	0.50	9,50ab	21.75b	3.28c
PH60-44 25WP	0.150	12.50ab	78.50b	0.00	0.25	9.75a	13.50b	2.30c
Diflubenzuron 25WP	0.075	10.50ab	84.25b	0.00	0.25	9.75a	14.50b	2.93c
Diflubenzuron 25WP	0.150	18.75a	47.75bc	0.00	0.25	9.75a	33.50b	7.75c
Diflubenzuron 25WP + Triazophos 30WP	0.075+0.25	8.00ab	81.00b	1.00	4.00	5.00c	67.25a	31.40a
Decamethrin 2.8EC	0.025	16.50a	142.50a	1.50	2.25	6.25c	73.00a	21.60b
Control		6.50ab	90.50b	0.00	0.50	9.50ab	14.75b	3.03c

[z] Cultivar: New King.
[y] Transplanting date: 2/26/82.
[x] Insecticides applied: 3/12/82, 3/19, 3/26, 4/2, 4/9, 4/16, 4/23.
[w] Harvest date: 4/29/82.
[v] Data shown are means of four replicates. Means in each column followed by the same letter are not significantly different at the 5% level.
[u] Plot size: 15 m^2.

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

Insecticides	Rate (kg ai/ha)	No. of diamondback moth larvae+pupae/10 plants		No. of infested plants/10 with estimated number of aphids/plant				Yield (t/ha)
		8/31/82	9/20/82	0-10	11-100	101-1000	1000+	
Diflubenzuron 25WP	0.075	1.50ab	10.00ab	0.00	0.00	0.00	10.00a	7.55c
Triazophos 30WP	0.25	2.00ab	10.50ab	4.75	2.75	1.75	0.75c	24.74a
Diflubenzuron+Triazophos	0.075+0.25	1.50ab	11.00ab	1.75	3.50	4.50	0.25c	25.85a
B. thuringiensis	0.5	0.50b	3.50c	0.00	0.00	0.00	10.00a	6.21c
PH60-44 25WP	0.10	1.25ab	5.00bc	0.00	0.00	0.00	10.00a	8.37c
Larvin 75WP	0.5	3.50a	13.75a	0.00	0.00	0.75	9.25a	7.44c
Cypermethrin 5EC	0.05	3.25a	13.75a	0.00	0.00	2.25	7.75b	17.39b
Cypermethrin + Bt	0.05+0.5	1.25ab	15.50a	0.25	0.50	0.25	9.00a	15.29b
Parathion 47EC	0.5	1.25ab	3.75c	7.00	2.25	0.75	0.00c	26.01a
Control		1.75ab	3.25c	0.00	0.00	0.00	10.00a	5.94c

[z] Cultivar: AVRDC #58.
[y] Transplanting date: 8/9/82.
[x] Insecticides applied: 8/12/82, 8/20, 8/27, 9/3, 9/10.
[w] Harvest date: 9/20/82.
[v] 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.
[u] Plot size: 15 m^2.

Chinese Cabbage Physiology

Effect of Temperature on Mineral Levels in Chinese Cabbage

Introduction

Genetic and environmental factors can influence plant nutrient uptake and photosynthate distribution, and consequently alter growth. The pattern of mineral levels under different temperature conditions was studied to facilitate the improvement of heading ability through cultural practices along with the use of heat tolerant varieties.

Materials and Methods

Two entries, one heat tolerant (F_1-58) and one heat sensitive (B-6), were cultured in sand and fertilized with Hoagland's No. 1 solution. One week after transplanting, part of the materials were placed in the greenhouse and part in the heat compartment of the greenhouse. Temperature conditions of both environments are shown in Figure 1. Six plants were sampled after 10, 20, 30, and 40 days. Leaves, stems, and roots were separated for analysis of N, K, Ca, and Mg contents.

Results

High temperature decreased the N and K contents in the roots but increased the K content in the outer leaves and the Ca content in the roots of both entries. Comparing the two entries, B-6 contained less N in the roots and less K in the roots and stem under both temperature conditions. Mineral levels seemed to be more influenced by high temperature in B-6 than in F_1-58. No difference in Mg content was found between the two entries or the two temperature treatments.

Conclusions

Heat causes changes in N, K, and Ca contents in Chinese cabbage. The roots are more influenced by heat than the aerial parts. Since these elements have been related to temperature stress resistance (N, K, Ca), ion uptake (K), and carbohydrate translocation (K), their levels may play an important role in the heading mechanism of Chinese cabbage.

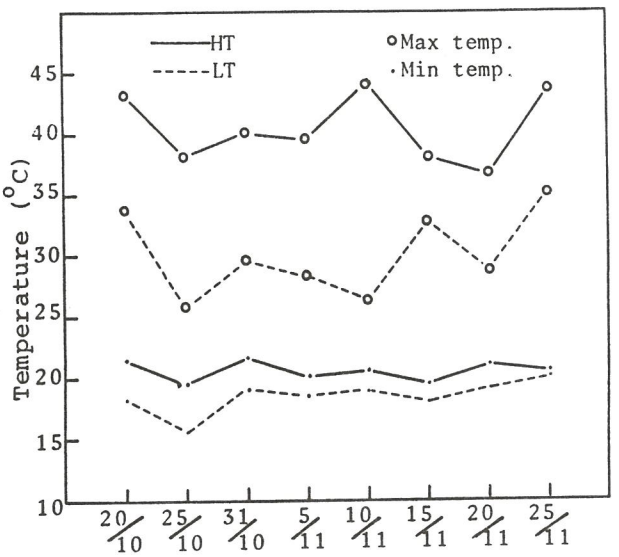


Figure 1.
Maximum and minimum temperatures of two experimental conditions in the study of mineral contents of Chinese cabbage.

Table 1. Effect of temperature on mineral contents in Chinese cabbage roots.[z]

Entry & treatment	Days after transplanting			
	10 days	20 days	30 days	40 days
		Nitrogen		
B-6, HT	2.07	1.95	1.59	1.44
B-6, LT	2.34	2.66	3.00	2.40
F_1-58, HT	2.27	2.16	2.07	2.07
F_1-58, LT	2.32	2.46	2.72	2.38
		Potassium		
B-6, HT	0.88	0.94	0.99	0.55
B-6, LT	1.12	1.60	1.80	1.07
F_1-58, HT	1.07	1.33	1.22	0.99
F_1-58, LT	1.35	1.19	2.02	1.27
		Calcium		
B-6, HT	7.55 a	9.92 a	6.07 ab	6.15 ab
B-6, LT	6.93 b	6.36 b	4.32 b	5.38 b
F_1-58, HT	9.37 a	8.24 ab	7.96 a	7.04 a
F_1-58, LT	6.87 b	8.34 ab	5.24 ab	5.33 ab

[z] Separation of means in each column by Duncan's multiple range test, 5% level.

Table 2. Potassium contents in stems and outer leaves of two Chinese cabbage entries under high and low temperature treatments.

Entry & treatment	Days after transplanting			
	10 days	20 days	30 days	40 days
		Stems		
B-6, HT	5.87	4.78	3.78	3.02
B-6, LT	6.66	4.98	3.85	3.97
F_1-58, HT	5.98	7.81	5.12	4.89
F_1-58, LT	6.66	9.48	5.07	4.50
		Outer leaves		
B-6, HT	-	8.32	8.36	8.11
B-6, LT	-	8.63	7.48	7.25
F_1-58, HT	-	8.20	8.30	7.72
F_1-58, LT	-	8.17	7.84	7.37

Sweet Potato Breeding

Hybridization and Outcrossing Populations

Feedback information from international cooperators has indicated that the high yielding orange-fleshed AVRDC sweet potato lines usually do not have the flavor and dry texture of preferred varieties. Crossing efforts in 1981-82 were therefore concentrated on improving eating quality. To increase seed production and to avoid laborious hand crossings, beginning in September, 1982, paired crosses were used in the isolated open field for some of the important cross combinations. In addition, polycrossing nurseries were established for improving certain inherited quantitative traits such as protein, sugar content, and stress resistance. Polycrossing was much more labor-efficient for gathering sweet potato seeds.

A total of 149,579 true seeds were collected in 1982. Twenty-six cross combinations were successfully made with hand crossing, producing 10,619 botanical seeds (Table 1). Tainung #57 was used as a major source for improving eating quality and flavor. I 117 was a source for witches' broom resistance. I 55 and I 92 were resistance sources for stem borer, but unfortunately no seeds could be obtained from these crosses.

Three outcrossing nurseries were established in 1981 for developing weevil resistant, dessert, and low sugar lines. A total of 18,978 true seeds were obtained from these polycrossing nurseries. In addition, 120,000 more open-pollinated seeds were gathered from the parental stocks in the hand crossing blocks. Selections of true seed materials from South Carolina were also maintained in a master polycrossing nursery. All clones were grafted on a free-flowering sweet potato root stock (I 172) to induce blooming in isolated fields.

Difficulties were again encountered in inducing and synchronizing sweet potato blooming. The incompatibility between certain parental clones also jeopordized crossing efforts. These problems require further study.

Table 1. Sweet potato hand crossing results, 1982.

Kind of cross	No. of crosses[z]	No. of seeds
To improve β-carotene and sugar content	4	2,286
To combine dryness & orange flesh-color	4	1,592
To raise dry matter content	2	2,078
To incorporate weevil resistance	5	1,734
To incorporate witches' broom resistance	3	1,782
To develop lines for vegetable greens	8	1,147
Total	26	10,619

[z] Not including reciprocal crosses.

Rapid Dry Matter Determination

Introduction

Unlike major grain staples, high moisture content in most root and tuber crops is an important disadvantage. The dry matter content of sweet potatoes ranges from 20 to 40%, but most AVRDC orange-fleshed advanced breeding lines contain less than 25%. These low dry matter lines are generally poor in eating and storage qualities and are more susceptible to pests and diseases in wet soil conditions than high dry matter lines. In addition, dry matter content is important in starch or feed cultivars. A 30% dry matter cultivar yields 50% more products or energy than a 20% cultivar. To raise dry matter content in breeding populations, screenings should be started from the seedling stage, as this trait is relatively stable over different environments. However, rapid and accurate determination methods must be developed in order to evaluate tens of thousands of seedlings in the field. The specific-gravity method used for white potato was therefore adopted and tested in seedling screenings during 1982.

Materials and Methods

In the first experiment, various sizes and portions of mature roots from 14 different sweet potato cultivars were used to determine the correlation between specific gravity and dry matter content. In the second experiment, roots from seedlings sized from 20 to 150 gms were used to determine the relationship between dry matter content and specific gravity, root size, and flesh color. The experiments were repeated three times at 24-27^{o}C using sodium chloride and alcohol to adjust the specific gravity of water from 0.940 to 1.050.

Results

Specific gravity correlated best to the dry matter contents of the cultivar for large and small whole roots (r = 0.728 and 0.866, respectively). Half roots gave the poorest correlation to the dry matter content of the whole roots (Table 2).

Specific gravity readings correlated well to the dry matter content of the seedling roots (r = 0.788, r^2 = 0.62). Root size, for seedling roots ranging from 20 to 150 g, does not affect the estimation. Dry matter content was found to be negatively correlated with intensity of orange flesh color (r = -0.618) and positively correlated with yellow flesh color (r = 0.576) (Table 3, Figure 1).

Table 2. Correlation between specific gravity (X) and dry matter content (Y) of various sizes of sweet potato root.[z]

Sample	r^2	r	Probability	CV (%)	Equation
Large root	0.530	0.728	0.0001	17.7	r = -138+161.956X
Half root[y]	0.500	0.707	0.049	11.2	-
Slice[x]	0.372	0.610	0.0001	24.8	-
Small root	0.750	0.866	0.0001	14.2	r = -114.579+139.597X

[z] Data obtained from means of 14 cultivars, replicated four times at 24°C.
[y] Longitudinal section of roots.
[x] Central cross-section, 2 cm thick.

Table 3. Relationship among dry matter content, specific gravity, root size, and flesh color of seedling sweet potato roots.[z]

Variables	Specific gravity	Root fresh wt.	Root dry wt.	Flesh color intensity[y]	
				Orange	Yellow
Dry matter	0.788**	-0.209^{NS}	0.213^{NS}	-0.618**	0.576**
Specific Gravity	(1.000)	-0.271^{NS}	0.030^{NS}	-0.614**	0.536**

[z] ** = significant at P = 0.01.
NS = non-significant at P = 0.01.
[y] Color intensity was rated on a 1-7 scale where 1 = low intensity (light colored).

Conclusions

Specific gravity is a good indication of the dry matter content of sweet potato roots. As dry matter content is known to be a heritable

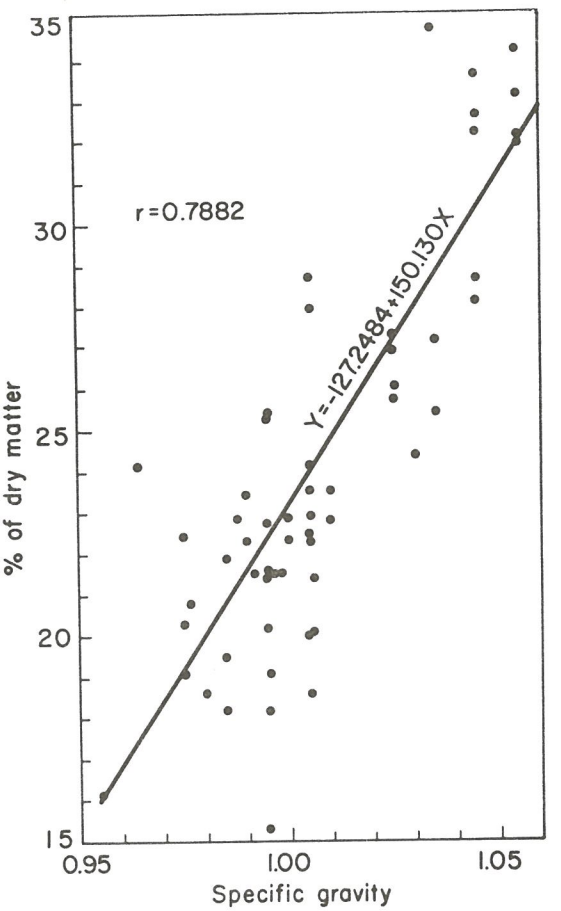


Figure 1. Correlation between specific gravity and dry matter content of sweet potato seedling roots.

trait and relatively stable in different years, this method can be used as a rapid preliminary method for the screening of high dry matter clones at the seedling stage in the field.

The relationship between dry matter content (Y) and specific gravity (X) is: Y = -127.2484 + 150.130X. Brine solution at specific gravity = 1.02 is an optimum concentration for screenings for dry matter content higher than 26% at 24°C.

Orange-fleshed clones were found to usually have less dry matter than the yellow-fleshed types. It is more difficult to obtain high dry matter lines with deep orange flesh. The optimum specific gravity for screening is 1.000 for DM = 23% in the population at early generation.

This method is particularly useful for screening large seedling populations. It cannot be applied to determine the real dry matter content of large roots, however, as specific gravity would be affected by variation in air spaces in the roots.

Dry Season Yield Trials

Introduction

The dry season, starting from early August to October, is the best time to plant sweet potatoes in southern Taiwan. To evaluate the yield potential and horticultural characteristics of promising breeding materials under favorible environments, preliminary and advanced yield trials were continued in this season. Major efforts were placed on improving dry matter content and eating quality in these trials.

Materials and Methods

Sixty-one entries were entered in preliminary yield trials transplanted on September 1, 1981 and harvested on December 31, 1981, with two replicates.

Twenty-two breeding lines selected from 1980-81 yield trials were entered in advanced yield trials grown from September 15, 1981 to January 13, 1982 (121 days).

Based on their performance in the 1981 preliminary and advanced trials, 18 entries were selected for further evaluation in 1982 advanced yield trials from August 26 to December 23 (120 days). All entries in both plantings were replicated four times.

Results

Preliminary yield trials: The eight highest yielding lines were selected from 61 entries in the 1981 preliminary trials. Most of these lines yielded better than the control cultivars, but their dry matter contents were generally lower (Table 4).

Advanced yield trials: In the 1981 trials, the nine best lines were selected based on superior yield and horticultural traits. The dry matter content of this population was also lower than that of the local control cultivar (Table 5).

Eleven elite lines were selected from the advanced yield trials in 1982. Six yielded more than 30 t/ha, which is significantly higher than the AVRDC control cultivar AIS 0122-2 and the local control Tainung 65. The dry matter content of this population was also comparable to or higher than the control's (Table 6).

Conclusions

In the two years' yield trials involving 100 breeding lines, seven elite selections were recommended to scientists at AVRDC and cooperators

Table 4. The eight highest yielding sweet potato breeding lines in the preliminary yield trials of fall, 1981.[z]

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 975-5	AIS 01-2/B-6712	32.6*	22.9-	O_3
CN 1055-8	B6708(OP)//Tainung 27/HDK 8///Taiwan 2/B 6708(OP)	26.5*	15.6	Y_4
CN 995-28	AIS 209-3/PI 344129	25.9*	20.0-	O_6P_1
CN 995-23	AIS 209-3/PI 344129	25.2*	18.8-	O_6
CN 1022-4	Taiwan 2/B 6708(OP)// B 7078/Tainung 56	25.2	26.1*	Y_1
CN 1028-15	PI 344129/B 6708(OP)// I 57(OP)-4	19.9	23.3	Y_6O_1
CN 1038-16	PI 344129//Red Tuber Tail/ OK 6-3-118///AIS 057-4	19.6	26.2	Y_4P_1
CN 1086-5	Poly Tainung 57(2)/PI 344129	16.0	22.8-	Y_2O_2
AIS 35-2	HDK 6/B 6708	7.5	27.9	O_6
Tainung 62	-	21.8	23.2	Y_2P_1
Tainung 60	-	20.0	20.7	Y_1

[z] Selections from 61 entries, planted on September 1, 1981, harvested on December 28, 1982 (119 days), replicated two times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

Table 5. The nine highest yielding breeding lines in the advanced yield trials of fall, 1981.[z]

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 708-20	PI 344129/B 7078(OP)	23.32*	18.5-	Y_4
CN 913-7	PI 344129//Red Tuber Tail /OK 6-3-118///B 6712	20.5	24.1-	Y_2
CN 941-32	PI 286621 (OP)	19.83*	22.5-	Y_5O_3
CN 591-28W	Poly Tainung 57 (2)	19.4	25.6-	W
CN 876-10	PI 344129(OP)/PI 286621	16.6*	26.3	Y_6
CN 942-47	B 6712 (OP)	16.06*	24.5-	Y_5O_3
CN 854-13	PI 344129/PI 315342 //PI 318856	15.1*	27.9	Y_6O_1
CN 854-15	PI 344129/PI 315342 //PI 318856	14.3*	27.9	Y_6
CN 934-29	Dilaw/Kuangkong	14.0*	29.8*	Y_1
Tainung 57	-	8.58	27.0	Y_6O_1
AIS 0122-2	Southern Queen/ OK 6-3-106	18.9	17.1	O_6

[z] Selections from 22 entries, planted on September 15, 1981, harvested on January 13, 1982 (121 days), replicated four times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at p = 0.05 in the same trial.

Table 6. The highest yielding breeding lines in the advanced yield trials of fall, 1982.[z]

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter (%)	Flesh color
CN 995-23	PI 344129/Dilaw	39.9*	20.0	O_6
CN 591-28W	Poly Tainung 57 (2)	38.1*	25.6	Y_4
CN 1108-13	PI 344129//HDK 6/B 7078 ///Tainung 63	35.1*	25.0	O_3Y_3
CN 941-32	PI 286621 (OP)	34.1*	22.5	WP
CN 1028-15	PI 344129/B 6708 (OP) //I 57 (OP)-4	33.1*	23.3	O_3Y_3
CN 913-7	PI 344129//Red Tuber Tail /OK 6-3-118///B 6712	30.8*	24.1	Y_3P
CN 1232-9	Centennial/OK 6-3-106// Kyushu No. 12 (OP)	28.4*	28.3	Y_3
CN 1038-16	PI 344129//Red Tuber Tail /OK 6-3-118///AIS 057-4	28.1	26.2	Y_5O_1P
CN 946-13	AIS 057-4/PI 344129	27.7	26.0	Y_3O_2P
CN 934-29	Dilaw/Kuangkong	21.0	29.8	Y_4P_2
CN 942-47	B 6712 (OP)	18.8-	24.5	Y_4O_3

[z] Selections from 18 entries, planted on August 26, 1982, harvested on December 23, 1982 (120 days); replicated four times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

for growing in the dry season. Among them, lines CN 1108-13 and CN 995-23, which have orange flesh color and fairly good taste, were recommended for use as dessert cultivars. Lines CN 1028-15 and CN 1232-9, which had a mean yield of 27 t/ha and moderately dry texture, were recommended for staple use. CN 1038-16, CN 941-32, and CN 591-28W were recommended as feed cultivars. In selections CN 1108-13 and CN 1028-15, orange flesh color was successfully combined with slightly dry texture; both have more than 26% dry matter content (Table 7).

The vine/root ratio can be used as a good yield indicator in early selections. To select high yielding lines with better plant type, it is better to select for phenotypes having smaller vine/root ratio rather than to select for small vines alone (Figure 2).

Table 7. Horticultural characteristics of the recommended breeding lines of the dry season trials.

AVRDC selection or accession no.	Mean marketable yield in dry season[z] (t/ha)	Dry matter (%)	Flesh color	Taste	Type
CN 1108-13	23.0	26.5	light orange	good-slightly dry	dessert
CN 995-23	32.5	19.0	deep orange	fair-moist	dessert
CN 1028-15	27.0	26.3	light orange	good-moderately dry	staple & feed
CN 1232-9	28.4	26.1	yellow	fair-moderately dry	staple & feed
CN 1038-16	24.0	26.6	yellow	poor-dry	
CN 941-32	27.0	24.6	white	fair-moist	feed
CN 591-28W	28.2	21.4	yellow	fair	feed

[z] Mean yield of the two years' trials.

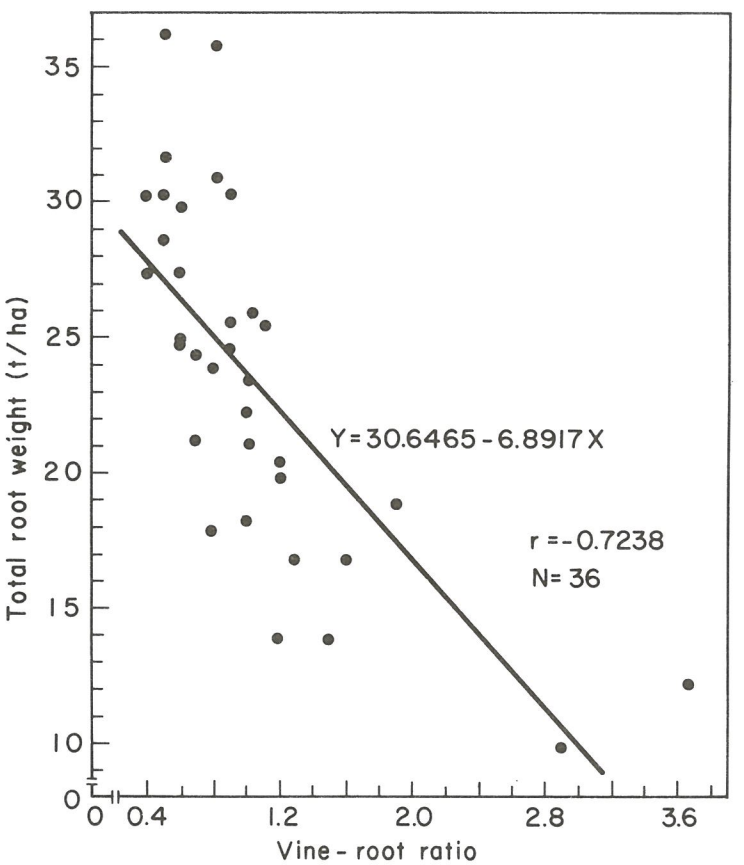


Figure 2. Correlation between vine/root ration and total root weight in sweet potato.

Good progress was made in raising dry matter content and yield of the breeding populations. Population mean for dry matter was raised from 22.1% in 1981 to 28.1% in 1982 in the preliminary lines. More importantly, the mean in net dry matter production (marketable root yield x % dry matter) increased from 2.93 t/ha to 6.30 t/ha in the

preliminary lines and to 6.58 t/ha in the advanced lines. The maximum dry matter yield obtained was close to 13 t/ha. The extraordinarily high yield potential and fast progress made indicate the possibility of developing high yielding cultivars to replace imported grain for feed or industrial uses in the tropics (Figures 3 and 4).

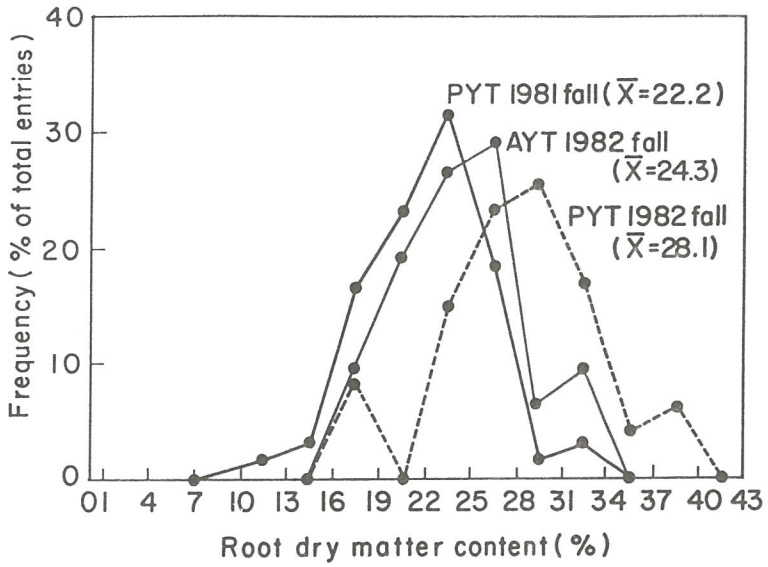


Figure 3. Distribution of dry matter content in various sweet potato populations.

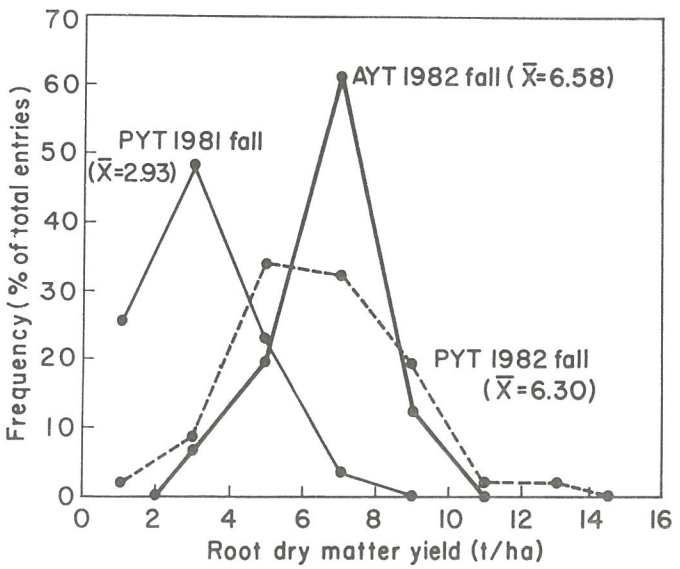


Figure 4. Distribution of the total dry matter yield in various sweet potato populations.

Wet Season Yield Trials

Introduction

Selection for adaptation to hot, wet environments is one of the most important breeding objectives of the variety development program. In Taiwan, the wet season lasts from the end of spring to late summer. Precipitation during this period is usually about 1,500 mm and the temperature ranges from 25 to 35°C. Many of the important sweet potato growing areas in Southeast Asia and the Pacific have a similar adverse environment which is responsible for the low average yield of sweet potatoes. Wet season trials were conducted during this period to select cultivars adapted to this environment.

Materials and Methods

Sixty entries were included in spring preliminary trials from February 23 to July 5 (133 days). Another 23 advanced lines were evaluated in advanced trials, using four replications, from February 25 to July 6, 1982 (134 days).

Most of these entries were repeated, with a number of additional entries, in summer preliminary and advanced trials planted on June 1 and harvested on September 27, 1982 (119 days). Only lines with superior dry matter content were entered in the summer preliminary trials.

Results

Spring trials: In preliminary trials, the marketable root yield of the 60 entries ranged from 0.9 t/ha to 36.6 t/ha with mean yield of 10.2 t/ha. The mean dry matter content of this population was 24.1%. Seventeen lines with superior yield and dry matter contents were selected for further evaluation. Five of the 17 selections were orange-fleshed and the remainder were yellow (Table 8).

In advanced yield trials, marketable root yield ranged from 2.9 to 39.7 t/ha. The mean yield and mean dry matter content were 15.2 t/ha and 22.2%, respectively. Six selections yielded more than 20 t/ha. Selections CN 708-20, CN 942-47, CN 1108-13, and CN 1028-15 show promise for superior yield and good horticultural traits. All of the control cultivars yielded less than 10 t/ha (Table 9).

Table 8. Selected breeding lines in spring, 1982 preliminary yield trials.[z]

AVRDC selecton or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 1232-9	Centennial/OK 6-3-106// Kyushu No. 12(OP)	19.9	23.5^{-}	Y_3
CN 1280-4	Centennial/OK 6-3-106// Ku Kei No. 53	19.6^{-}	22.2	Y_3
CN 1232-3	Centennial/OK 6-3-106// Kyushu No. 12(OP)	19.2	19.7^{-}	Y_3
CN 1275-16	Bagui 01/PI 344129/	19.1^{-}	23.3	Y_6O_4
CN 1254-5	Nun Lin #25/Poly I 171	17.8	25.7^{-}	Y_4O_1
CN 1274-4	Bagui 01//PI 344129/ Tainung New 31	14.5^{-}	28.9*	Y_5O_1
CN 1219-4	Ku Kei No. 63/ Poly Tainung 57(2)	12.1^{-}	23.6	Y_3
CN 1216-10	Ku Kei No. 63// Centennial/OK 6-3-106	12.0^{-}	24.1	Y_3
CN 1221-2	Nun Lin No. 17(OP)/ Ku Kei No. 63	12.0^{-}	28.6*	Y_3
CN 1217-2	Ku Kei No. 63// PI 344129/Tainung New 31	10.5^{-}	30.5*	Y_1
CN 1253-1	Nun Lin #25/Kyushu No.12(OP)	9.1^{-}	37.8	Y_3
CN 1190-3	Poly Tainung 57(1)// HDK 6/B 6708	8.9	24.0	O_4
CN 1182-3	B 6708/OK 9-3// B 6708(OP)/PI 344129	8.1	23.2	Y_4O_4
CN 1221-1	Nun Lin No. 17(OP)/ Ku Kei No. 63	7.2^{-}	32.9	Y_2
CN 1254-2	Nun Lin #25/Poly I 171	4.7^{-}	32.1	Y_5
CN 1229-9	Centennial/OK 6-3-106// Ku Kei No. 63	4.6^{-}	27.3	Y_2
CN 1229-16	Centennial/OK 6-3-106// Ku Kei No. 63	3.6^{-}	32.3	Y_5
AIS 35-2	HDK 6/B 6708	5.5	22.5	O_5
Tainung 63	-	5.9	26.6	O_4
AIS 0122-2	Southern Queen/OK 6-3-106	21.0	17.3	O_6

[z] Selections from 60 entries, planted on February 23, 1982, harvested on July 5, 1982 (133 days), replicated four times.

[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

Table 9. The ten highest yielding breeding lines in spring, 1982 advanced yield trials.[z]

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 1055-8	B 6708(OP)//Tainung 27/ HDK 8///Taiwan 2/B 6708(OP)	39.7*	19.0	Y_4
CN 708-20	PI 344129/B 7078(OP)	33.3*	25.8	Y_6
CN 995-23	AIS 209-3/PI 344129	27.2*	17.6	O_4
CN 942-47	B 6712(OP)	24.8*	27.3	O_3Y_2
CN 1108-13	PI 344129//HDK 6/B 7078 ///Tainung 63	21.4*	17.1	O_3Y_2
CN 1028-15	PI 344129/B 6708(OP) //I 57(OP)-4	20.3	20.5	O_2Y_3
CN 913-7	PI 344129//Red Tuber Tail/OK 6-3-118///B 6712	19.7	26.6	Y_3
CN 946-13	AIS 057-4/PI 344129	17.6*	24.0	O_2Y_2
CN 941-32	PI 286621(OP)	16.2	30.1*	WP
CN 1038-16	PI 344129//Red Tuber Tail /OK 6-3-118///AIS 057-4	14.8	23.8	Y_4
AIS 35-2	HDK 6/ B 6708	9.4	20.8	O_6
Tainung 57	-	9.9	22.2	Y_6O_1

[z] Selections from 23 entries, planted on February 25, 1982, harvested on July 6, 1982 (134 days), replicated four times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

Summer trials: The mean yield of 32 entries was 8.4 t/ha and individual yields ranged from 0 to 21.2 t/ha. Mean dry matter content of this population was 27.6%. From these entries ten superior lines were selected (Table 10).

In the advanced yield trials, marketable root yield ranged from 6 to 28.1 t/ha. The mean yield and mean dry matter content were 17.3 t/ha and 24.2%. Eight of the highest yielding lines with superior horticultural traits were selected from the advanced trials. Among them, lines CN 1028-15, CN 995-23, CN 1108-13, and CN 1038-16 were consistently high yielding throughout the wet season. All four had at least 20 t/ha marketable yield and, except for CN 995-23, dry matter content in excess of 24% (Table 11). The local wet season cultivar, Tainan 17, yielded 16.1 t/ha, which was significantly lower than the elite lines mentioned above. Seven of the eight lines with orange flesh color, signifying high β-carotene content, were selected in these trials.

Table 10. The ten highest yielding breeding lines in summer, 1982 preliminary yield trials.[z]

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 1229-14	Centennial/OK 6-3-106// Ku Kei No. 63	19.0	30.2	Y_3
CN 1232-9	Centennial/OK 6-3-106// Kyushu No. 12(OP)	17.3	24.8	Y_3
CN 1221-1	Nun Lin No. 17(OP)/ Ku Kei No. 63	14.2⁻	33.0	Y_3
CN 1219-1	Ku Kei No. 63/ Poly Tainung 57(2)	12.8⁻	26.9	Y_5
CN 1229-2	Centennial/OK 6-3-106// Ku Kei No. 63	11.8⁻	30.7	W
CN 1280-4	Centennial/OK 6-3-106// Ku Kei No. 53	10.7	27.6	Y_3
CN 1229-16	Centennial/OK 6-3-106// Ku Kei No. 63	10.4	31.0	Y_4
CN 1280-3	Centennial/OK 6-3-106// Ku Kei No. 53	10.0⁻	25.0	Y_2
CN 1279	Centennial/OK 6-3-106// Tainung #20	9.6⁻	29.3	Y_6
CN 1219-4	Ku Kei No. 63/ Poly Tainung 57(2)	8.1⁻	28.0	Y_4
AIS 35-2	-	9.7	22.7	O_5
Tainan 17	-	10.7	26.1	Y_2

[z] Selections from 32 entries, planted on June 1, 1982, harvested on September 29, 1982 (121 days), replicated four times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

Conclusions

Based on the two years' wet season trials, five elite lines, CN 1108-13, CN 995-23, CN 942-47, CN 1028-15, and CN 1038-16, were chosen for further evaluation in 1983 regional yield trials. Three of these lines have orange flesh color and slightly to moderately dry texture. The yield and horticultural traits of these recommended lines are listed in Table 12.

These trial results suggest that there are good prospects for developing high yielding sweet potato cultivars suited to the hot, wet environments of the tropics. More attention should be placed on adaptability testing, however. Multi-locational trials are probably needed to accelerate the progress of developing stable cultivars with better adaptability.

Table 11. The eight highest yielding[z] sweet potato breeding lines in summer, 1982 advanced yield trials.

AVRDC selection or accession no.	Pedigree	Marketable yield[y] (t/ha)	Dry matter[y] (%)	Flesh color
CN 1028-15	PI 344129/B 6708(OP)// Tainung 63	28.1*	25.2	O_4Y_3
CN 995-23	AIS 209-3/PI 344129	26.8*	18.7⁻	O_6
CN 1108-13	PI 344129//HDK 6/B 7078/// Tainung 63	24.6*	23.6⁻	O_3Y_3
CN 946-13	AIS 057-4/PI 344129	22.8	26.9	Y_3O_2
CN 1038-16	PI 344129//Red Tuber Tail /OK 6-3-118///AIS 057-4	21.9*	25.8	Y_5O_1
CN 1058-10	B 6708(OP)//Tainung 27/ HDK 8///PI 344129//OK 8-25/ Rose Centernnial(OP)	20.5	22.9⁻	O_7
CN 942-47	B 6712(OP)	16.7	23.5⁻	O_3Y_2
CN 941-32	PI 286621(OP)	10.7	21.8⁻	W
AIS 35-2	HDK 6/B 6708	13.6	24.1	O_6
Tainan 17	-	16.1	25.9	Y_1

[z] Selections from 15 entries. Planted on June 1, 1982, harvested on September 27, 1982 (119 days); replicated four times.
[y] * = Significantly higher than the superior control cultivar.
- = Significantly lower than the superior control cultivar at P = 0.05 in the same trial.

Table 12. Horticultural characteristics of the breeding lines recommended for wet season trials.

AVRDC selection or accession no.	Mean marketable yield in wet season[z] (t/ha)	Dry matter (%)	Flesh color	Taste	Type
CN 1108-13	23.0	26.5	light orange	good-slightly dry	dessert
CN 995-23	25.5	19.0	deep orange	fair-moist	dessert
CN 942-47	21.3	24.3	light orange	good-slightly dry	staple
CN 1028-15	24.0	26.3	light orange	good-moderately dry	staple & feed
CN 1038-16	19.0	26.6	yellow	poor-dry	feed

[z] Mean yield of the two years' trials.

Selection of Sweet Potatoes Suitable for Consumption as Vegetable Greens

Introduction

Sweet potato greens (tips, leaves, and petioles) are consumed as a vegetable in many Asian countries. They are particularly rich in vitamin B, iron and protein, and are more tolerant of diseases, pests, and high moisture than many other leafy vegetables grown in the tropics. One of the few vegetables that can be grown easily during the monsoon seasons of the tropics, sweet potato leaves are usually the only greens available in Taiwan markets after a typhoon. In spite of all these advantages, the lack of high yielding, tender cultivars makes the greens unpopular in the tropics. As only the terminal 10 cm part of the vine is tender enough to be consumed, less than 10 t/ha of the edible tips can be harvested from conventional prostrated vine type cultivars. This study was therefore aimed at selecting bush or semi-bush types in order to obtain high yielding lines. These types have more branching than the prostrated type; thus high harvest index could be expected.

Materials and Methods

In observational trials conducted from October 9, 1981 to February 5, 1982, 29 clones suitable for tip consumption were selected from crosses made in 1980. These lines were immediately evaluated in a replicated trial from February 8 to June 10, 1982. Based on these two trials, seven elite lines were selected for final evaluation in advanced yield trials, using four replications, from June 10 to September 29, 1982. Cultural practices used in growing leafy vegetables were adopted in these trials. Plants spaced with 40 cm between hills were planted on 1.5 m double-row beds. Plots received three applications of N, P_2O_5, and K_2O at 90, 60 and 80 kg/ha respectively during the growing period.

Results

In advanced yield trials, three of the AVRDC selections outyielded the control cultivar Dilaw. The number of harvested tips was higher in the bush or semi-bush selections than in the prostrated control, but the weight per tip was usually smaller. The highest yielding line was selection CN 1199-1, but, although its 16.1 t/ha was higher than the control, it was still much lower than the yield of most other commercial leafy vegetables (Table 13). Fiber and oxalate contents ranged from 12.9 to 14.3% and 2.24 to 5.87%, respectively, on a dry weight basis.

Table 13. Promising sweet potato selections suitable for consumption as vegetable greens.

AVRDC selection or accession no	Tip yield[z] Weight(kg/ha)	Tip yield[z] No.	Fiber (% dry wt. basis)	Tenderness/ flavor	Plant type
CN 1195-2	15,183	3,531,128	13.0	fair/good	bush
CN 1193-1	12,340	3,184,167	13.0	fair/good	semi
CN 1199-1	16,065	2,948,409	13.8	poor/fair	bush
CN 1199-2	10,273	2,117,686	13.2	fair/fair	prostrated
CN 1201	10,152	2,685,132	14.3	fair/fair	small bush
CN 1207-1	12,357	3,148,291	13.4	good/fair	semi
I 426 (Dilaw)	13,699	1,832,808	12.9	good/fair	prostrated

[z] Selections from three seasons' (spring, summer, and fall) trials.

However, great difficulties were encountered in trying to obtain tender clones with qualities comparable to Ipomoea aquatica (water convolvulus).

Conclusions

The selection of high yielding sweet potato cultivars suitable for consumption as vegetable greens can be approached through the selection of better plant types. Bush or semi-bush types have significantly higher tip yield and number than the conventional prostrated type due to large number of branches per plant. It is probably possible to improve yield and quality by proper management practices such as shading, high density planting, and more frequent fertilization.

As sweet potato tips must be harvested continuously, not once like many other commercially grown vegetables, they are probably more suitable for the home garden than for commercial production. Future variety improvement efforts should be focused on developing low management and high quality types.

Screening for Flooding and Moisture Tolerance

Introduction

According to a survey recently conducted by AVRDC, more than 26% of the sweet potatoes in Asia and the Pacific are grown under frequent flooding or high moisture conditions. Very few cultivars are adapted to this unfavorable environment. High soil moisture coupled with high temperature and flooding usually cause poor root yield and excessive vine growth. In Taiwan, for example, the major sweet potato plantings are now only made in the dry season or in sandy soil where drainage is good during the monsoon season. In order to identify flooding or

moisture tolerant germplasm for the Center's breeding programs and to find adequate screening methods, the following experiments were conducted in the wet season of 1982.

Materials and Methods

Flood tolerance screening: Three hundred seventy entries from the AVRDC germplasm collection were divided into twenty groups and evaluated for flood tolerance from May 25 to September 23, 1982 in replicated trials. Plots were flooded over the bed top twice, at 63 and 102 days after planting (July 25 and September 23). The entries were evaluated against the local wet season cultivar, Tainung 63, for yield, vigor, and numbers of marketable and cull roots.

Moisture tolerance screening: Two hundred thirty new germplasm entries were grown at the peak of the wet season, from May 24 to October 4, 1982, to evaluate their performance under a hot, wet environment. The entries were arranged in 11 groups with the control cultivar, Tainung 63, in each group in this replicated trial.

Results

Very few cultivars responded favorably to the flooding treatments. Only 22 of the 372 clones yielded more than the control cultivar. Accessions I 103, I 423, and I 100 yielded more than 10 t/ha under flooding stresses. Of these three, the latter two accessions had a larger percentage of cull roots in wet soil conditions.

Preliminary results indicated that most of the existing cultivars do not have the ability to initiate and develop enough roots in flooded soil. The clones selected from this trial require further improvement via hybridization and selection (Table 14).

Twelve clones outyielded the control cultivar in the moisture tolerance experiment (Table 15). The mean yield of the 230 entries was higher than in the flooding experiment, as the entries were grown in wet soil without receiving additional flooding treatments. Four lines had marketable root yield close to 20 t/ha, which is already comparable to AVRDC's wet season elite lines. One of these, I 444 (Kin-men), which yielded 19.7 t/ha in this trial, was also selected in drought tolerance trials. This cultivar apparently has a wide adaptability to different environments. Some of the new introductions from Papua New Guinea performed well in the hot, wet environment of this trial; 11 of the 14 selected clones originated from that country.

Table 14. Yield of selected cultivars in flood tolerance screening.[z]

AVRDC accession no.	Cultivar name	Yield (t/ha) Marketable[y]	Cull	Total	Top
I 103	PI 31885	11.6*	2.2	13.8	40.8
I 246	Nun Lin 16	8.2*	1.4	9.6	19.9
I 71	PI 153907	8.0*	1.7	9.7	21.7
I 253	Nun Lin 23	7.8*	0.8	8.6	20.6
I 423	Tainan #17	6.8*	3.7	10.5	28.0
I 72	PI 153909	6.5*	1.7	8.2	14.4
I 100	PI 318844	6.2*	6.8	13.0	30.8
I 212	BNAS #45	5.9*	1.6	7.5	12.4
I 367	Lo-323	5.8*	1.1	6.9	11.1
I 122	B6708	5.6*	1.0	6.6	34.4
I 389	Indonesia 6/2	5.5*	1.1	6.6	25.3
I 432	Seno No. 1	5.3	1.7	7.0	16.6
I 82	PI 286621	5.1*	1.1	6.2	20.4
I 69	Georgia Red	5.0*	1.5	6.5	25.3
I 234	Nun Lin 4	4.6	1.1	5.7	28.1
I 416	Orchid Island 8	4.6	0.7	5.3	22.7
I 392	CV Rak	4.4*	0.1	4.5	32.4
I 36	Cooper Skin Goldrush	4.4*	1.6	6.0	18.8
I 232	Nun Lin 2	4.2	0.4	4.6	22.6
I 231	Nun Lin 1	4.2	0.0	4.2	21.5
I 136	OK6-3-106	3.3	1.2	4.5	18.8
I 173	Chu Shan	3.0*	0.4	3.4	18.8
I 278	Tainung 23	2.3*	0.3	2.6	26.2
I 293	Tainung 50	2.3*	1.2	3.5	24.1
I 7	Karja #381 J	2.3*	1.1	3.4	17.1
I 16	HDK 12	2.1*	1.3	3.4	7.7
I 154	Tainung 10	1.9*	0.7	2.6	17.4
I 171[x]	Tainung 63	0.5	0.3	0.8	16.1

[z] Selections from 372 entries, transplanted on May 25, 26, and 27 and harvested on September 23; replicated two times. All entries were flooded twice, on July 26 and September 13 (63 and 102 days after transplanting).

[y] * = Significantly higher than the control cultivar, Tainung 63, in the same group.

[x] The control cultivar, means of the 20 groups.

Table 15. Marketable yield of selected cultivars/clones from moisture tolerance screening, summer, 1982.[z]

Entry	Marketable yield[y] (t/ha)	Origin
NG 7570	19.8*	PNG
I 444	19.7*	Taiwan
Piksin	19.3*	PNG
I 435	19.1*	Japan
7477	15.2*	PNG
1576	11.8*	PNG
I 438	11.6*	Taiwan
Merenge	10.1*	PNG
No. 1	9.6*	PNG
NG 7572	7.7	PNG
Lea 2	7.5	PNG
Aforema-iae	7.3*	PNG
Lae 4	7.1*	PNG
Mata	6.4*	PNG
Tainung No. 63[x]	4.1	Taiwan

[z] Selections from 230 entries, transplanted on May 24 and harvested on October 4, 1982; replicated two times.

[y] * = Significantly higher than the control cultivar, Tainung 63, in the same group.

[x] The control cultivar, means of the 11 groups.

Conclusions

Results suggest that the selection for flood tolerant clones is probably much more difficult than selecting for clones adapted to wet soil. Very few existing cultivars have the ability to tolerate flooding stress. More efficient screening methods that are capable of encompassing larger seedling populations will probably be required to allow for exploiting and selecting new genotypes from larger genetic bases.

Most of the clones from Papua New Guinea were obtained from highland areas where the annual rainfall is close to 2,500 mm. These clones were probably already adapted to high moisture environments, and can be used in our hybridization programs for developing moisture tolerant cultivars.

Selection for Drought Tolerance

Introduction

Drought is one of the most important environmental factors limiting sweet potato yield and production. According to the Center's recent survey conducted in the Asian and Pacific region, about 76% of the area's sweet potatoes are grown under conditions where drought is usually a severe problem. As sweet potato is usually considered a low input crop, only about 10% of the farmers regularly irrigate their fields in this region. The necessity for developing cultivars tolerant to drought conditions is clear.

Materials and Methods

Twenty-nine clones derived from local drought tolerant cultivars were selected based on yield potential in fall, 1981, observation trials. In 1982 these lines were further evaluated under dry conditions in early spring (transplanted February 23) and fall (transplanted August 25) in replicated trials. As AVRDC does not have a real drought environment, these trials were conducted in the dry season with no irrigation.

Results

In the spring trials none of the new clones outyielded the local drought tolerant cultivar, I 444. In fall plantings, only the selection

CN 1244-5 produced marketable roots comparable to the control cultivar. This line also appeared to be late maturing (Table 16).

Conclusions

To select for drought tolerance, more critical environments or screening methods for selecting from a larger population are needed. In the two seasons' trials, none of the new clones was found to be superior to the local cultivar. The only advantages of the selection CN 1244-5 were its orange flesh and higher dry matter. This line requires further improvement as its yield and maturity are inferior to the control's. Cultivar I 444 was identified as having excellent environmental adaptability in trials throughout different seasons. This accession is being included on the list for international cooperators.

Table 16. Elite drought tolerant lines/accessions at AVRDC.[z]

AVRDC accession or crossing no.	Marketable root yield[y] (t/ha)	Dry matter[y] (%)	Protein (% dry wt. basis)	Flesh color
CN 1244-5	19.7 ab	29.6 b	1.8	light orange
CN 1244-6	17.2 bc	28.4 b	2.3	yellow
I 444	22.8 a	23.8 c	2.2	yellow

[z] Selections from 29 entries in the two seasons' trials.
[y] Yield and dry matter of the fall trials, transplanted on August 25 and harvested on December 28, 1982.

Evaluation of New Introductions and Parental Materials

Introduction

Among the new germplasm introduced in 1982, 541 clones were successfully established and evaluated for their yield and other horticultural characteristics. The purpose of these trials was to evaluate the potential for using these clones in the breeding programs. In addition, certain previous elite germplasm accessions were evaluated to reconfirm their specific characteristics needed for AVRDC hybridization programs, such as high protein or dry matter content.

Materials and Methods

New germplasm was evaluated in three separate trials. The first set of 226 lines was planted February 24 to June 14, 1982 at AVRDC, and 211 of these lines were grown from April 25 to October 3, 1982 at Penghu Island in the Taiwan Straits. Both trials were replicated twice.

The second set of 353 clones was evaluated in an observational trial without replication from June 9 to October 19, 1982 at AVRDC.

Sixty-three accessions and breeding lines planned as parental materials for hybridization were grouped into four separate trials to evaluate their 1) protein 2) sugar 3) starch and dry matter contents, and 4) eating qualities. These trials were transplanted on November 23, 1981 and harvested in April 1982 in replicated trials.

Results

Root yields of the new introductions were generally very low. In the first trial at AVRDC, the mean yield for all entries was only 1.6 t/ha, and in the Penghu trial the mean was 2.29 t/ha. Very few lines yielded more than 10 t/ha in both trials. There was wide variation in the sugar, dry matter, and starch contents of this population. For example, sugar contents ranged from 12.5 to 29.4% (dry weight basis). The protein contents were quite low, ranging from 1.14 to 3.97% (dry weight basis) with the population mean only 2.15% (Figures 5 and 6).

The mean yield of the 353 entries planted in the middle of the wet season was 0.788 t/ha. Only eight entries yielded more than 10 t/ha, but the best accession, K 79 from Papua New Guinea, had an unusually high yield of 36 t/ha (Table 17).

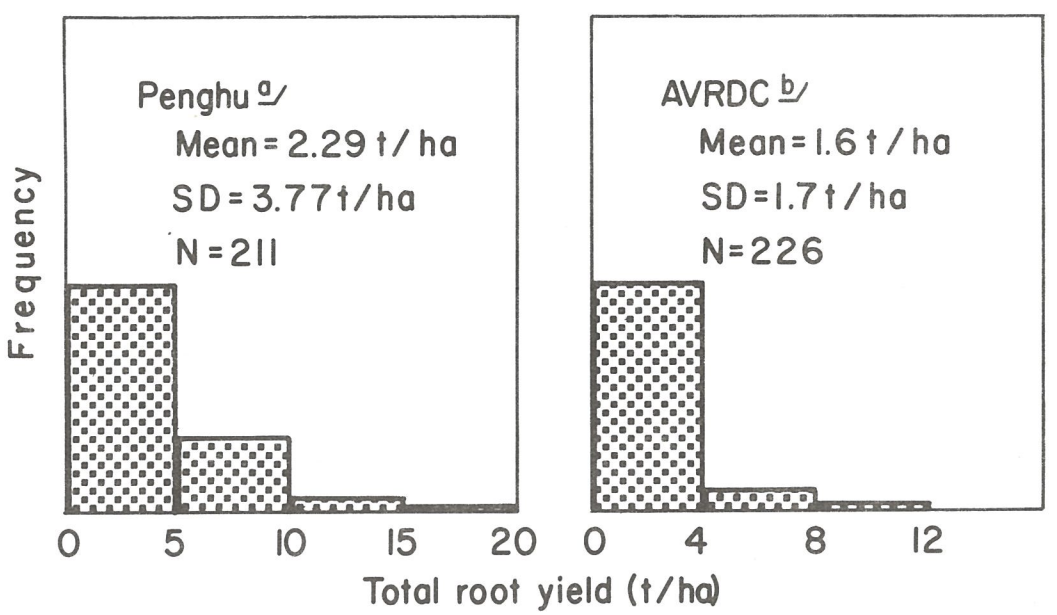


Figure 5. Yield distribution of new germplasm from Papua New Guinea.

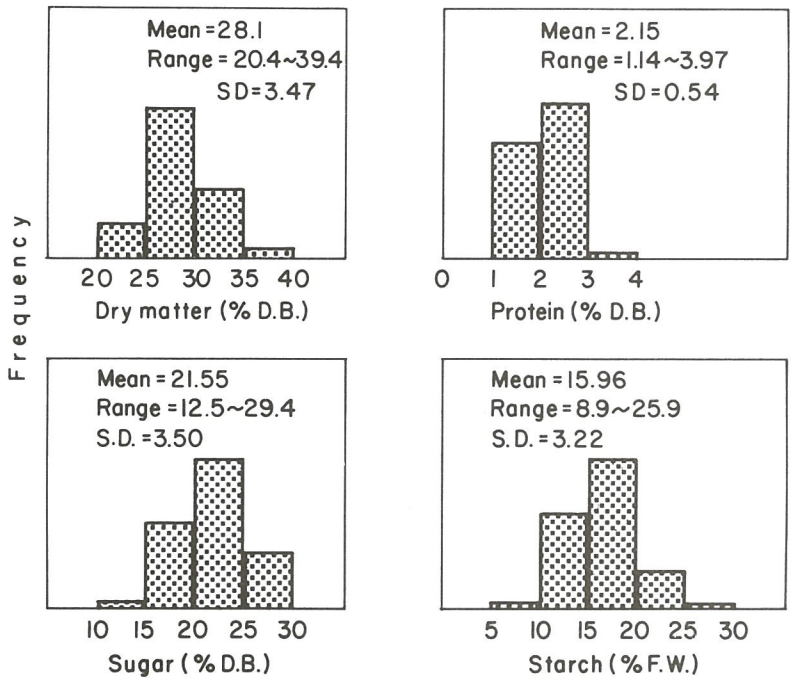


Figure 6. Frequency distribution of nutritional attributes of new sweet potato accessions

Table 17. Yield distribution of new germplasm in summer observational trial.[z]

Marketable yield (t/ha)	No. of entries	% of total
0-5	337	95.5
5-10	8	2.3
10-15	4	1.3
15-20	3	0.8
20-25	0	0
over 25	1	0.3
Total	353	100

[z] Transplanted on June 9 and harvested on October 19, 1982. Population mean, 0.788 t/ha; range, 0-36 t/ha.

In the trials screening for particular traits, six superior accessions with more than 10% protein contents (dry weight basis) were identified for the protein crosses, six accessions and breeding lines for the low sugar crosses, and two for crosses to improve starch content (Table 18).

Table 18. Characteristics of selected parental lines/cultivars for hybridization.

AVRDC accession or selection no.	Dry Matter (%)	Protein (% dry wt. basis)	Sugar (% dry wt. basis)	Remarks[z]
For protein crosses				
I 107	30	11.9	-	nice shape
I 148	25	11.9	-	low yield
I 139	19	11.2	-	-
I 130	25	10.9	-	nice shape
I 154	22	10.4	-	poor shape
I 152	21	11.9	-	-
For low sugar crosses				
I 307	39	-	6.9	low yield
I 361	41	-	6.9	low yield
I 215	35	-	7.8	-
LS 19-4	30	-	11.7	low yield
LS 24-11	30	-	13.4	low yield
LS 27-12	29	-	12.1	low yield
For starch crosses				
I 347	36	1.9	9.8	-
I 307	39	3.5	6.9	low yield

[z] All entries yielded more than 20 t/ha except entries with low yield noted.

Conclusions

With few exceptions, most of the accessions introduced in 1982 were extremely low yielding. The germplasm lines from Japan and the USA are probably not adapted to hot, wet tropical conditions.

The wide range of yield and nutritional contents suggests that most of the germplasm from Papua New Guinea represents very primitive types of clones. They were probably chance seedlings picked up and selected by the villagers in the highland areas of Papua New Guinea where sweet potato blooms and sets seeds freely. These materials have extensive genetic variations which may be invaluable sources of unusual traits such as disease or pest resistance for future breeding programs.

The Development of Low Sugar Sweet Potatoes

Introduction

The program aimed at developing low sugar staple cultivars, initiated in 1979, was continued during 1982. In 1981 the breeding method was shifted from conventional crossing to population improvement to accelerate progress.

One of the major difficulties of using polycrosses was the unmanageable number of seedlings. An applicable method for rapid screening for sugar content was required for the population improvement breeding scheme. Therefore, efforts were also made to find such a method during 1982.

Materials and Methods

Sixteen original crosses between low sugar accessions had been made in 1979. Various populations derived from the original crosses were made by three-way crossing and open-pollination in 1980. After their sugar content was evaluated, a polycrossing nursery was established in 1981 and was continued through the second cycles of random mating in the fall of 1982. A method of rapid screening low sugar lines by looking at the specific gravity of seedling roots was applied and evaluated in the first cycle of selection.

Results

Three populations derived from the 16 original low sugar crosses were compared with the parental cultivars for sugar content. None of the three populations had reduced sugar contents. The population mean was 10.8% (dry weight basis), for single crosses, 11.7% for three-way crosses, and 10.1% for open-pollinated. These figures represent no significant difference from the 10.1% mean sugar content of the original parental cultivars. More importantly, sugar distribution was similar in all four populations. The range was never lower than 5%, which is still higher than the original target of 3 to 5% proposed by AVRDC's biochemist for low sugar staple and animal feed cultivars (Figure 7).

The negative correlation found by the Center's chemistry lab in 1979 between sugar and dry matter content was confirmed by analyzing the four low sugar populations. As dry matter content is highly correlated with the specific gravity of the root, specific gravity is now used as an indicator of sugar content in screening large populations of clones in the population improvement program.

Conclusions

Results suggest that conventional pedigree methods cannot reduce sugar content effectively. The use of recurrent selection to deal with this inherited qualitative trait should facilitate progress.

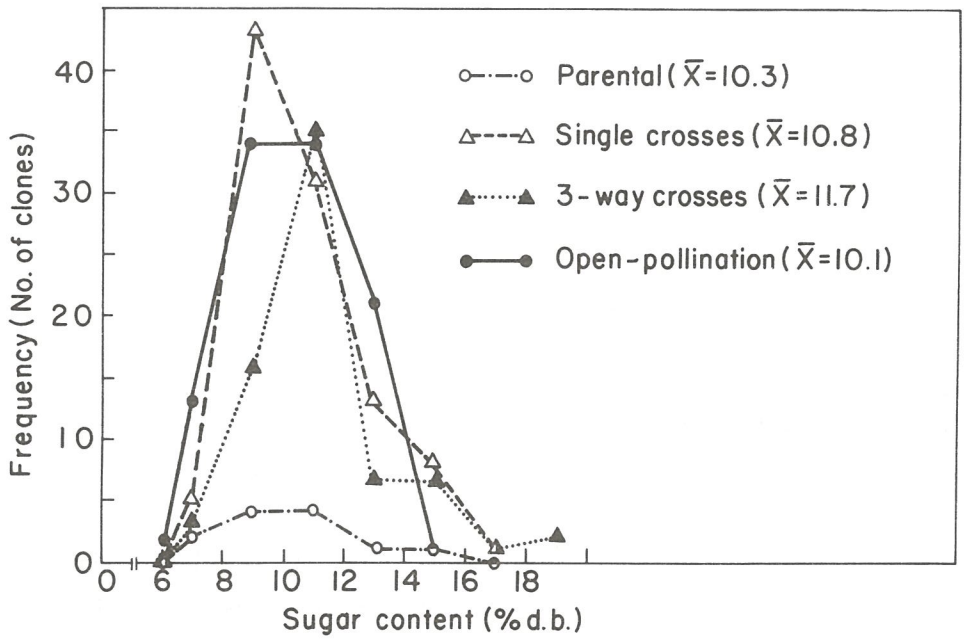


Figure 7. Distribution of sugar content in sweet potato parental cultivars and their progeny populations.

Although the correlation between sugar and specific gravity of seedling roots is indirect, it still provides for a practical method of evaluating sugar content in large populations for the following reasons: a) a selection cycle can be completed in only one year; b) genotypes combining high dry matter and low sugar, two traits needed in the cultivars the program is trying to develop, are more likely to be selected; and c) a larger population can be evaluated without tedious and laborious laboratory work. The large genetic base in such a population could also prevent unfavorable linkages such as low yield in the improved population.

Survey on Sweet Potato Production and Utilizaton in Asia and the Pacific

Introduction

To strengthen and sharpen the focus of the sweet potato research programs, an overall survey on sweet potato production and utilization was conducted among cooperators by joint effort of the Social Anthopology, Breeding, Economics, and Outreach Programs.

The specific objectives of the survey were to:

1) Collect the most recent national and regional statistical data on sweet potato production and utilization.
2) Collect data on current patterns and future trends in sweet potato utilization.
3) Collect detailed information on the current status of sweet potato research and farmers' production practices.
4) Determine the major problems and constraints in sweet potato production and utilization.

Materials and Methods

With suggestions and assistance from all AVRDC scientists and the Office of Information Services, survey forms were prepared in April, 1982.

The questionnaires were sent from June to October, 1982 to 170 cooperators in 40 countries and trust territories in Asia and the Pacific. (The Mayaguez Institute of Tropical Agriculture in Puerto Rico is conducting a joint survey with AVRDC to cover Central and South America.) Four major groups of recipients were chosen for the survey:

a) Participants of the First International Symposium on Sweet Potato.
b) Recipients of AVRDC sweet potato breeding materials in the past.
c) Former AVRDC trainees.
d) Persons on the Center's mailing or correspondent list.

In Thailand, Korea, and the Philippines the survey was coordinated by resident scientists of the Outreach Programs.

Results

As of December, 1982, 48 copies (28%) of the completed survey questionnaires from 23 countries and trust territories had been returned. Most of the important regions in Asia and the Pacific were covered excluding Nepal, Pakistan, Burma, and the Maldives. Unfortunately, mainland China was not included in the survey. About 79.6% of the sweet potatoes in Asia are grown in mainland China.

In the preliminary analysis, the answers were grouped into I) developed or developing, II) Asian, and III) the Oceania countries. Japan, USA, Korea, and Taiwan were grouped together in group I as these countries were considered similar in economic status, production

pattern, and/or culture. Puerto Rico was temporarily included in Group III for this analysis.

Sweet potato production: Indonesia, the Philippines, and India have the largest sweet potato acreages in Asia apart from mainland China. Papua New Guinea, Oceania, and the Philippines are the three locations where sweet potato is most important to agriculture. For example, sweet potato acreage accounts for 64.7% of the total agricultural area in Papua New Guinea. However, Tonga and the Solomon Islands were ranked first in the importance of sweet potato as a staple food; the population consumes 532.3 kg of sweet potato roots per person per year. Regardless of the importance of sweet potato in these countries, the average yields are generally low, ranging from only 4.6 t/ha in Papua New Guinea to 11.4 t/ha in Oceania, compared with 20.0 t/ha in Japan (Tables 19 and 20).

Table 19. Sweet potato production in Asia and the Pacific.

	Sweet potato area[y] (1,000 ha)	Average yield (t/ha)
Japan	70 (-)	20.0
Korea	70 (-)	19.8
Taiwan	74 (-)	16.6
Bangladesh	73 (+)	10.9
India	225 (+)	6.9
Indonesia	309 (-)	7.6
Malaysia	4	9.7
Philippines	228 (+)	4.6
Sri Lanka	21	6.2
Thailand	36 (-)	9.7
Papua New Guinea	96 (+)	4.6
Oceania[z]	13 (+)	11.4
World total	13,638	8.4
Asia total	12,330	8.5
China	10,860	8.5

[z] Includes Fiji, New Caledonia, Tonga, and the Solomon Islands.
[y] + = Increased in the past ten years.
- = Decreased in the past ten years.

Source: FAO Production Year Book 1980 and the AVRDC survey, 1982.

Table 20. Sweet potato consumption in Asia and the Pacific.

	Sweet potato area / Agricultural area (%)	kg/person
Japan	2.1	12.1
Korea	6.2	37.2
Taiwan	8.1	70.1
Bangladesh	5.0	9.2
India	0.6	2.3
Indonesia	5.8	15.8
Malaysia	1.2	2.7
Philippines	20.5	21.0
Sri Lanka	3.9	8.9
Thailand	1.4	7.6
Papua New Guinea	64.7	145.2
Oceania[z]	23.8	532.3
World total	-	-
Asia total	-	-
China	-	-

[z] Tonga and the Solomon Islands.

Sweet potato utilization: Sweet potato roots are mainly used as human food (80-100%) in group II and III countries; only small quantities are used as animal feed, and negligible amounts are used as industrial raw materials in these areas. In Japan, Korea, and Taiwan, 16-36% of the roots are used for industrial purposes (mainly for starch extraction). Only 11 and 38% of the roots are consumed by humans in Taiwan and Japan.

Sweet potato greens are consumed as vegetables in most of the countries surveyed, except Sri Lanka and a few Pacific Islands. Different parts are consumed in different areas, however. For example, Japanese and Koreans consume only the petioles and Taiwanese only the leaves, while consumers in most of the other areas prefer the terminal tips (Table 21).

Research priorities: Variety improvement was ranked as the first priority in all three groups of countries, followed by crop protection as the second priority in the Asian and Oceania countries. The storage and processing problem becomes important with the growth of the economy - it is ranked sixth in Oceania, third in Asia, and second in the countries of group I. Surprisingly, crop management was rated a low

Table 21. Utilization of sweet potatoes in Asia and the Pacific.[z]

	% Utilized				Greens
	Food	Feed	Industry	(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 (tips and leaves)
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
Oceania[y]	91	9			some (tips and leaves)

[z] Data from the AVRDC survey on sweet potato production and utilization, 1982.

[y] Niue Island, Palan, the Cook Islands, Fiji, Tahiti, Vanuatu, Tonga, Guam, and Ponape.

priority in most countries, suggesting that sweet potato is considered a low input crop in Asia and the Pacific.

Most of the countries have variety improvement programs, but only about half of them have breeding programs via hybridization. Varieties are improved through the introduction and evaluation of improved local or foreign cultivars.

Desirable variety traits: It was also very interesting to find that eating qualities and nutrition were rated of more importance than high yield in the survey. Apparently, sweet potato is considered a vegetable or supplemental (not major) food crop in Asia and the Pacific; otherwise, yield would be the most important characteristic needing improvement.

Regarding eating qualities, 60 to 80% of the respondents reported that dry or moderately dry textures were preferred. Moist texture was only preferred in the developing countries. Also, more than 80% reported local preference for sweet or moderately sweet cultivars.

Production constraints: Drought is apparently the most severe of the environmental stresses affecting sweet potato production. Seventy-eight percent of the respondents felt strongly that there is a need to develop drought tolerant cultivars. Flooding is also an

important problem; 43% expressed a strong need for flood tolerant cultivars, and another 45% felt it would be helpful to develop such cultivars.

Weevil, the primary insect problem, was rated much more serious than other insects in this survey. Stem borer was rated second. Sweet potato scab, nematodes, and viruses are the important diseases. Witches' broom is important in Oceania and some areas of Papua New Guinea, but minor elsewhere.

Conclusions

The preliminary analysis of the survey has suggested some new ideas and reconfirmed many old assumptions. In general, sweet potato in Asia and the Pacific is considered and treated as a low input crop, used mainly as a supplementary food in most of the countries. The importance of this crop as a major human food is greatly influenced by environmental and social or economic factors. People hesitate to invest research or other inputs to increase the productivity of this crop as they have recognized other grain crops which are more stable in yield and more easily processed, stored, and consumed as a staple food. However, sweet potato cannot be overlooked as it is the only crop that can be grown successfully under minimal input conditions with the least irrigation, fertilizers, and pesticides on marginal lands. Like many other traditional food crops, sweet potato is grown as a major food only where agricultural technology or irrigation systems are less developed or food demand is so high that something must be grown on marginal lands. It would be very interesting to know why China is now growing 70% of the world's sweet potatoes.

The survey results suggest that two types of sweet potatoes should be developed for the tropics.

1) A supplemental food or vegetable cultivar, aiming more for nutritional and eating qualities. This type can be bred for maximum marketable yield under relatively high input conditions.

2) A major source of raw materials for feed and industry. Sweet potato can produce up to 13 t/ha of dry matter under favorable environments. It provides one of the highest dry matter yields of all major food crops grown in tropical areas. This

type should be bred mainly for high yield with wide environmental adaptability.

Sweet potato is more likely than most of the introduced grains to adapt itself to the high rainfall or drought conditions of the tropics. A systematic research program should be conducted in variety development, crop protection, management, and particularily utilization methods to exploit this crop's real potential for the tropics.

Sweet Potato Entomology

Identification of Resistance to Sweet Potato Weevil

Introduction

Sweet potato weevil (Cylas formicarius F.) is the most destructive insect pest of sweet potato in the tropics. The larvae and adults feed on roots and vines and, although feeding does not reduce root yield, the quality of roots is impaired even by minor infestations. In order to control this insect cheaply and effectively, a screening program was initiated to identify resistant sweet potato accessions. Described here are results obtained during 1982.

Materials and Methods

Resistance screening tests were conducted on the AVRDC campus and on Penghu Island in the Taiwan Straits.

At AVRDC, three sets of materials were screened, planted in September-October 1981 and harvested in March, 1982. Sweet potato accessions were planted between two weevil source rows - a susceptible cultivar had been planted ten weeks earlier and had been infested with laboratory reared weevils before the transplanting of the test materials. The crop was grown using traditional cultural practices except that no insecticide was used. At harvest the roots were evaluated for weevil infestation by cutting open each root and counting the number of weevils feeding within. In addition, damaged and healthy portions of each root were separated and the percentage of roots damaged was determined by weight. The number of weevils feeding in the crown was also recorded. Insect count and damage data were statistically analyzed to select less affected materials. In each test, the mean number of insects (larvae + pupae + adults)/kg roots and mean percent damaged roots were subjected to a statistical analysis based on mean ($\bar{x}$) and standard deviation (SD). The accessions that had insect number or percent damage less than $\bar{x}$ - 2SD were considered highly resistant (HR), between $\bar{x}$ - 1SD and $\bar{x}$ - 2SD moderately resistant (MR), between $\bar{x}$ and $\bar{x}$ -

1SD as having low resistance (LR), between $\bar{x}$ and $\bar{x}$ + 2SD susceptible (S), and more than $\bar{x}$ + 2SD highly susceptible (HS).

Penghu Island tests were similar to those conducted at AVRDC, except that at Penghu weevil source rows were not maintained. Instead, test materials were planted in the field and laboratory reared weevils were released three times at intervals from six weeks after transplanting until six weeks before harvest. Three sets of materials were screened, planted in April, 1982 and harvested in October-November, the first set 160 days and the second and third sets 210 days after transplanting. The first set included 234 new accessions from Papua New Guinea and four check entries. The second and third sets included entries that had shown relatively little sweet potato weevil infestation in tests conducted earlier at AVRDC. Entries in the first test were replicated twice and those in the second and third tests six and 12 times, respectively. The weevil infestation evaluation procedure was identical to that used in the AVRDC tests.

Results

First AVRDC test: Seven entries that yielded less than 1 kg roots/5 m single row plot were not evaluated. No immune lines were found among the remaining 53 entries. Statistical analysis based on mean and standard deviation of the number of insects/kg roots and the percent damaged roots, and Duncan's multiple range test showed that accession I 413 had the least weevil infestation (Table 1).

Table 1. Performance of selected sweet potato accessions against sweet potato weevil (first AVRDC test).[z-x]

Accession	No. weevils /kg roots	Resistance rating	Damaged roots (%)	Resistance rating	Yield (t/ha)
I 413	16.22 i	HR	20.83 k	MR	7.4
I 57[w]	115.25 a-d	S	55.00 a-h	S	4.9

[z] Plot size: 5 m^2.
[y] HR = Highly resistant, MR = moderately resistant, S = susceptible.
[x] Data shown are means of six replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[w] Susceptible check.

Second AVRDC test: Forty new accessions were screened including four that had been reported resistant at IITA in Nigeria. None were

immune at AVRDC. I 413, I 416, and Tis 2532 were the least damaged (Table 2).

Table 2. Performance of selected sweet potato accessions against sweet potato weevil (second AVRDC test).[z-x]

Entry	No. weevils/ kg roots	Resistance rating	Damaged roots (%)	Resistance rating	Yield (t/ha)
I 413	24.2 b	LR	47.7	LR	3.7
I 416	24.4 b	LR	35.0	MR	2.5
Tis 2532	15.5 b	LR	43.0	LR	5.5
I 415[w]	194.0 a	HS	57.0	S	4.3

[z] Plot size: 5 m^2.
[y] MR = moderate resistance, LR = low resistance, S = susceptible, HS = highly susceptible.
[x] Data are means of three replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[w] Most susceptible entry.

Third AVRDC test: The entries in this test, all breeding materials selected from the plant breeder's field, were all heavily damaged and none were selected for further screening.

Penghu tests: Despite the long growing period and the fact that weevils were released twice in the first test and three times in the second and third tests, practically all roots of each entry were free of weevil infestation at harvest. This was the first time in seven years that weevil infestation did not occur in tests at Penghu Island. No plausible explanation could be found for this phenomenon.

Conclusions

Accessions I 413, I 416, and Tis 2532 showed a certain level of resistance. Since sweet potato weevil resistance is influenced strongly by the environment, it is essential that these entries be tested at other locations and in other seasons. They are included in 1983 tests at AVRDC. In order to select additional materials with better levels of resistance, it is also necessary to look for new sources of germplasm.

Flooding for Sweet Potato Weevil Control

Introduction

Planting sweet potato in a field where a previous sweet potato crop has been infested by weevil increases the possibility of further sweet potato weevil infestation. Past AVRDC results showed that if sweet potato is rotated with paddy rice, weevil infestation of sweet potato is minimal provided that other infestation sources such as alternate hosts and contaminated planting materials are controlled. Planting paddy rice entails flooding the field for about four months. This flooding results in the rotting and disintegration of sweet potato root and shoot pieces left over from the previous sweet potato crop. This in turn should destroy the source of weevils, which feed only on living sweet potato plant parts. It was therefore thought that flooding alone might control the weevil source and that rice planting might not be necessary. A study was conducted to test this hypothesis.

Materials and Methods

The experiment was performed from late 1981 to early 1982 at three locations on the AVRDC farm where the sweet potato crop was weevil infested. At harvest most of the roots and crowns were deliberately left in the field. The land was rototilled and worked into 10 x 8 m flat beds. The experiment included five treatments: No flooding and flooding for one, two, three, and four weeks. At the first location the experiment was not replicated, at the second treatments were duplicated, and at the third each treatment had four replicates. Water was confined in specific plots for the designated duration. After cessation of flooding the land was left fallow for several weeks. At eight weeks after cessation of the last flooding treatment, the number of volunteer sweet potato plants and the number of weevil larvae, pupae, and adults feeding in them were recorded.

Results

Two or more weeks' flooding considerably reduced the emergence of volunteer sweet potato plants from materials left over from the previous crop (Table 3). The volunteer plants that emerged contained practically no weevils.

Table 3. Emergence of volunteer sweet potato plants and weevil infestation after flooding an infested field for varying lengths of time.[z-x]

Flooding period (weeks)	No. plants/plot	No. insects[w]/plant
0	15.6	2.20
1	4.2	0.22
2	0.3	0
3	3.3	0
4	0.4	0.08

[z] Flooding initiated: November 11, 1981.
[y] Date of observation: February 5, 1982.
[x] Plot size: 10 x 8 m.
[w] Includes larvae, pupae, and adults.

Conclusions

It would have been ideal to plant weevil-free sweet potato cuttings after the discontinuation of flooding treatments and observe the sweet potato weevil infestation of this crop. However, past results revealed that sweet potatoes planted after flooded rice paddy also suffer infestation if a sweet potato weevil infested field is in the vicinity. The sweet potatoes in the unflooded check plot would have acted as a weevil source and infested the crop planted in the area that had been flooded.

The experiment demonstrated that it is possible to eliminate the sweet potato weevil source from a weevil-infested previous crop by flooding the infested field for two weeks or more instead of rotating with rice paddy.

Chemical Control of Sweet Potato Weevil

Introduction

Past AVRDC studies indicated that carbofuran 3G broadcast on soil at the rate of 2 kg ai/ha at least once every three weeks gives good control of sweet potato weevil. Since sweet potato weevil infestation shows wide variation from location to location and season to season, it was felt that this experiment must be repeated three to four times before coming to a definite conclusion. Information on carbofuran residues in the roots was also sought, to determine the suitability of roots for human consumption. One insecticide screening trial was

therefore conducted at AVRDC from late 1981 to early 1982, and carbofuran residues in the roots were monitored.

Materials and Methods

Ten treatments including one untreated check were replicated four times in ten 3 x 3.3 m plots per replicate, each plot containing three 1 m wide beds. Stem cuttings of breeding line AIS 35-2 were used as planting materials. In the first nine treatments, the cuttings were dipped in 0.05% ai carbofuran solution for 20 minutes. The insecticide applications were initiated two weeks after planting. In treatments 1 through 4 carbofuran 3G at 2 kg ai/ha was applied once every one, two, three, and four weeks, respectively. In treatments 5 through 8 the same formulation of insecticide was applied at 1 kg ai/ha at the same intervals. Treatment 9 did not receive any insecticide application after transplanting and treatment 10 was maintained as the untreated check. Insecticide granules were applied by broadcasting on the soil around the vines in each plot. At six and ten weeks after transplanting laboratory reared weevils were released on each plot. At harvest, 5 kg root samples were taken from each plot and cut open; the number of sweet potato weevils within each root and the quantity of weevil damaged roots were recorded.

A 2 kg root sample was also taken from each plot and aliquot subsamples were extracted and analyzed for carbofuran residue concentration by a routine gas chromatographic method (Talekar et al. 1977. J. Agr. Food Chem. 25:348-352).

Results

Little or practically no sweet potato weevil infestation was found in all treatments. Only traces of infestation were recorded in the untreated check.

Carbofuran residues were detectable in the roots of all treatments (Table 4). However, the concentrations were very low.

Conclusions

Broadcasting carbofuran 3G at 2 kg ai/ha once every three or less weeks gives good weevil control and only minimal insecticide residues in sweet potato roots. Insecticide granules broadcast on the soil surface kill the insect as it crawls over the soil in search of cracks that provide access to the roots, thus reducing or eliminating root infestation. Insecticide residues in the edible roots are avoided,

however, probably because the broadcast granules do not come in direct contact with the roots. The minor amounts of residue in the roots are possibly due to insecticide seepage after rain or irrigation.

Table 4. Carbofuran residues in sweet potato roots.

Carbofuran (kg ai/ha)	Applicaton frequency	Carbofuran residue (ppm)
2	once/week	0.165 ±0.035
2	once/2 weeks	0.082 ±0.019
2	once/3 weeks	0.057 ±0.018
2	once/4 weeks	0.033 ±0.010
1	once/week	0.112 ±0.050
1	once/2 weeks	0.039 ±0.021
1	once/3 weeks	0.026 ±0.007
1	once/4 weeks	0.015 ±0.004
Cutting dip only	-	0
Control	-	0

Confirmation of Stem Borer Resistance in Sweet Potato

Introduction

In 1980 two sweet potato accessions, I 55 and I 92, were identified as having moderate to high levels of resistance to a stem borer, Omphisa illisalis. The resistance was confirmed in 1981. During 1982, additional tests were conducted in larger plots at two locations to confirm the stability of the resistance.

Materials and Methods

Tests were performed at two locations on Penghu Island. Each test included two resistant accessions and one susceptible check. Stem cuttings of each entry were planted in 5 x 4 m plots. Each entry had four replicates arranged in a randomized complete block design. The crop was raised with customary cultural practices except that no insecticide was applied. Prior to harvest each plot was observed for stem borer infestation. Numbers of insect infested and total plants in each plot were recorded and data were converted to percent damage and statistically analyzed for comparison of infestation rates.

Results

At one location the sweet potato crop was destroyed by typhoon. The results of the evaluation at the second location are summarized in Table 5.

Table 5. Resistance reaction of selected AVRDC accessions against stem borer (Omphisa illisalis) at Penghu island.[z-w]

AVRDC Accession	Damaged plants (%)	Total yield (t/ha)
I 55	23.50 b	7.2
I 92	16.95 b	7.6
AIS 35-2	83.28 a	26.95

[z] Planting date: April 28, 1982.
[y] Observation date: October 4, 1982.
[x] Data are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[w] Plot size: 5 x 4 m.

The resistant entries suffered significantly less stem borer damage than the susceptible cultivar. The yield potential of the resistant entries is rather poor, however, compared with the yield of the susceptible agronomic cultivar AIS 35-2.

Conclusions

Accessions I 55 and I 92 have consistently shown moderate to high levels of resistance to stem borer for three years at Penghu Island. The entries have rather low yield but they can be used as sources of resistance in breeding stem borer resistant sweet potato cultivars.

Search for Additional Sources of Resistance to Stem Borer in Sweet Potato

Introduction

In 1981 AVRDC received 300 new sweet potato accessions from Papua New Guinea. These accessions were planted at Penghu Island during spring, 1982, mainly to screen for resistance to sweet potato weevil. Since stem borer also infests sweet potato plants during spring and summer, all accessions were observed for stem borer infestation.

Materials and Methods

A 0.35 ha field was rototilled and worked into 5 m long and 1 m wide beds. Stem cuttings of each entry, including those of two known resistant and susceptible checks, were planted as single rows in each bed. Each entry was duplicated. The crop was raised using all

traditional cultural practices except that no insecticide was applied. A week before the crop was to be harvested, each entry was observed for stem borer infestation, which could be easily judged by the presence of holes in the crown through which adults escape and at times by the accumulation of frass around the crown position, which is caused by the insect feeding within the stem. Infested plants also have hollow vines. Stem borer infested and total number of plants were recorded and the damage data was converted to percent damaged plants for comparison. The percent damage data were subjected to a statistical analysis based on the mean and standard deviation of all entries. This analysis was similar to that used in sweet potato weevil resistance rating.

Results

None of the 234 entries was immune to stemborer infestation. However, five entries had stem borer damage comparable to or less than AVRDC's two standard resistant checks (Table 6).

Table 6. Performance of sweet potato entries selected for resistance to stem borer (*Omphisa illisalis*).[z-w]

AVRDC Accession	Identification	Damaged plants (%)	Resistance rating[v]	Yield (t/ha)
I 542	Sauriki	12.9	MR	0.4
I 563	Opume	16.3	MR	0.7
I 600	Meumun	17.7	MR	0.0
I 614	Aforema-lae	6.3	MR	0.7
I 673	No. 1	12.2	MR	3.0
I 55	PI 324889[u]	20.5	MR	3.7
I 92	PI 308208[u]	6.7	MR	2.6
	AIS 35-2[t]	73.3	S	10.5

[z] Planting date: April 1982.
[y] Observation date: September 23, 1982.
[x] No. of replicates: 2.
[w] Plot size: 5 x 1 m.
[v] Resistance ratings: MR = moderately resistant, S = susceptible.
[u] Resistant checks.
[t] Susceptible check.

Conclusions

Five new accessions, I 542, I 563, I 600, I 614, and I 673, represent additional sources for breeding stem borer resistant cultivars. However, the resistance will be reconfirmed before these materials are utilized in the resistance breeding program.

Sweet Potato Physiology

Evaluation of Storage Root Formation and Flooding Damage of Sweet Potato Using a Simplified Blade-Petiole-Root System

Introduction

The great variation in data of field sweet potato studies makes evaluation of environmental stress difficult. Isolated sweet potato parts are easily rooted, and a simple blade-petiole-root system has been reported useful for flood tolerance screening. This experiment was performed to evaluate the practicality of the system and investigate varietal yield potential under flooding and non-flooding conditions.

Materials and Methods

The first experiment involved five accessions and two breeding lines. The fourth, fifth, and sixth leaves from the vine tip were cut at the petiole base. Twenty leaves per entry were separated into five pots/replicate in four replicates and planted in vermiculite fertilized with 1/10 strength Hoagland's solution three times per week. Eight weeks later, they were investigated for storage root formation and other growth parameters.

The second experiment involved the same entries. At six weeks after planting, plastic pots containing leaf cuttings were immersed in water to the level of 1 cm above the vermiculite surface for one week. Blade-petiole-root systems were investigated for storage root formation and other growth parameters immediately after flooding and two and six weeks after flooding.

Results

Leaf cuttings developed fibrous roots and storage roots. AIS 35-2 produced fibrous roots readily in four to seven days, but roots of I 1, I 57, and I 428 developed more slowly. There were varietal differences in storage root formation (Table 1), and a relationship was observed between leaf area and storage root dry weight accumulation ($r = 0.72^*$).

In the second experiment, flooding for seven days tended to reduce storage root formation, although reduction was significant only for I 428 and AIS 0122-2 (Table 2). The extent of flooding damage to fibrous roots was much less. Although flooding has a tendency to reduce storage root formation, flooding in fact increased net assimilation rate of sweet potato leaf blades during the two weeks immediately after the completion of flooding (i.e. 0.42 vs. 1.77 mg/cm^2/week). As previously reported, flooding also increased root respiration rate (i.e. 2.85 vs. 4.04 CO_2 mg/g fresh root/hr). Comparison at six weeks after flooding showed no difference between flooded and non-flooded cuttings, which suggested that leaf cuttings tended to recover after flooding.

Table 1. Storage root formation, leaf area, and dry weight of sweet potato blade-petiole-root formation.[z]

Entry	Stge. root yield (g/cutting)	Stge. root no./ cutting	Leaf area (cm^2/ blade)	Dry wt. (g/cutting)			
				Blade	Petiole	Fibrous root	Stge. root
I 1	2.81 a[y]	1.3 ab	49.5 a	0.22 ab	0.10 b	0.43 a	0.58 a
I 6	0.89 bc	0.8 cd	44.5 ab	0.24 a	0.10 b	0.37 a	0.20 cd
I 57	0.40 c	0.6 d	22.6 d	0.12 d	0.08 b	0.20 b	0.09 d
I 232	0.62 c	0.6 d	34.6 c	0.17 c	0.09 b	0.36 a	0.16 cd
I 428	3.09 a	1.6 a	45.8 ab	0.24 a	0.10 b	0.19 b	0.68 a
AIS 35-2	2.56 a	1.2 bc	40.8 bc	0.19 bc	0.19 a	0.31 ab	0.48 ab
AIS 0122-2	1.64 b	0.9 bcd	46.4 ab	0.22 ab	0.19 a	0.30 ab	0.35 bc

[z] Sweet potato leaf cuttings were planted on March 22, investigated on May 18, 1982.
[y] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Effect of flooding on storage root formation of sweet potato blade-petiole-root cuttings.[z]

Entry	Immediately after flooding			2 weeks after flooding		
	Fibrous root	Stge. root no.	Stge. root dry wt.	Fibrous root	Stge. root no.	Stge. root dry wt.
I 1	0.79	0.45	0.56	1.39	0.49	0.78
I 6	0.96	0.94	1.00	1.09	0.84	0.44
I 57	3.73	0	1.00	0.53	0.75	0.93
I 232	1.04	1.32	0.67	1.17	1.34	1.23
I 428	0.74+[y]	0.71	0.49*	0.55	0.56	0.50
AIS 35-2	0.77	0.67	0.68	1.78	0.50	0.82
AIS 0122-2	1.25	1.20	0.36	1.06	1.20	0.57+

[z] Expressed as flooded/control. Leaf cuttings were planted on April 15, 1982 and flooded for one week at six weeks after planting.
[y] +,* = significant difference between flooded and unflooded at 10 and 5% levels, respectively.

Conclusions

Blade-petiole-roct systems may be useful for screening germplasm. There was a varietal difference in storage root formation after a

certain period of growth in small plastic pots. However, the system may not be useful for evaluating yield potential for different germplasm due to variations in rooting ability and blade size of blade-petiole-root systems and leaf number and canopy differences among germplasm grown in the field. Flooding tended to reduce storage root formation, and the extent of reduction appeared high in some entries. However, variation among data suggests that further improvement of the system is needed.

Growth Analysis of Sweet Potato in the Hot, Wet Season

Introduction

High temperature and excessive soil moisture limit the storage root formation of sweet potato. The influence of hot, wet conditions on the growth of various plant parts was investigated.

Materials and Methods

Two entries (C 64-108 and AIS 0122-2), four blocks (planted April 6, May 11, June 7, and July 5), and 12 random-pairing plots/block were used. Plants were sampled at two week intervals for growth analysis. Soil cores were sampled weekly for moisture analysis. After 140 days, one row was harvested from each plot for evaluation of yield and quality.

Results

All materials encountered a flooding stress from a typhoon on July 29, but from September through the end of 1982 there was almost no rainfall (Figure 1). During the early growth stage, high rainfall benefitted aerial growth and leaf area (Figure 2), but suppressed storage root growth especially in AIS 0122-2 (Figure 3, block 2). Moderate soil moisture in the early stage did not seem to increase crop growth to the extent of high rainfall, but benefitted storage root growth (block 3, samplings 1, 2, and 3). In the later stage, growth of storage roots was not limited by low soil moisture (blocks 2 and 3), but was suppressed by high soil moisture (block 1).

According to the analysis, C 64-108 is superior to AIS 0122-2 in yield and starch and dry matter contents (Table 3).

Conclusions

Under local hot, wet conditions, C 64-108 produces storage roots more efficiently than AIS 0122-2. However, while storage root growth of

C 64-108 seems resistant to flooding in the early stage, both entries are susceptible in the later stage.

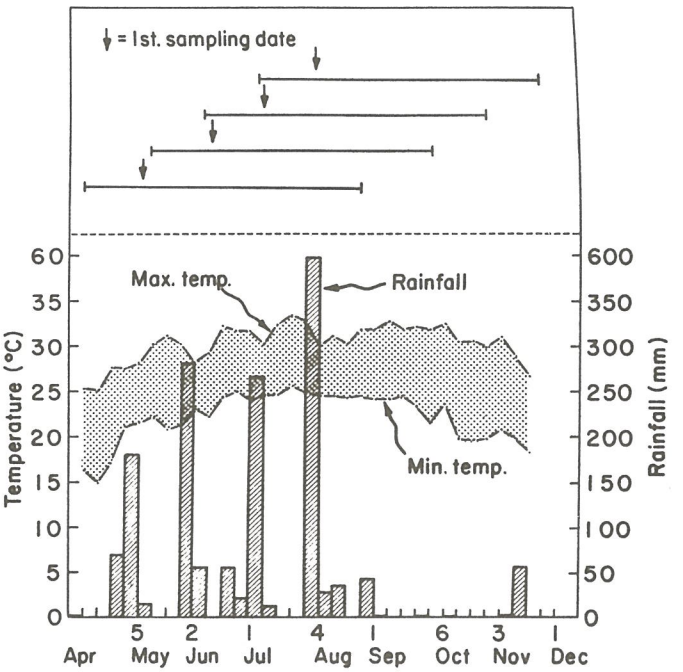


Figure 1. Growth periods of four sweet potato blocks and correlative weekly maximum-minimum temperature and rainfall.

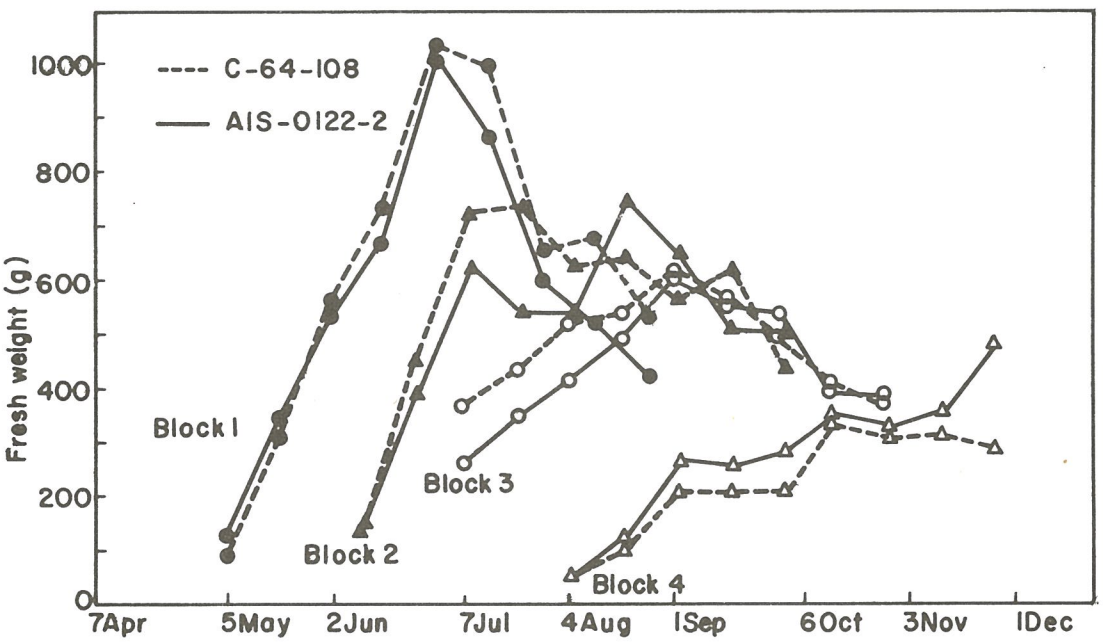


Figure 2. Variation in fresh weight of aerial parts during the growth period in four sweet potato blocks.

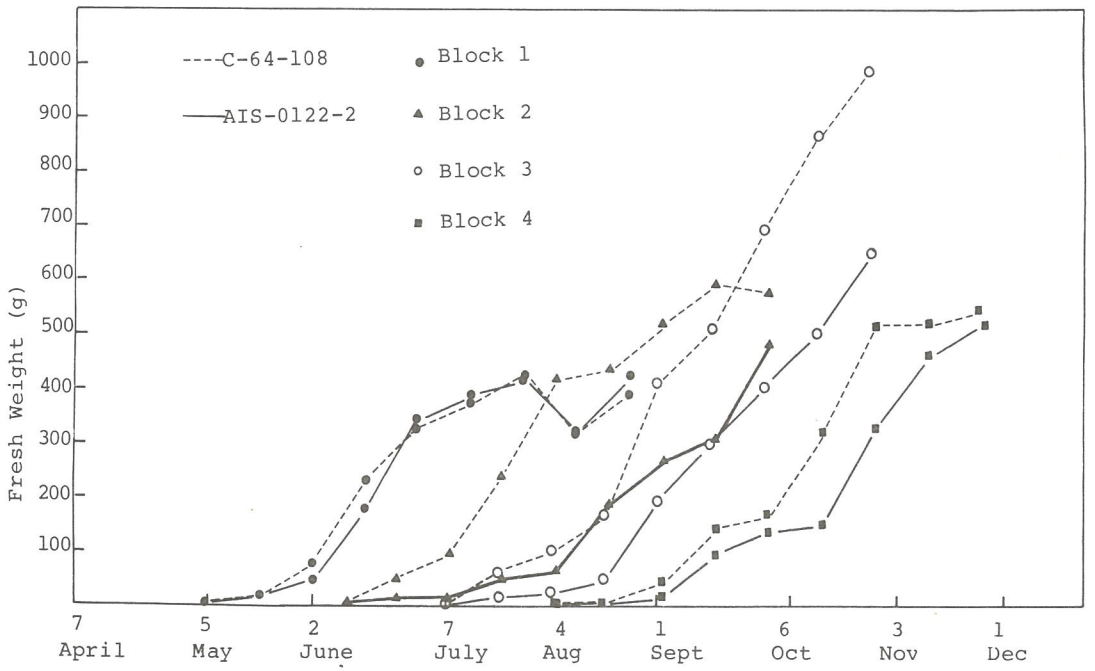


Figure 3. Variation in storage root fresh weight during the growth period in four sweet potato blocks.

Table 3. Effect of planting date during the hot, wet season on yield and other characteristics of sweet potato.

Planting date	Sugar (%)	Starch (%)	Dry matter (%)	Total yield (kg/pl.)	Marketable yield (kg/pl.)
AIS 0122-2					
April 6	25.9 a[z]	53.6 bc	17.9 b	0.49 b	0.37 b
May 11	20.5 b	57.8 a	20.2 a	0.54 b	0.35 b
June 7	25.4 a	51.8 c	19.3 ab	0.72 a	0.57 a
July 5	21.7 b	56.9 ab	19.4 a	0.58 ab	0.46 ab
C 64-108					
April 6	20.0 a	64.8 a	22.7 b	0.49 c	0.28 c
May 11	16.7 b	62.6 a	22.9 b	0.88 b	0.70 b
June 7	17.3 ab	63.7 a	25.6 a	1.05 a	0.82 a
July 5	15.6 b	65.4 a	25.6 a	0.78 b	0.67 b

[z] Separation of means in each column of same entry by Duncan's multiple range test, 5% level.

Mungbean Breeding

Hybridization and Segregating Populations

In 1982, 116 single or multiple crosses were made among predominantly AVRDC selections with high yield potential, higher levels of resistance to diseases, and uniform maturity (Table 1). Thirty-nine additional crosses were made for specific purposes, such as to incorporate resistance to beanflies and to study inheritance of Cercospora leafspot (CLS) and powdery mildew (PM) resistance.

Table 1. Mungbean crosses made in 1982, AVRDC.

Type of cross	Spring	Summer	Fall	Total
Single cross	38	51	8	97
3-way cross	26	14	-	40
Double cross	12	-	-	12
Backcross	-	2	4	6
Total	76	67	12	155

Poor light penetration into the crop canopy has been suggested as one of the important factors limiting mungbean yield potential (AVRDC Progress Report 1975). In order to evaluate the possible advantages of different leaflet types, namely the entire trifoliolate, lobed trifoliolate, and multifoliolate, four single crosses and six backcrosses were made as a first step in developing near-isogenic lines for different leaflet types.

At the request of researchers in Pakistan, nine crosses between three AVRDC high yielding selections and three recommended Pakistani lines were made.

Segregating populations from the crosses are grown in three seasons for rapid generation advance and selection under different environmental conditions and disease pressures. Two check cultivars, VC 1628 A for agronomic traits and VC 1560 D for disease resistance, are planted every 10 or 12 rows to facilitate field selection. Pedigree or mass selection is employed depending upon family performance. Lodging tolerance and good seed quality are additional selection criteria.

Evaluation of Germplasm for Early and Uniform Maturity

Introduction

Unsynchronous pod maturity, which necessitates multiple harvests using hand labor, is a serious problem that needs genetic improvement. The highest level of uniform maturity presently available in AVRDC's high yielding breeding lines is only about 80% of the total yield from the first harvest. Therefore new accessions, most of them lines improved by national programs for early and uniform maturity, were evaluated during 1982.

Materials and Methods

In spring, 67 accessions were planted on February 25 in one row plots, 3 m long, 0.75 m between rows and 0.1 m between hills, in two replications. V 3476 served as the check. From these observational plots, 25 accessions which matured more uniformly were selected. The selected accessions with the same check were planted on July 15 in 2 row plots, 5 m long, 0.5 m between rows and 0.1 m between hills, in a randomized complete block design with three replications. The summer trial was repeated in the fall (planted on September 9).

Results

Genotypic differences for maturity were not clearly expressed in fall plantings because the plants dried prematurely due to severe root damage. From the preliminary evaluations, however, five lines were selected for early and uniform maturity (Table 2). The selected lines were generally low yielding, small seeded, and susceptible to diseases and lodging.

Conclusions

The selected lines will be further evaluated during 1983 in spring and summer plantings when the genotypic differences for maturity are more clearly expressed.

Table 2. Potential genetic sources for early and uniform maturity, 1982, AVRDC.[z]

Acc. no.	Variety	Days to maturity	% 1st harvest[y]	Yield (t/ha)	1000 seed wt.(g)	Disease[x] CLS	Disease[x] PM	Lodging[w]
V 6037	BNP 3124	51	96	0.78	26	VS	VS	5.0
V 6080	Sr. No. 61	62	95	1.50	22	MS	MS	1.9
V 6027	NI-37	55	91	1.86	42	VS	VS	2.7
V 6078	ML-282	61	91	1.40	28	VS	MS	2.0
V 6083	Okl. 5579-8	58	88	1.92	60	VS	VS	2.2
V 3476 (CK)	CES 1D-21	57	83	1.84	48	MS	VS	0.7

[z] Data are means of summer and fall trials.
[y] Expressed as a percentage of total yield.
[x] Cercospora leafspot (CLS) and powdery mildew (PM) were rated in summer and fall from natural epiphytotic. MS = moderately susceptible and VS = very susceptible.
[w] Rated on a scale of 1 to 5, 1 = no lodging and 5 = all lodging.

Yield Trials

Introduction

The objective of the mungbean breeding program at AVRDC is to develop widely adaptable, high and stable yielding genotypes with early and synchronous maturity, resistance to important diseases and insects, and improved seed quality. Breeding lines are evaluated in three successive seasons for identification of widely adaptable genotypes through disruptive seasonal selections under distinctly different environmental and biological stresses. All the yield trial entries are simultaneously tested in separate trials for disease resistance in three seasons and for photoperiod sensitivity in the fall.

Materials and Methods

Preliminary yield trials (PYTs), intermediate yield trials (IYTs), advanced yield trials (AYTs), and elite yield trials (EYTs) were conducted in spring, summer, and fall, 1982. Number of entries, dates of sowing and harvests, plot size, population density, and number of replications are shown in Table 3. A randomized complete block design was used in all trials.

Results

The average yield of 24 lines in the EYTs was 1.69, 2.43, and 1.05 t/ha in spring, summer, and fall, respectively. The highest yield of 2.36 t/ha in spring and 2.85 t/ha in summer was produced by the same line, VC 2768 A. This breeding line was also rated as highly resistant to powdery mildew (PM) and moderately resistant to Cercospora leafspot

Table 3. Mungbean yield trials conducted during 1982, AVRDC.

Type of trial	No. of entries (checks)	Sowing date	Harvesting date 1st	2nd	3rd	Plot size (m^2)	Population density 1,000 plants/ha	No. of reps.	Mean yield (t/ha)	Highest yield (t/ha)
1. Spring plantings										
EYT-I	12 (2)	2/24	5/12	6/7	6/15	14.4	500	5	2.02	2.36
EYT-II	12 (2)	2/24	5/12	6/7	6/15	14.4	500	5	1.36	1.85
AYT	30 (1)	2/23	5/13	6/4	6/15	12	400	4	1.38	1.85
IYT	40 (1)	2/24	5/14	6/4	6/16	6	400	3	2.11	2.74
PYT-I	110	2/24	5/14	6/4	6/16	6	400	2	2.05	2.72
2. Summer plantings										
EYT	24 (4)	7/19	9/30	10/22	11/3	14.4	250	5	2.43	2.85
AYT	25 (2)	7/17	9/21	10/14		10	200	4	2.30	2.69
IYT	25 (2)	7/16	9/21	10/14		5	200	3	2.23	2.74
PYT-I	55 (1)	7/17	9/27	10/27		5	200	3	2.55	2.99
PYT-II	262	7/17	9/22	10/18		5	200	2	2.52	3.26
3. Fall plantings										
EYT	24 (4)	9/8	11/10	11/18		18	400	5	1.05	1.37
AYT	25 (2)	9/9	11/11	11/17	11/26	10	400	4	1.20	1.63
IYT	25 (2)	9/8	11/11	11/22		5	400	3	1.15	1.62
PYT-I	55 (1)	9/8	11/10	11/22		5	400	3	1.20	1.72

(CLS). The yields and other important characters of eight of the higher yielding lines over three seasons are given in Table 4.

In the AYTs, average yields of more than 1.7 t/ha over three seasons were produced by six breeding lines compared with 1.5 t/ha from the check cultivar V 3476 (Table 5). VC 2307-3-B-26-2B-1-B, which produced 2.7 t/ha in summer, was the highest yielder in both spring and summer.

From the IYTs, 10 high yielding lines were selected for further evaluation (Table 6). VC 2768-16-B-3-B was the highest yielder with 2.74 t/ha in both spring and summer.

In addition to the above high yielding selections, three lines from the EYTs, four lines from the AYTs, and five lines from the IYTs were selected for disease resistance or uniform maturity.

Thirty-three lines from PYT-1 and 134 lines from PYT-II were selected for high yield, disease resistance, and/or uniform maturity.

Conclusions

Yield potential, stable performance over seasons, and disease resistance have been substantially improved in the new selections.

Improvement for uniform maturity requires particular attention. This will be reflected in future hybridization and selection programs.

Table 4. Performance of eight selected lines from elite yield trials over three seasons, 1982, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st harvest[z]	Disease[y]		Photoperiod sensitivity[x]	1000 seed wt.[w] (g)
	Spring	Summer	Fall	Mean		CLS	PM		
VC 2768 A	2.36 a[v]	2.85 a	1.47 a	2.23	71.0	MR	HR	0	60.0
VC 1973 A	2.22 ab	2.48 ab	1.43 ab	2.04	74.7	MS	MS	0	60.0
VC 2755 A	2.35 a	2.24 b	1.46 a	2.02	76.0	MR	VS	1	64.7
VC 1168 B	1.63[z]	2.75 ab	1.69 a	2.02	69.3	MS	MR	0	52.7
VC 2778 A	2.13 ab	2.29 b	1.28 ab	1.90	78.0	MR	VS	0	58.7
VC 2764 A	1.72[u]	2.49 ab	1.42 ab	1.88	74.7	MR	MR	0	58.5
VC 2764 B	1.85[u]	2.56 ab	1.20 ab	1.87	73.7	MR	MR	0	54.7
VC 1647 B	1.77 b	2.66 ab	0.97 b	1.80	77.0	MS	MR	0	51.0
V 3476 (CK)	2.00 ab	2.41 b	1.22 ab	1.88	77.3	MS	VS	0	47.0

z
y Expressed as a percentage of total yield, average of three seasons.
Cercospora leafspot (CLS) was rated in summer and fall and powdery mildew (PM) in spring and fall from the natural epiphytotic disease nurseries:
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: 0 ≤ 4 and 1 = 5-8 days.
w Average of three seasons.
v Means followed by the same letter are not significantly different at the 5% level as per Duncan's multiple range test.
u Data from different trial.

Table 5. High yielding lines from advanced yield trials over three seasons, 1982, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st harvest	Disease		1000 seed wt. (g)
	Spring	Summer	Fall	Mean		CLS	PM	
VC 2307-3-B-26-2B-1-B	1.85 a	2.69 a	1.37 ac	1.96	67.7	MR	MS	43.3
VC 2572 A	1.69 ab	2.36 b	1.63 a	1.89	67.3	MR	MS	54.3
VC 2720-5-B-2-B	1.76 ab	2.12 b	1.54 a	1.81	60.0	MR	MR	45.0
VC 2778-3-B-1-B	1.84 a	2.06 b	1.48 ab	1.79	75.3	MS	MR	62.7
VC 1000 A-1-B	1.46 ab	2.66 a	1.11 c	1.74	67.7	HR	HR	55.0
VC 1482 C-12-B	1.32 ab	2.63 a	1.16 bc	1.70	72.0	MR	HR	48.7
V 3476 (CK)	1.14 b	2.29 b	1.08 c	1.50	75.3	MS	VS	47.0

Table 6. Promising selections from intermediate yield trials over three seasons, 1982, AVRDC.

AVRDC no.	Yield (t/ha)				% 1st harvest	Disease		1000 seed wt. (g)
	Spring	Summer	Fall	Mean		CLS	PM	
VC 2768-16-B-3-B	2.74 a	2.74 a	1.22 ac	2.33	71.7	MR	MR	61.0
VC 2763-39-B-10-B	2.59 a	2.40 ac	1.33 ac	2.11	71.7	MR	HR	56.7
VC 2750-B-16-B	2.55 ab	2.12 c	1.62 a	2.10	78.3	MR	HR	55.7
VC 2763-26-2B-1-B	2.44 ab	2.18 bc	1.45 ab	2.02	73.7	HR	MR	57.7
VC 1482 C-15-1-B	2.43 ac	2.67 ab	0.91 c	2.00	72.3	HR	HR	48.3
VC 2742-26-2B-3-B	2.36 ac	2.32 ac	1.29 ac	1.99	75.3	HR	MR	65.0
VC 2804-9-B-2-B	2.25 ac	2.33 ac	1.38 ac	1.99	70.3	MR	MS	60.0
VC 2754-3B-2-B	2.32 ac	2.25 bc	1.27 ac	1.95	79.0	MR	MR	63.7
VC 2802-4-B-2-B	2.09 bc	2.39 ac	1.18 ac	1.89	79.7	MR	HR	53.7
VC 2770-40-B-3-B	2.34 ac	2.27 ac	0.94 c	1.85	82.7	MS	MS	64.0
V 3476 (CK)	1.87 c	2.37 ac	1.27 ac	1.84	82.7	MS	VS	48.0

Development of Disease Resistant Lines

Introduction

Cercospora leafspot (CLS) and powdery mildew (PM) can cause yield reductions of 47% and 40%, respectively, and are the two major disease problems common to most mungbean growing areas. CLS is most severe during warm rainy weather, while PM thrives in cooler drier weather. To develop lines with multiple resistance to these diseases, all the advanced breeding lines being evaluated under various yield trials and selected accessions are routinely screened for three seasons.

Materials and Methods

Two hundred and one breeding lines and 74 accessions were evaluated in spring, 386 breeding lines and 52 accessions in summer, and 120 breeding lines and 73 accessions in fall. Spring, summer, and fall crops were planted on February 26, July 16, and September 6, respectively. Each entry was planted in single row plots, 2 to 3 m long, 0.75 m between rows and 0.1 m between hills, and replicated twice. Check plots, consisting of one row of susceptible check (V 1944 in spring and V 2010 in summer and fall) between rows of resistant check (V 2773), were planted in every five test lines. CLS was rated in summer and fall, and PM in spring and fall under natural epiphytotic conditions. The lines showing higher levels of resistance than V 2773 were rated highly resistant and those showing the same levels as V 2773 were named moderately resistant.

Results

Among the 120 breeding lines and 52 accessions that were evaluated across three seasons, nine breeding lines were consistently rated highly resistant to both CLS and PM (Table 7). VC 1560 D, which was reported as highly resistant last year, also maintained its high level of resistance. An additional 68 breeding lines were moderately to highly resistant to both diseases.

Conclusions

It is obvious that the disease resistance of the breeding population is progressively improving. The highly resistant lines will be further evaluated in 1983 for agronomic characters and for confirmation of resistance as well.

Table 7. Breeding lines highly resistant to Cercospora leafspot and powdery mildew, 1982, AVRDC.

Selection no.	Parentage	Yield (t/ha)				% 1st harvest	Yield trial
		Spring	Summer	Fall	Mean		
VC 1560 D	BPI glab. 3//CES 44 /ML-3	1.05	2.51	1.34	1.63	56.0	EYT
VC 1000 A-1-4-B	EG-MG-16/ML-3	1.46	2.66	1.11	1.74	67.7	AYT
VC 2778-3-B-4-B	VC 1560 C//CES 1D-21/PHLV 18	1.44	2.18	1.04	1.55	73.3	AYT
VC 1482 C-15-1-B	EG-MD-6D/ML-3	2.43	2.67	0.91	2.00	73.0	IYT
VC 1560 D-7-2B-1-B	BPI glab. 3//CES 44/ML-3	2.26	2.41	1.14	1.94	72.0	PYT
VC 2719-B-18-B-3-B	Shanhua 1//EG-MG-4/ML-6	2.04	2.18	0.99	1.74	69.3	PYT
VC 2742-30-2B-3-B	VC 1000 A/VC 1560 A	2.43	2.88	1.05	2.12	66.7	PYT
VC 2777-B-1-2-B	VC 1560 C/VC 1000 A	2.20	2.77	1.37	2.11	71.7	PYT
VC 2797-9-2B-3-B	ML-3/CES 55//BPI glab. 3///VC 1560 A	2.07	2.43	1.58	2.03	67.7	PYT

Performance of Breeding Lines With and Without Management

Introduction

In most of Southeast Asia, mungbean is usually grown with few or no inputs, as a catch crop between major crops. The objective of this experiment was to identify breeding lines that have genetic potential to give high yields under no management situations.

Materials and Methods

The 20 breeding lines and four check cultivars of the elite yield trial (EYT) were evaluated. This trial was conducted in land adjacent to the summer EYT in a randomized complete block design with three replications. As in the EYT, mungbeans were planted on July 19 in six row plots, 6 m long, 0.4 m between rows, and at a population density of 250,000 plants/ha. No management input was given except thinning after emergence to adjust the population density.

Results

On an average, the no management trial produced 55.1% of the yield of the trial with management. Number of pods per plant and plant height were greatly reduced under no management (Table 8).

The highly significant positive correlation (0.67**) between yields of individual lines under management and no management indicated that the higher yielding lines under proper management tended to perform better under no management as well. In this no management trial, six breeding lines produced more than 1.5 t/ha compared to 1.1 t/ha by the best check cultivar, V 3476 (Table 9).

Table 8. Comparison of mungbean yield and agronomic characters between management and no management, summer 1982, AVRDC[z].

Character	Management	No management	Difference (%)
Yield (t/ha)	2.43	1.34	- 1.09 (44.9)
Plant height (cm)	69.0	59.0	-10.0 (14.5)
Days to flowering	47.0	48.0	+ 1.0 (2.1)
Days to mean maturity	82.0	85.0	+ 3.0 (3.7)
Pods/plant	22.7	14.6	- 8.1 (35.7)
Seeds/pod	10.8	10.4	- 0.4 (3.7)
1000 seed weight (g)	55.0	54.0	- 1.0 (1.8)

[z] Data are means of the same 24 entries from two separate trials.

Table 9. Performance of mungbean breeding lines under no management in summer, 1982, AVRDC.

AVRDC No.	Yield (t/ha)		Yield increase under management (%)
	No management	Management	
VC 2719 A	1.82 a	2.56 ab	0.74 (40.7)
VC 1482 C	1.81 a	2.65 ab	0.84 (46.4)
VC 1482 D	1.73 a	2.64 ab	0.91 (52.6)
VC 1168 B	1.59 ab	2.75 ab	1.16 (73.0)
VC 2768 A	1.54 ab	2.85 a	1.31 (85.1)
VC 2764 A	1.49 ab	2.49 ab	1.00 (67.1)
V 3476 (CK)	1.13 b	2.41 b	1.28 (113.3)
Mean of 24 entries	1.34	2.43	1.09 (76.2)

Conclusions

Several high yielding selections also performed relatively well under no management. Selection for both management and no management situations may be done under high yielding environments. Further testing is needed, however, under different locations and seasons with varying environmental and biological stresses.

Interspecific Hybridization

Introduction

Mungbean and black gram are closely related species. The black gram characters that are desired in mungbean improvement include higher levels of resistance to major diseases and insects, better tolerance to environmental stresses and shattering, and higher methionine content.

Hybrid inviability, sterility, and breakdown are the major reproductive barriers between these two species. However, the strength of isolating mechanisms varies depending upon the parental genotypes, especially mungbean female lines used in the crosses. This indicates the possibility of locating mungbean lines that can cross better with black gram and thus serve as genetic bridges between the two species.

Materials and Methods

Two improved mungbean lines (VC 1973 A and V 3476), six selected mungbean accessions (V 2719, V 4110, V 4111, V 4586, V 4997, and V 5183), three highly fertile selections from previous mungbean x black gram crosses (IC 1, IC 2, and IC 3), two lines interspecifically derived at Punjab Agricultural University, India (MG 122 and MG 143), and two black gram lines (VM 2135 and VM 2164) were used. In spring, each parental line was planted in five clay pots (20 cm diameter), two plants per pot in the greenhouse. Three plantings were made at one week intervals to ensure the availability of flowers. Twenty-six interspecific crosses (13 mungbean lines x 2 black gram lines) and 22 intraspecific crosses (2 improved mungbean lines x 11 other lines) were made. About 20 flowers were pollinated for each cross. Data taken from each cross were: Percent pod set; number of seeds per pod (with empty, cracked, and crinkled seeds counted separately in the case of interspecific crosses); number of F_1 plants that died before flowering; pollen stainability by staining pollen grains from at least three flowers per plant with cotton blue in lactophenol; and number of pods, usually with one seed/pod, set on F_1 plants.

Results

Differences in pod set were not significant either between or among intraspecific and interspecific crosses. Seeds obtained from intraspecific crosses were normal and no hybrid weakness or sterility was observed, suggesting that there is no reproductive barrier in the interline crosses within the mungbeans. From the interspecific crosses, however, only crinkled, cracked, and empty seeds were produced. No empty seeds germinated. On the average, 30% of the cracked seeds and 80% of the crinkled seeds germinated. Genotypic differences of the mungbeans in producing germinable seeds, viable F_1 plants, and F_2 seeds were clearly shown. The crosses derived from the six mungbean

accessions were more successful in terms of hybrid embryo development, hybrid survival, and fertility (Table 10).

Conclusions

The six mungbean lines that showed no reproductive barrier to the improved mungbean lines and that crossed better with the black gram lines have potential for genetic bridges. The possible breakdown and fertility of the advanced generations must still be examined.

Table 10. Mungbean lines that crossed most successfully with black gram, 1982, AVRDC.[z]

Accession or Selection No.	Variety or parentage	% pod set	No seeds/pod (% germination) cracked	No seeds/pod (% germination) crinkled	% F_1 survival	F_1 pollen stainability (%)	No. pods/F_1 plants
IC 2	M 86/PI 174907[+]//M 86[y]	78.4	0.1 (0)	5.0 (90)	76	27	38.7
V 6099	MG 143	85.7	0.1 (100)	5.9 (98)	93	23	11.5
IC 3	M 86//M 86/PI 237689[+]	82.8	0.4 (78)	4.7 (83)	87	28	19.8
V 6085	MG 122	65.0	0.1 (50)	6.4 (95)	33	30	11.0
V 4997	M 921	77.5	1.2 (27)	2.6 (68)	53	23	19.7
IC 1	M 85//M 85/PI 174907[+]	71.4	0.1 (25)	4.7 (85)	85	21	9.0
V 3476 (CK)	CES 1D-21	77.8	2.8 (0)	2.9 (73)	19	15	0
VC 1973 A (CK)	CES 1D-21/EG-MG-16	81.0	6.5 (10)	0.6 (29)	0	-	-
Mean of 13 lines		79.3	1.9 (31)	3.1 (80)	39	18	9.1

[z] Data are means from about 20 crosses each with two black gram lines, VM 2135 and VM 2164.
[y] + = black gram.

Mungbean Pathology

Controlling the Mungbean Root Disease Complex

Introduction

The mungbean root disease complex has become a serious problem at AVRDC. Previous experiments indicated that soil fumigation with chloropicrin will control the disease complex, but this fumigant is impractical for AVRDC use. The purpose of this study was to identify control measures that are more applicable to the AVRDC situation than chloropicrin application.

Materials and Methods

The experiment was planted on November 9, 1982 in the mungbean root disease nursery in a randomized complete block design with three replications. The treatments were: 1) preplanting with sorghum and removing above ground parts before preparing soil for planting mungbean one month later; 2) soil fumigation with Basamid W.P. (25 g/m^2) ten days before planting; 3) seed treatment with Captan 75% W.P. and soil application of granular Nemacur 10% (30 kg/ha) one day before planting; and 4) control. Plot size was 4-5 x 6 m. Percent germination and percent survival data were determined in five randomly selected sites (1 m^2) within each replication. The root disease susceptible cultivar, V 2010, was planted on November 9 and data were collected 13, 44, and 71 days after planting (DAP).

Results

Germination was good in all treatments, ranging from 78 to 92% (Table 1). Plant survival was high only in the treatment fumigated with Basamid W.P., but these plants were weak and stunted, showing symptoms of severe stress. Mean plant height at 71 DAP in the Basamid treatment was only 13 cm.

Table 1. Effect of soil fumigation, seed treatment/nematicide, and sorghum preplant on germination and survival of mungbean in a field infested with mungbean root disease complex pathogens.[z]

Treatment	Germination (%) 13 DAP	Survival (%) 44 DAP	Survival (%) 71 DAP	Plant height (cm) 71 DAP
Soil fumigation (Basamid)	92	88	79	13
Seed treatment with Captan; soil treatment with Nemacur	85	15	0	--
Sorghum preplant	78	18	2	--
Control	87	7	0	--

[z] Data represent means of three replications.

Conclusions

None of the treatments, at the rates and/or application methods used, were effective in controlling the mungbean root disease complex throughout the crop growth period in the late fall season. However, Basamid was effective during early crop growth, and may have potential at other concentrations or application rates.

Mungbean Entomology

Study of Beanfly Resistance Inheritance in Mungbean

Introduction

In late 1979, three mungbean accessions were found that showed moderate resistance to beanflies (Ophiomyia phaseoli, O. centrosematis, and Melanagromyza sojae). In 1980, AVRDC's mungbean breeder made three crosses using each of the resistant accessions with V 2184, a high yielding mungbean cultivar. The resulting populations are screened each fall, the season when beanflies cause significant damage at AVRDC. Each year resistant entries are selected. In fall, 1982, one F_4 and one F_6 population were screened in the field.

Materials and Methods

First set: When the selected F_5 entries were multiplied in spring, 1982, the seeds of several entries were found to segregate for seed coat color which ranged from green to black. Several seeds had green seed coats with varying densities of black spots. The seeds were separated based on seed color, and 36 entries were planted in the summer to select breeding lines as all had already been selected twice before. Twenty-nine plants that matured early and uniformly were selected in late summer and tested for beanfly resistance. The late maturing plants in each entry were bulked and tested along with the parents for beanfly resistance in fall, 1982.

Second set: A second set of materials that had been tested and selected for beanfly resistance only once in fall, 1981, was multiplied in spring, 1982, and in the fall 862 entries, including resistant and susceptible parents, were tested in the field at AVRDC and in Thailand.

To test for beanfly resistance, seeds of each entry were planted as a single row on top of a 5 x 0.75 m raised bed. The crop was raised using traditional cultural practices except that no insecticide was applied. Four to five weeks after germination each entry was sampled, the stem of each plant was cut open, and the number of beanfly larvae and pupae within was recorded.

Results

First set: Only two of the 29 early maturing plants, VC 2832-4-133-93-B-B-2 and VC 2832-4-193-135-B-B-2, showed beanfly resistance. These two entries mature early but have distinctly small seeds. They will be tested in Indonesia and Thailand in spring, 1983.

The performance of selected late maturing entries is shown in Table 1. These entries will be tested in Indonesia and Thailand in spring, 1983.

Table 1. Performance of selected F_6 entries for resistance to beanflies.

Entry designation	No. beanfly larvae+ pupae/20 plants
VC 2839-6-164-271-B-YB-B	0.67 c
VC 2839-6-74-200-B-ZB-B	1.00 c
VC 2839-6-41-172-B-WB-B	1.00 c
VC 2832-4-36-295-B-B-B	1.00 c
V 4281[z]	2.00 bc
V 2184[y]	4.00 abc

[z] Resistant parent.
[y] Susceptible parent.

Second set: In the AVRDC test, 24 entries were free from beanfly infestation and 45 had one beanfly larvae or pupae/20 plants. These entries had a seed weight range of 2.8 to 5.1 g/100 seeds. They will be tested in Indonesia and Vietnam in spring 1983. Results of the Thailand tests have not yet been reported.

Conclusions

At AVRDC and elsewhere in Taiwan the beanfly population is high only in the fall season. Even then the population pressure, especially that of O. phaseoli, which is the principal species attacking mungbean, is not high enough to kill susceptible plants. Rarely are more than 50% of the plants damaged in tests during Taiwan's fall season. As a result, resistant breeding materials can not be reliably selected. All future selection work will therefore be conducted in Indonesia and Thailand where the population of beanflies is very high.

Screening Accessions for Resistance to Beanflies

Introduction

Since 1979, when three accessions with moderate to high levels of resistance to beanflies were identified, additional germplasm has been received. These materials were therefore screened along with others that had either been missing or multiplied in insufficient quantity for use in the earlier screening.

Materials and Methods

Materials were screened in the fall season, September through October, when beanfly population is relatively high. A 1 ha field was divided into 2.25 m wide insect source blocks alternating with nine 7.5 m wide varietal testing blocks. Two weeks before testing, soybean, mungbean, and snap bean were planted in source blocks to maintain the insect population. The test blocks were then rototilled and worked into 75 cm wide raised beds. Every week 225 accessions were sown, 25 accessions per test block. Seeds were planted on top of 2 m long beds. Planting was sequenced so that in each test block the first week's 25 accessions were seeded adjacent to the insect source block, and each subsequent week's accessions were planted in the neighboring row.

Four weeks after planting, ten plants from each plot were uprooted and dissected, and the number of larvae and pupae found in each plant was recorded. The number of plants with damage was also recorded.

Each week the mean number of insects (larvae + pupae) found per 10-plant sample was subjected to a statistical analysis based on mean ($\bar{x}$) and standard deviation (SD). The accessions that had insect number less than $\bar{x}$ - 2SD were considered highly resistant (HR), between $\bar{x}$ - 1 SD and $\bar{x}$ - 2SD moderately resistant (MR), between $\bar{x}$ and $\bar{x}$ - 1SD as having low resistance (LR), between $\bar{x}$ and $\bar{x}$ + 2SD susceptible (S), and more than $\bar{x}$ + 2SD highly susceptible (HS). Since the past several studies showed highly significant positive correlation between insect numbers and percent damaged plants, only mean number of insects was used as the criterion for resistance rating.

Results

The results of the screening are shown in Figure 1. Of the 1,346 accessions tested, none fell in the HR category. 222 were rated MR, 545 LR and the remainder fell in the two susceptible categories.

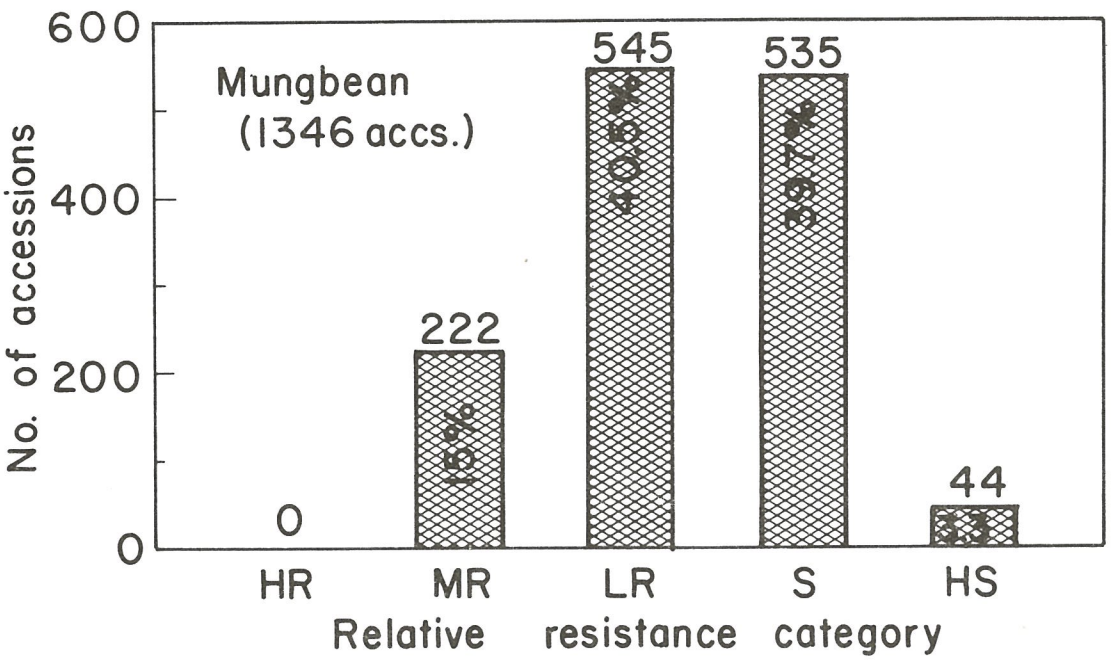


Figure 1. Relative resistance reaction of mungbean accessions to agromyzid flies.

Performance of the five least affected accessions and the one most affected is summarized in Table 2. Because of the wide variation in insect numbers found in a particular screening, the least affected accessions were still considered only moderately resistant. Accession V 1160 belongs to species Vigna glabrescens, a natural tetraploid of mungbean.

Table 2. Response of selected mungbean accessions for resistance to beanflies.[z,y]

Accession No.	Varietal identification	Origin	No. larvae+ pupae/10 plants	Resistance rating
V 1160	M 221	Philippines	0	MR
V 3540	M 528	Ethiopia	0	MR
V 4517	PLM 669	India	0	MR
V 4958	LM 186 (green)	India	0	MR
V 4959	LM 186 (mottled)	India	0	MR
V 3233	PI 425618	Afghanistan	24	HS

[z] The accessions were selected from six weekly screenings from September 20 through October 26, 1982 and were evaluated four weeks after germination.

[y] Resistance ratings: HR = highly resistant, MR = moderately resistant, S = susceptible, and HS = highly susceptible, based on mean and standard deviation of entries included in each planting.

Conclusions

The 222 entries rated moderately resistant will be screened in spring 1983 in Thailand, Indonesia, and possibly Vietnam where beanfly population pressures are much higher than at AVRDC. This will make possible the selection of truly resistant accessions.

Characterization of Beanfly Resistant Mungbean Accessions

Introduction

Three mungbean accessions rated moderately resistant to beanfly in 1979, V 2396, V 3495, and V 4281, were examined for the morphological and physiological traits entailing resistance. Especially sought was the identification of any observable or quantifiable plant characters that could be linked to the resistance. The presence of such characters, especially in the early growth stage, could give a criterion for selecting materials for beanfly resistance and preclude the need to wait for beanfly to infest the plants. Breeding and selection work could then be carried out throughout the year rather than only in the fall.

Materials and Methods

The experiment was performed in summer, planted in July, and again in fall, planted in September. Seeds of the three resistant cultivars, V 2396, V 3495, and V 4281, and two susceptible cultivars, V 2184 and V 3428, were planted in 5 x 3 m plots each consisting of four 5 m long and 0.75 m wide beds. Seeds were planted as single rows with 10 cm between plants. In the fall experiment, a 3 x 2 m plot was also maintained as untreated check in the vicinity of each main plot. The main plots were sprayed with monocrotophos at 3, 7, 10, 14, 21, and 28 days after seedling emergence to control beanflies. In summer no insecticide was sprayed and beanfly infestation was observed in plant samples taken randomly from each plot.

Plant samples were taken at three and five weeks after emergence and the following characters of susceptible and resistant accessions were studied:

1. Unifoliolate leaves: thickness, area, trichome density, leaf color, fresh weight, dry weight, and moisture content.
2. Plant height, fresh and dry weight.

3. Nodes on main stem, branching tendency.
4. Trifoliolate leaves: number, color, trichome density, leaf area, fresh weight, dry weight, moisture content, and nonprotein nitrogen.
5. Stems: stem color, shape, diameter, trichome density, fresh weight, dry weight, moisture content, and nonprotein nitrogen.
6. Petioles: length, fresh weight, dry weight, and moisture content.
7. Flowers: color and date of first flowering.

At harvest, yield components such as number of pods/plant, number of seeds/pod, and 100 seed weight were recorded.

A supplemental experiment was initiated about three weeks after the initial fall planting so that beanfly visitation habits and stem damage could be examined in greater detail. Each accession was planted on October 15 in single 3 m long rows, each 0.75 m wide, with four replications. V 1160, Vigna glabrescens, a natural tetraploid of mungbean found almost immune to beanfly in this year's beanfly resistance screening (see preceding experiment), was also included for stem analysis, as its stem character resembled that of the other resistant accessions.

Results

Unifoliolate leaves: Since beanfly infestation at the unifoliolate leaf stage causes drastic yield reduction and at times death of the plant, unifoliolate leaves were studied in greater detail. Unifoliolate leaves of resistant accessions were found to be significantly thinner and had a greater number of trichomes per unit area, less dry weight, less moisture content, and smaller leaf area.

When leaf preferences of beanflies were examined in the supplemental experiment, the number of beanfly adults visiting unifoliolate leaves of resistant accessions was found to be significantly lower than on susceptible accessions (Figure 2). Moreover, the number of oviposition or feeding punctures made by beanflies, especially in the most resistant of the three accessions, V 4281, was observed to be significantly less than in susceptible cultivars. There was statistically no significant correlation between the unifoliolate leaf area and the number of insects visiting the plant or making punctures.

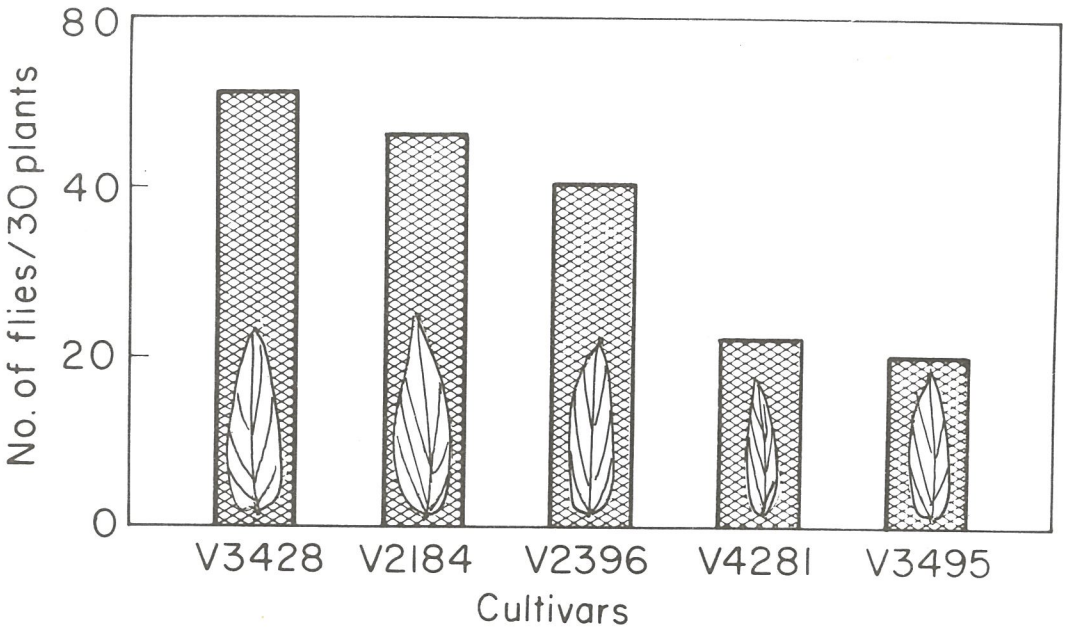


Figure 2. Number of beanflies observed on unifoliolate leaves of selected accessions. Inset: Relative size of unifoliolate leaf of respective accessions.

Trifoliolate leaves: Since beanflies are also found on trifoliolate leaves, they were examined in the same way as unifoliolate leaves. The trifoliolate leaves of resistant entries had significantly more trichomes and less moisture content than those of susceptible accessions. There was no significant correlation, however, between beanfly infestation and trifoliolate leaf thickness or dry weight. Some of these parameters did not show a clear-cut significant correlation with beanfly resistance in the fall experiment, however. This could be due to differences in photoperiod and temperature during these two seasons.

Stem: Since beanfly feeds in the stem, various characters of this plant part were investigated. In both seasons a significant negative correlation was found between resistance level and trichome density. Neither stem diameter nor moisture content had any significant relationship to beanfly infestation.

When the supplemental planting was conducted in October, the stem epidermis, where larvae of O. phaseoli and O. centrosematis feed, was analyzed. The concentration of phenolic compounds was found to be almost ten times greater in the highly resistant accession than in slightly resistant or susceptible accessions. The stem epidermis of the

nearly immune tetraploid Vigna glabrescens, V 1160, also had high levels of phenolic compounds (Table 3).

Also in the additional fall experiment, the nature of beanfly damage was examined in a 50 plant sample of each of the three resistant and two susceptible accessions. In the three resistant accessions significantly fewer larvae and pupae were found inside the damaged parts. The higher the level of resistance, the fewer were the insects inside (Table 4). It is possible that due to potentially toxic chemicals inside the stems of resistant accessions, the beanflies die in the early larval stage inside the stem after a period of feeding. Death probably occurs in the second instar when the larvae are very small and difficult to detect. It was also noticed that among the insects still alive inside, the majority of them were already in the pupal stage in susceptible accessions while in resistant accessions greater numbers were still in the larval stage.

Table 3. Concentration of phenolic compounds in the epidermis of beanfly resistant and susceptible accessions.

Acc. no.	Catechin/dry cortex (mg/g)
V 2184[z]	0.06
V 3428[z]	0.07
V 2396[y]	0.00
V 3495[y]	0.00
V 4281[x]	0.51
V 1160[w]	0.50

[z] Susceptible.
[y] Low resistance.
[x] Highly resistant.
[w] V. glabrescens, almost immune to beanfly infestation.

Conclusions

Significant differences between beanfly resistant and susceptible accessions were found in trichome density, leaf thickness, and moisture content of unifoliolate leaves, trifoliolate leaves, and stems. Beanfly resistant accessions had greater trichome density on these three plant parts. Leaves of beanfly resistant accessions were thinner and

contained less moisture than those of susceptible accessions. The high concentration of phenolic compounds in highly resistant accessions coupled with the fewer insects found in damaged stems indicate that antibiosis is possibly the mechanism of resistance.

Since beanfly resistant accessions are highly photoperiod sensitive and since photoperiod can affect the expression of resistance, this experiment must be repeated in another season and at other latitudes to arrive at more definite conclusions.

Table 4. Characteristics of beanfly damage in resistant and susceptible accessions.[z-v]

Accession	Total damage (%)	Damage (%)	
		With larvae or pupae present	No larvae or pupae found[u]
V 2396	74.4 b	21.8 b	78.3 b
V 3495	67.0	19.0 bc	81.0 ab
V 4281	66.3 b	9.4 c	90.6 a
V 2184	85.9 a	43.4 a	56.7 c
V 3428	87.3 a	43.3 a	56.8 c

[z] Planting date: 10/15/82.
[y] Observation date: four weeks after germination.
[x] Sample size: 50 plants.
[w] Plot size: 75 cm wide, 3 m long single row.
[v] Data shown are means of four replications. Means in each vertical column followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.
[u] Characteristic beanfly damage was observed but no larvae and pupae were found, presumably due to their mortality in the larval stage.

Chemical Control of Beanflies on Mungbean

Introduction

In past AVRDC insecticide screenings three insecticides, monocrotophos, dimethoate, and omethoate, sprayed at 3, 7, 14, 21, and 28 days after germination, gave excellent control of beanflies. Since all three compounds have sufficient water solubility to act as systemics, their effectiveness as foliar sprays and soil systemics was compared in controlling beanflies on mungbean. Three new insecticide sprays, isofenphos, flucythrinate, and MK-936, were also included in this test.

Materials and Methods

Details of the methodology are described in the AVRDC publication "Vegetable Pest Control: Insecticide Evaluation Tests." Nine insecticide treatments and one untreated check were included. Insecticides were evaluated on 10 m^2 field plots each measuring 3.3 x 3 m. The crop was planted in two rows on the top of three 1 m wide beds. Each insecticide was applied to four replicated plots arranged in a randomized complete block design.

Granular formulations of monocrotophos, dimethoate, and omethoate were prepared in the laboratory using Ottawa sand as the carrier base. These formulations were band applied by hand along the seeds at sowing time with the amount for each plot row having been previously weighed.

Emulsifiable formulations were applied with 10 l air pressure sprayers charged to 2.7 kg/cm^2 (40 psi) for each plot. Each sprayer was individually calibrated with a stopwatch so that specific volumes of spray could be accurately and uniformly delivered to each plot.

At three and five weeks after germination a 30-plant sample was taken from each plot. The stem of each plant was cut open and the number of larvae and pupae within was recorded. The number of plants with beanfly damage was also recorded, as at times the larvae died within the stem in an early instar, making it difficult to count insect numbers. At harvest the seed yield was recorded.

Results

Monocrotophos, dimethoate, and omethoate gave excellent beanfly control when sprayed on plants but failed to control this insect when applied as granules (Table 5). This could be due to the degradation of insecticide from high soil pH before enough is absorbed by the roots, inefficient translocation or rapid degradation within the plants, or ineffectiveness against beanfly larvae that feed within the stem. All three new insecticides gave reasonably good control of beanflies. MK-936 was slightly more effective than the other two.

A significant negative correlation was found between yield and the number of larvae and pupae per 30 plants at three weeks after germination. There was a highly significant positive correlation between the number of insects in the stems and the percentage of damaged stems at both observations.

Table 5. Evaluation of insecticides for the control of beanflies on mungbean.[z-u]

Insecticides	Rate (kg ai/ha)	No. larvae+pupae/30 plants		Damaged stems (%)		Yield (t/ha)
		10/18/82	11/4/82	10/18/82	11/4/82	
Monocrotophos 2.5G	2.0	9.50 a	5.25 a	39.13 ab	45.85 a	1.81 cd
Dimethoate 2.5G	2.0	6.75 a	4.75 a	29.98 bc	40.83 a	1.76 d
Omethoate 2.5G	2.0	9.75 a	4.75 a	39.13 ab	41.67 a	1.82 cd
Isofenphos 50EC	0.5	1.75 b	1.25 bc	16.63 cd	15.13 b	1.68 d
Flucythrinate 30EC	0.05	1.50 b	1.00 bc	12.48 de	15.00 b	1.98 ab
MK-936 0.36SL	0.02	1.75 b	0.25 c	6.65 de	4.23 b	1.96 abc
Monocrotophos 55EC	0.5	0.25 b	0.00 c	1.65 de	4.23 b	2.01 a
Dimethoate 44EC	0.5	0.75 b	1.25 bc	5.80 de	19.15 b	1.95 abc
Omethoate 50EC	0.5	0.00 b	0.00 c	0.83 e	13.25 b	2.00 a
Control	-	10.50 a	4.00 ab	49.15 a	40.83 a	1.83 bcd

[z] Cultivar: Tainan No. 3.
[y] Planting date: 9/22/82.
[x] Insecticide granules, all laboratory-made formulations, were applied along the seeds at planting. EC and SL were sprayed on: 9/27, 9/30, 10/7, 10/14, and 10/21/82.
[w] Harvest date: 12/3/82.
[v] 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.
[u] Plot size: 10 m^2.

Conclusions

Monocrotophos, dimethoate, and omethoate when sprayed at the rate of 0.5 kg ai/ha at 3, 7, 14, 21, and 28 days after germination gave excellent control of beanfly, but the same insecticides when applied to the soil as granules at planting time failed to control this pest. MK-936, a new antibiotic type insecticide, also gave good control of beanflies on mungbean.

Mungbean Physiology

Growth and Yield of Multiple Leaflet and Lobate Leaflet Mungbeans

Introduction

Mungbean yield can be improved by increasing the total dry matter production per unit land area, and/or enhancing the dry matter diverted to the economic plant part. This study was based on the hypothesis that the level of yield can be increased by using the characteristic of a large number of leaves with small leaflets. Theoretically, this should provide better light penetration in the canopy, thereby increasing the potential of dry matter production.

Materials and Methods

V 2773 (normal trifoliolate leaflet), V 2773 S (lobate trifoliolate leaflet), VC 1973 A (normal trifoliolate leaflet), and V 5926 (9-leaflet leaves) were grown at 2.0×10^5, 2.5×10^5, 4.0×10^5, and 5×10^5 plants/ha in a split plot design with three replications from July 22 to October 14, 1982. Plot sizes were 2.5 x 6.0 m at a single plant/hill, and spacing between hills was kept constant at 10 cm for all densities. Growth parameters and light transmission in the canopy were evaluated at 35 and 55 days after emergence. Yield and yield components were measured at 81 days after emergence.

Results

At 35 days after emergence there was no significant difference in leaf area index (LAI) between varieties and V 5926 had the highest light transmission (Table 1). At 55 days after emergence V 5926 tended to have the highest LAI in all four population densities and VC 1973 A had the lowest LAI, resulting in a partially completed canopy as indicated in the high light transmission (Table 2). High LAI did not result in high net assimilation rate (NAR). On the contrary, the low LAI entry (VC 1973 A) tended to have high NAR although statistically not significantly different from the other entries. Crop growth rate (CGR) is the product of LAI and NAR; however, varietal difference in CGR was

not as great as in LAI. Virus infection on V 5926 and lodging on plots with 4.0 and 5.0 x 10^5 population densities in V 2773 S may partially explain the anomaly in NAR and CGR.

V 5926 had the lowest seed yield among varieties, whereas VC 1973 A tended to have high yield (Table 3). On the contrary, VC 1973 A had the lowest yield in total dry matter production. VC 1973 A consistently had the highest harvest index (HI) and 1000-seed weight among entries in all population densities. V 2773 S and V 5926 had the highest total dry matter in plots with 2.5 x 10^5 and 4.0 x 10^5 plants/ha, respectively.

Conclusions

This study indicates distribution of dry matter is still an overriding character that significantly influences economic yield of mungbean cultivars. Potential exists for increasing total dry matter production by using a large number of small leaflets; however, this may not necessarily entail increased economic yield. The same experiment will be conducted again in 1983.

Table 1. Leaf area index and light transmission at 35 days after emergence.

Population (x 10^5 pl./ha)	Entry	LAI[y]	Light transmission (%)	
			Row	Middle of row
2.0	V 2773	2.18	12a[z]	30
	V 2773 S	1.95	23a	35
	V 5926	2.20	22a	27
	V 1973 A	2.05	13a	25
2.5	V 2773	2.68	14a	22
	V 2773 S	2.41	17a	24
	V 5926	2.62	11a	16
	V 1973 A	2.53	9a	12
4.0	V 2773	3.67	7b	7
	V 2773 S	3.35	8b	9
	V 5926	3.25	14a	15
	V 1973 A	3.24	10ab	11
5.0	V 2773	4.52	4b	5
	V 2773 S	4.81	5b	6
	V 5926	5.16	8a	7
	VC 1973 A	4.12	4b	5

[z] Mean separation in the column of the same population density, 5% level.
[y] Not significant at the 5% level.

Table 2. Estimates of physiological parameters at 55 days after emergence.

Population ($\times 10^5$ pl./ha)	Entry	LAI	Light transmission (%)	NAR[y] ($g/m^2/day$)	CGR ($g/m^2/day$)
2.0	V 2773	2.92b[z]	8a	4.9	12.4a
	V 2773 S	3.53b	5a	5.4	14.0a
	V 5926	5.24a	7a	4.7	16.1a
	VC 1973 A	1.83b	17a	6.2	11.8a
2.5	V 2773	3.96b	6b	5.1	16.8a
	V 2773 S	4.04b	4b	4.6	13.0a
	V 5926	6.67a	5b	4.8	20.6a
	VC 1973 A	2.02b	18a	5.4	11.8a
4.0	V 2773	6.70a	4b	5.5	27.8a
	V 2773 S	5.46a	3b	4.6	19.9ab
	V 5926	6.52a	3b	4.4	19.4b
	VC 1973 A	2.30b	11a	6.0	16.2b
5.0	V 2773	5.37b	2b	4.3	20.8a
	V 2773 S	4.94bc	5b	3.7	18.3a
	V 5926	7.95a	3b	3.1	19.0a
	VC 1973 A	2.89c	18a	5.0	17.8a

[z] Mean separation in the column of the same population density, 5% level.
[y] Not significant at the 5% level.

Table 3. Estimates of seed yield, biological yield, and harvest index.

Population ($\times 10^5$ pl./ha)	Entry	Seed yield (t/ha)	Biological yield (t/ha)	Harvest index
2.0	V 2773	1.35a[z]	3.70a	0.36b
	V 2773 S	1.31a	4.01a	0.33b
	V 5926	0.74a	3.52a	0.21c
	VC 1973 A	1.28a	2.58a	0.50a
2.5	V 2773	1.30a	3.65b	0.36ab
	V 2773 S	1.54a	5.62a	0.28bc
	V 5926	0.58b	3.57c	0.18c
	VC 1973 A	1.62a	3.21d	0.45a
4.0	V 2773	1.36ab	4.07b	0.33b
	V 2773 S	1.06b	3.80b	0.28c
	V 5926	1.05b	5.47a	0.19d
	VC 1973 A	1.52a	3.10b	0.49a
5.0	V 2773	1.53a	4.37a	0.35a
	V 2773 S	1.22b	4.68a	0.26ab
	V 5926	0.79c	4.93a	0.18b
	VC 1973 A	1.80a	4.46a	0.41a

[z] Mean separation in the column of the same population density, 5% level.

Table 4. Estimates of yield components.

Population ($\times 10^5$ pl./ha)	Entry	Plant no./m^2	Pod no./plant	Seeds/pod	1000-seed wt. (g)
2.0	V 2773	16.9a[z]	31.9a	10.4ab	28.7d
	V 2773 S	17.6a	29.9ab	11.1a	38.6c
	V 5926	15.3a	22.1ab	10.6a	49.5b
	VC 1973 A	18.7a	16.5b	9.7b	58.3a
2.5	V 2773	20.3a	33.6a	11.1a	28.3d
	V 2773 S	21.4a	23.8ab	10.1a	36.6c
	V 5926	17.8a	11.9b	9.8a	49.6b
	VC 1973 A	23.5a	13.8b	10.3a	56.4a
4.0	V 2773	31.1b	28.1a	8.9b	27.5d
	V 2773 S	34.0a	15.2ab	11.0a	36.3c
	V 5926	30.3b	10.5b	10.7a	48.6b
	VC 1973 A	35.9a	12.6ab	9.6ab	55.0a
5.0	V 2773	38.8a	25.0a	10.2a	27.3d
	V 2773 S	38.7a	12.9b	10.5a	35.5c
	V 5926	39.7a	8.2b	11.4a	46.9b
	VC 1973 A	42.4a	11.0b	10.2a	54.8a

[z] Mean separation in the column of the same population density, 5% level.

Soybean Breeding

Hybridization Program

From March to October, 1982, ten accessions carrying resistance to rust, two to beanfly (G. soja), two to pod borer and/or leaf hopper, seven to bacterial pustule and downy mildew, eight with large seed size, and five with other desirable characters were used for crossed with 23 AGS lines. A total of 373 crosses were made during the year (Table 1). F_1 plants were grown in the field and in the greenhouse. Selected beanfly resistance crosses were advanced to the F_2 generation in the greenhouse by AVRDC's entomologist. These new crosses will further the development of improved selections with multiple disease and/or insect resistance and wide adaptability. Selections will also be made for optimum yield and early maturity.

Evaluation of Soybean Germplasm

Introduction

Soybean accessions are multiplied in the greenhouse and evaluated in the field to select for desirable attributes.

Materials and Methods

In February, July, and September, 210, 178, and 224 accessions, respectively, were evaluated in unreplicated observational trials. Observations were made on a number of descriptor variables. Days to maturity, 100 seed weight, and plot yield were used to select entries for use in the breeding program.

Results

The range in maturity was 77 to 127 days in the February planting, 73 to 121 days in the July planting, and 73 to 106 days in the September planting. Seventeen accessions were selected for their early maturity, large seed size, high yield potential, or a combination of these traits (Table 2).

Table 1. Hybrid crosses, 1982.

Objective	No. of crosses
Resistance to insects and diseases (beanfly, bacterial pustule, downy mildew)	85
Resistance to insects (beanfly, leaf hopper)	6
Multiple disease resistance (soybean rust, downy mildew, bacterial pustule)	109
Rust resistance	37
Downy mildew resistance	36
Bacterial pustule resistance	31
Vegetable soybean	56
High yield and photoperiod insensitivity	13
TOTAL	373

A total of 57 parents were used: 23 AVRDC breeding lines and 34 germplasm accessions.

Table 2. Selected accessions from the soybean germplasm collection.

Acc. no.	P.I. No. or name	Origin	Days to maturity	100 seed wt. (g)	Yield g/5m^2	Remarks
Selected for early maturity:						
G 10213	423953	USDA	78	11	205	Sp
G 10214	424148	USDA	78	10	198	Sp
G 10342	205005	USDA	73	11	148	Su
G 10343	253656 A	USDA	73	10	177	Su
Selected for large seed size:						
G 10153	Su Tou #1	Mainland China	94	29	761	Sp
G 10285	131102 G, BL	Australia	98	25	479	Su
G 10286	131301	Australia	98	33	325	Su
Selected for high yield potential:						
G 10131	IDIAP-19	Panama	116	13	905	Su
G 10133	Bayand	Panama	116	13	888	Su
G 10155	UGM-25	India	94	11	849	Su
G 10278	130502	Australia	108	18	783	Sp
G 10294	131503	Australia	103	19	835	Sp
G 10313	132802	Australia	101	13	873	Su
G 10316	133101	Australia	101	12	904	Su
Selected for early maturity and high yield potential:						
G 4284	171652	Korea	82	9	459	Sp
G 10146	SJ #239	Cameroon	73	10	799	Su
G 10147	SJ #244	Cameroon	73	12	791	Su
G 10153	Su Tou #1	Mainland China	92	16	1,316	Su

__ = Early maturity, large seed size, or high yield.

Conclusions

Seventeen new genetic sources have been identified to increase genetic variability and to improve AVRDC selections for early maturity and high yield potential.

Evaluation of Vegetable Soybeans

Introduction

Vegetable soybeans can be grown even during the rainy season when other vegetables are unavailable and are a good proteinaceous vegetable. Vegetable soybean can also serve as an export crop and can provide employment opportunities in rural areas. Processing is unnecessary for domestic use.

Materials and Methods

Forty-two accessions were evaluated in a preliminary yield trial (PYT) in the summer (July 15 planting) and in the autumn (September 14 planting) in a 6 x 7 lattice design with two replications. Plot size was 5 x 1 m. Observations were made on major agronomic characters.

A total of 174 additional accessions (61 summer, 113 autumn) were planted for seed multiplication and evaluated for 100 seed weight and pubescence color in a non-replicated plot.

Results

In the summer PYT, five accessions gave a yield of 1.6 to 1.9 t/ha (Table 3). Fifty-five percent of the entries had gray pubescence, which is a preferred character for vegetable soybean.

About 25% of the seed multiplication entries had a 100 seed weight of 25 g or more. The correlation between 100 seed weight in the summer and in the autumn was 0.56**. This indicates that selection for seed size can be carried out in both the summer and autumn seasons.

Conclusions

Eight accessions were selected on the basis of seed size, plant height, node number, pod number, and yield potential for inclusion in the first AVRDC Vegetable Soybean Evaluation Trial (AVSET) (Table 4). The trial will be conducted in Taiwan during 1983 at seven locations in the spring and autumn and five locations in the summer.

Table 3. Grain yield and other agronomic characters of vegetable soybean in summer preliminary yield trials.

AVRDC acc. no.	Varietal name	Yield (t/ha)	Days to maturity	Pods/ plant	100 seed weight (g)
G 5019 Br	Dobrogeance	1.9 a (1.2 ab)	85	38	17
G 10140	BPI #4	1.9 ab (1.2 ab)	95	31	29
G 10138	Vesoy #3	1.8 abc (1.3 a)	91	45	15
G 10136	Vesoy #1	1.6 abc (1.0 ab)	104	51	17
G 5094	Yoshida-1	1.6 abc (1.1 ab)	94	42	22
G 9053 (check)	Tzurunoku	1.1 e (0.9 bc)	87	29	24

Values in parentheses represent yield during autumn.

Table 4. Accessions included in the first AVRDC Vegetable Soybean Evaluation Trial (AVSET).

AVRDC acc. no.	Varietal name	Origin	Days to maturity	Pods/ plant	100 seed weight (g)
G 2264	203	Japan	92	24	24
G 4713	Houjaku	Japan	88	29	23
G 5094	Yoshida-1	Japan	90	32	24
G 5176	Disoy	USA	83	30	23
G 6113	Y 386	Korea	85	20	24
G 7321	P.I. 157424	Korea	83	10	26
G 10139	Vesoy #3	Philippines	95	32	26
G 10140	BPI #4	Philippines	92	19	27
G 9053 (check)	Tzurunoku	Japan	84	12	24
G 10134 (check)	Ryokkoh	Japan	84	12	30

Preliminary and Intermediate Yield Trials

Introduction

Promising breeding lines undergo different stages of selection. Preliminary yield trials (PYTs) are the first stage of a series of replicated trials. Selections from the PYTs are then entered in intermediate yield trials (IYTs). Both PYTs and IYTs are conducted during all three seasons in a single year. Lines selected from the IYTs are entered in advanced yield trials (AYTs).

Materials and Methods

In two groups of PYTs, a total of 171 selections were evaluated. Both 9 x 9 and 10 x 9 lattice designs with two replications were used.

Similarly, two groups of IYTs (both 10 x 9 lattice) were evaluated. Plot size for the PYTs and IYTs was 5 x 2 m. The trials were conducted in the spring, summer, and autumn seasons. Data for all agronomic characters were collected and analyzed. Selections were based on yield, days to maturity, adaptability to more than one season, seed quality, and field tolerance to diseases.

Results

In general, yields during the spring and summer seasons were higher than those of the autumn season. Fifty-six entries in the spring and 76 in the summer PYTs and IYTs yielded 3 t/ha or more. In the autumn plantings only 64 entries yielded 2 t/ha or more. Selected examples of high yielding and early maturing selections are given in Tables 5 and 6. Of the 325 entries tested, two were tolerant to soybean rust, 28 were free from bacterial pustule, and 185 exhibited no downy mildew symptoms.

Conclusions

In 1982 the experimental design was changed from the routine randomized complete block design to lattice design. Through this design, superior selections can be identified more easily than before (Table 7).

Table 5. Selections with high yield potential and/or early maturity in the PYTs.

Pedigree designation	Yield (t/ha)[z]			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
PYT I[y]						
GC 50047-1-12-8-6-1	3.3 a	3.8 a	2.5 a	110 a	90 ab	89 ab
GC 50245-8-1-12-6-6	3.0 ab	3.3 abc	2.5 a	105 ab	94 a	89 ab
GC 50030-4-3-6-6-6-6	2.9 abc	3.3 abc	2.4 ab	110 a	90 ab	90 a
GC 60009-2-8-6-6		3.5 ab			87 bcd	
GC 60053-11-6-6-8			2.1 abc			82 c
Shih-Shih (check)	2.6 bcd	2.8 cd	1.7 c	92 c	84 d	81 c
PYT II[x]						
GC 60053-8-6-8	3.0 a			90 a		
Shih-Shih (check)	2.8 ab			95 a		

[z] Means within columns followed by the same letter are not significantly different at the 5% level.
[y] Trials planted on 2/9, 7/16, and 9/14/82.
[x] Trials planted on 2/10, 7/16, and 9/17/82.

Table 6. Selections with high yield potential and/or early maturity in the IYTs.

Pedigree designation	Yield (t/ha)[z]			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
IYT I[y]						
GC 60062-8-7-6	2.8 a			96 ab		
GC 50268-1-6-6		3.2 a			83 a	
GC 50106-26-8-6	2.0 bc		1.3 ab	92 c		77 a
GC 50228-1-48-6		2.8 ab	1.4 a		85 a	81 a
Shih-Shih (check)	2.2 b	2.8 ab	0.7 c	99 a	83 a	78 a
IYT II[x]						
GC 60065-9-6-6	3.2 ab		2.2 a	105 a		82 a
GC 60102-8-7-6	3.3 a	3.2 a		105 a	88 a	
Shih-Shih (check)	2.5 c	2.8 b	1.7 b	99 b	83 a	78 a

[z] Means within columns followed by the same letter are not significantly different at the 5% level.
[y] Trials planted on 2/2, 7/16, and 9/17/82.
[x] Trials planted on 2/2, 7/16, and 9/14/82.

Table 7. Relative efficiency (RE) of lattice design (L) over RCBD and CRB.

Trial	Season	Lattice	RE L/RCBD	RE L/CRB
IYT I	Spring	8 x 8	1.34	1.34
	Summer		1.19	1.26
	Autumn		3.19	3.26
IYT II	Spring	9 x 10	1.78	2.07
	Summer		1.12	1.10
	Autumn		4.44	7.32
PYT I	Spring	9 x 10	1.41	1.48
	Summer		1.01	1.00
	Autumn		4.42	4.63
PYT II	Spring	9 x 9	1.22	1.49
	Summer		1.23	1.22
	Autumn		10.26	10.68

Advanced Yield Trials

Introduction

Selections from either preliminary or intermediate yield trials and promising new cultivars from other breeders are entered in advanced yield trials (AYTs). Outstanding selections from the AYTs will be included in the AVRDC Soybean Evaluation Trial (ASET).

Materials and Methods

A total of 28 AGS lines were evaluated in two AYTs (AYT-1, 15 lines and AYT-2, 13 lines). Shih-Shih and TN #15 were used as checks. The experiments were conducted in a randomized complete block design with four replications in spring (January 29), summer (June 22), and autumn (September 24). Agronomic characters and response to disease were observed.

Results

Among the lines evaluated, AGS 172, 180, 182, and 183 exhibited tolerance to soybean rust. AGS 182 and 183 matured as early as the check cultivar, Shih-Shih, but their yields were low (Table 8). In AYT-2 during the summer, three entries significantly outyielded the check and matured only slightly later (Table 9). Among the 32 entries evaluated, 59% showed bacterial pustule resistance and 69% showed downy mildew resistance.

Conclusions

Promising new high yielding, early maturing, and disease resistant selections have been identified for the next ASET. One hundred percent disease resistance will be sought in future AYTs.

Mutation Breeding in Soybean

Introduction

Germplasm variability for soybean rust resistance is limited, but it is believed that irradiation can be used to generate additional variation for breeding purposes. Irradiation was initiated in pursuit of three specific characters: Disease resistance, early maturity, and seed size.

Materials and Methods

Seeds of AGS 2 (G 2120) were irradiated with Co^{60} at the Korean Atomic Energy Agency in Seoul. Three radiation levels, 15, 20, and 25 Kr, were used. The M_1 generation was grown during the 1981 autumn season, planted October 13. On February 2, 1982, 365 M_2 lines were sown in the field. The M_3 generation, 119 plants from one selected mutant, was planted in the greenhouse on June 3, 1982. The M_4 generation was planted on September 14, 1982 as lines in the field with AGS 2 as the check cultivar. From the remnant seeds, new M_1

Table 8. Entries selected from AYT-1 for yield, disease resistance, and early maturity.

Entry no.	Yield (t/ha)[z-x]			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
AGS 169	2.5 a	2.6 ab	1.4 b	107 bc	94 c	83 b
AGS 177	2.5*a	2.6+a	1.2 b	118 a	100 b	85 b
AGS 172	2.3*ab	2.2+de	1.3 b	109 b	95 b	82 b
AGS 180	2.3*ab	2.5 ab	2.0 a	109 b	104 a	82 b
AGS 182	1.4*e	2.3 de	1.5 b	94 e	89 d	78 c
AGS 183	2.4 ab	2.1+ef	1.5 b	105 c	89 d	91 a
Shih-Shih (check)	2.0 bc	1.6+g	1.1 b	102 d	93 d	77 c

[z] Means within columns followed by the same letter are not significantly different at the 5% level.
[y] * = Tolerant to soybean rust.
[x] + = Susceptible to bacterial pustule.

Table 9. Entries selected from AYT-2 for yield, disease resistance, and early maturity.

Entry no.	Yield (t/ha)[z,y]			Days to maturity		
	Spring	Summer	Autumn	Spring	Summer	Autumn
AGS 147	3.1 ab+	2.9 a	1.5	109 a	96 a	83 a
AGS 149	2.9 bc+	2.7 abc	1.3	95 b	93 b	81 a
AGS 151	2.8 bc	2.7 abc	1.2	97 b	92 b	80 ab
Shih-Shih (check)	2.8 bc	2.0 g	1.3	95 b	88 c	77 b

[z] Means within columns followed by the same letter are not significantly different at the 5% level.
[y] + = Susceptible to downy mildew.

and M_2 generations were also grown in the field. Variability within the mutant lines, between the mutants and wild types, and between the M_3 and M_4 lines was determined.

Results

From about 50,000 M_2 plants, one mutant in the 25 Kr group flowered in 65 days and matured in 107 days compared with 75 days to flowering for the wild type (AGS 2) which did not mature even at 150 days. Days to flowering of the M_3 plants ranged from 36 to 44 (mean 37 days) and days to maturity varied from 79 to 112 (mean 92 days). AGS 2 flowered in 55 days and matured in 122 days.

Mean days to flowering and days to maturity of M_3 and M_4 lines were distinctly earlier than AGS 2 (Figures 1 and 2). Forty of 119 lines were selected based on agronomic characters (Table 10).

From the M_2 generation grown in the 1982 autumn season, six selections from the 15 Kr group, seven selections from the 20 Kr group, and three selections from the 25 Kr group were selected for high pod number, seed size, and short stem. These lines will be further evaluated in 1983.

Conclusions

Early maturing, large seed size mutants have been obtained from AGS 2. Soybean rust tolerant early mutants need to be reevaluated. Yield potential and stability of selected mutants must still be determined.

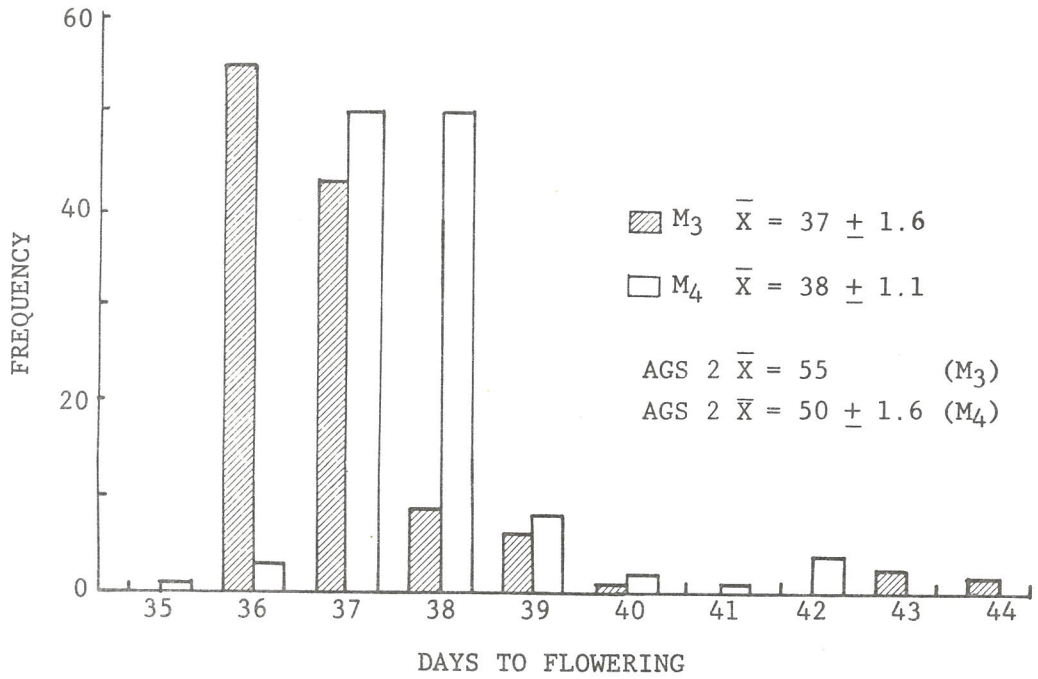


Figure 1. Frequency distribution of M_4 lines for days to flowering.

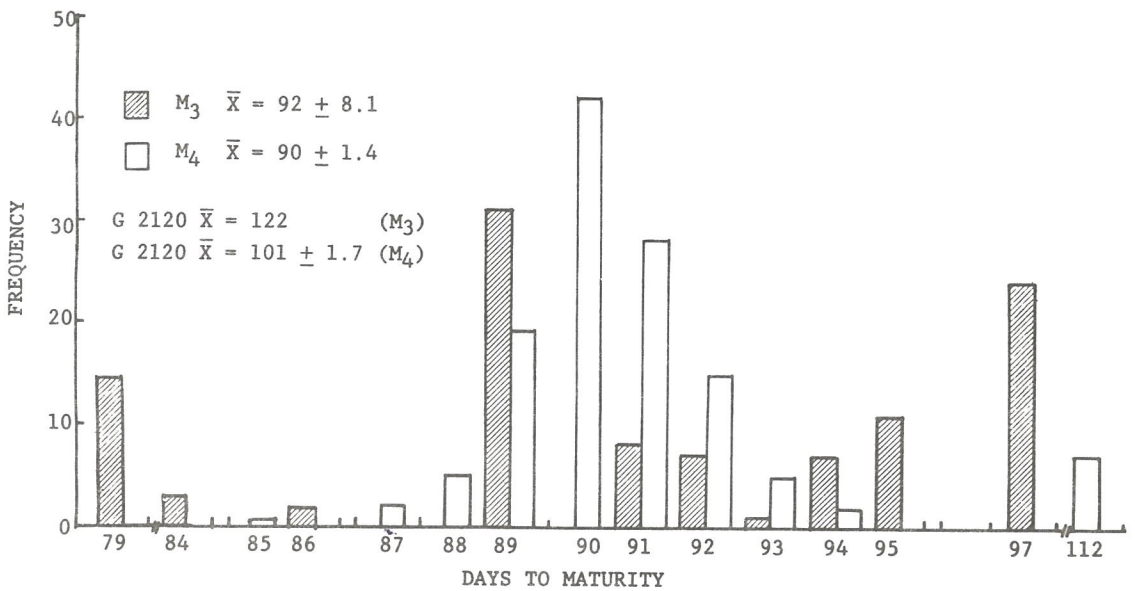


Figure 2. Frequency distribution of M_4 lines for days to maturity.

Table 10. Agronomic traits of early mutants selected from the M_4 generation.

Character	No. selected
Green seed coat, more pods	6
Green seed coat, fewer pods	6
Yellow seed coat, more pods	5
Yellow seed coat, fewer pods	18
Green seed, soybean rust tolerant	2
Green seed, large seed size	3
Total	40

Selection for Soybean Rust Resistance

Introduction

Soybean rust is one of the most important soybean disease problems in the tropics and subtropics. To facilitate intensive screening of segregating populations by plant pathologists, potential rust tolerant genotypes are identified by visual observation.

Materials and Methods

A total of 2,173 F_7, 3,461 F_8, and 1,321 F_9 pedigree lines were evaluated without fungicide spray in non-replicated single row plots with natural rust infection in the spring and autumn. One row of SRE-Z-11B and KS #8 serving as the resistant checks and Shih-Shih and TK #5 as the susceptible checks were planted in every tenth row.

Results

Soybean rust was more severe at some locations than at others although the planting dates were similar (Table 11). Under severe rust infection, when no fungicides were sprayed, yield losses varied from 69 to 79%, depending upon genotype. Inoculum pressure and source proximity to the crop seem to be among the factors that determine the severity of rust infection.

Some of the pedigrees with promising rust tolerance from the F_8 and F_9 generations are given in Tables 12 and 13.

Conclusions

Nine hundred thirty-one breeding lines (130 F_7, 549 F_8, and 252 F_9) were selected for further screening in 1983.

Table 11. Yield data (kg/ha) of check cultivars used in the soybean rust resistance screening plot.

Cultivars	Location (field no.)					Max. yield reduction (%)
	33	57A	57B	58	83	
SRE-Z-11B	1,864	576	648	1,224		69
KS #8	2,316	500	664	1,072	880[z]	78
G 38	1,584	388	476	736	648	75
TK #5	1,832	436	384	760	792	79
Rust severity[y]	2	5	5	4	4	
Date planted	Sept. 21	Sept. 22	Sept. 22	Sept. 23	Sept. 28	
LSD 0.05	289	NS	59	72	106	
0.01	386		77	96	144	

[z] AGS 12.
[y] 5 = most severe
1 = least severe.

Table 12. Accessions and pedigrees selected for potential soybean rust tolerance (at least one parent has been reported to have soybean rust tolerance).

Acc. or Pedigree no.	Name of cultivar or parents
G 42	Mikawajima
G 10348	Ohsode early
GC 60062-8-13-7-10	Yagi 1 x AGS #2
GC 50228-1-44-6-7	KS 482 x Aochi
GC 50245-8-1-12-6-9	SJ 2 x KS 473
GC 50265-1-7-6-8	Q 68 x TN #3
GC 50265-2-9-6-8	Q 68 x TN #3
GC 50261-1-20-6E-7	KS 739 x Akiyoshi

Table 13. Pedigrees selected for potential rust tolerance.

Pedigree no.	Parentage
GC 60053-7-7-6-8	PI 194647 x PI 227224
GC 60053-8-6-8	PI 194647 x PI 227224
GC 60056-6-14-6-10	PI 248407 x Clark 63
GC 60056-8-15-6-7	PI 248407 x Clark 63
GC 60066-87A-16-2-7-6-6-10	PI 317334 A x AGS 2
GC 60066-106A-6-7-6-11	PI 317334 A x AGS 2
GC 60074-6-6-8	PI 194647 x Shinsei
GC 50106-47-6-6-6	AGS 2 x PI 194647
GC 50223-9-10-6-6	TK #5 x unknown

Note: Parents are known to have no soybean rust tolerance.

Genotypic Responses for Minimum and Maximum Input in Soybean

Introduction

Crops express maximum yield potential when grown in favorable environments with appropriate agronomic inputs. In Southeast Asia, however, soybean is often included in rice-based cropping systems with minimum tillage and/or minimum inputs. Suitable cultivars are thus required to meet the needs of farmers who use these cropping systems.

Materials and Methods

Eleven AVRDC Glycine selections (AGS) and three check cultivars were evaluated. Two treatments were used: AVRDC's suggested cultural practices (maximum input) and minimum management input (land preparation, planting, and harvesting only). Plantings were carried out in February-March (spring season), July (summer season) and September-October (autumn season), 1980, 1981, and 1982, except during the 1981 spring season (Table 14). Each experiment was conducted in a randomized complete block design with four replications. Different seasons and years were considered as series of the same experiment.

Results

Under minimum input, the highest yields were produced by AGS 143 (1.7 t/ha, spring) and AGS 59 (1.1 t/ha, autumn). The yield gap between minimum and maximum input varied with season (Figure 3) and with genotype. The spring and autumn seasons had the highest yield gap; the response to maximum input was lowest during the summer. Genotypes with high yield potential under minimum input conditions and those that responded to maximum input in different seasons are listed in Table 15.

The simple correlation coefficients between yield under minimum and maximum input during the summer and autumn seasons were highly significant ($r = 0.658^{**}$ and 0.508^{**}, respectively). For the X^2 value of 7.783, with seven degrees of freedom, P was 0.39. Therefore, the correlations for all seasons of the three years were combined; the corresponding r was 0.551^{**}. This suggests that selections with high yield potential under maximum input conditions are high yielders under minimum input as well.

Conclusions

Entries that are suitable for minimum input situations can be selected from regular advanced yield trials. Multi-location trials will be

required, however, to determine the applicability of the findings. The responses to various inputs also must be examined to develop the means to obtain maximum economic yield.

Table 14. Dates of planting of minimum and maximum input trials.

Year	Season		
	Spring	Summer	Autumn
1980	February 10	July 15	September 5
1981	-	July 9	October 2
1982	February 23	July 22	September 9

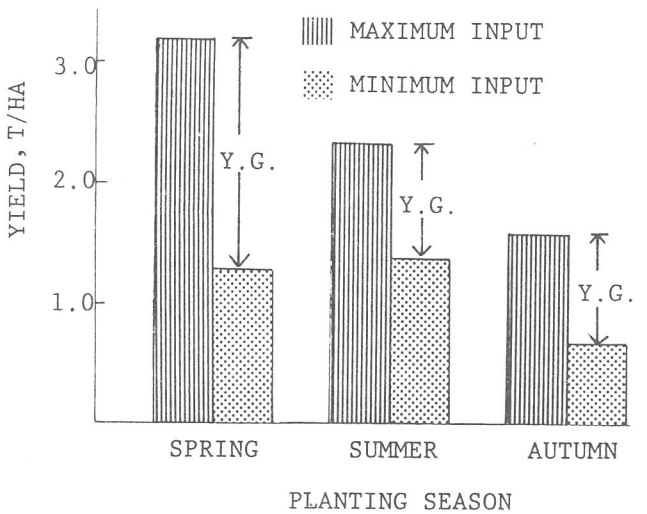


Figure 3. Yield gap (Y.G.) between maximum and minimum input soybean in three seasons; mean of three years, 1980, '81, and '82.

Table 15. Genotypes that are highly responsive to maximum management input and those which have high yield potential under minimum input in different seasons.

Genotype character	Spring	Summer	Autumn
Responsive to maximum input	AGS 62 Shih-Shih	AGS 74 AGS 143 KS #3	AGS 62 AGS 68 AGS 74
High yielding under minimum input	AGS 143 AGS 59	AGS 66 AGS 71 AGS 144	AGS 59 H 15

Continuous Cropping of Soybeans

Introduction

Continuous soybean cropping on the same piece of land is common in Indonesia. A three-season experiment was conducted in 1982 to assess the impact of this practice, particularly on grain yield.

Materials and Methods

AGS 129 (narrow leaflet type) and AGS 154 (broad leaflet type) soybeans were planted on January 20, June 14, and September 29 in a randomized complete block design. Selections were replicated four times. Plot size was 5 x 10 m. Three to four seeds were sown per hill, with a spacing of 50 cm between rows and 10 cm between hills. Upon emergence stands were thinned to two plants per hill in the spring and summer and three plants per hill in the autumn.

Results

Three soybean crops were successfully harvested from the same piece of land. The yield of AGS 129 was significantly higher than AGS 154 in the January and June plantings. The varietal differences for yield of the September planting were not significant (Figure 4). Maturity duration for the January and June plantings was longer than for the September planting. The yield/ha/day was similar for both selections. The combined January and June plantings provided 70 to 75% of the total three crop yield (Figure 5). AGS 129 gave a total yield of 7.8 t/ha in 283 days while AGS 154 gave 7.2 t/ha from the three crops in 270 days (Figure 5).

Conclusions

Three successive soybean crops were successfully harvested from the same piece of land with no obvious harmful effects.

Techniques to Hasten Soybean Maturity for Generation Advance

Introduction

Three or more soybean generations can be advanced per year if heavy rainfall during crop maturity can be prevented from damaging seed viability. Paraquat spraying can force soybeans to mature earlier and hence escape the rainy season. As rain damage at AVRDC occurs during the February and July planting seasons, tests were carried out

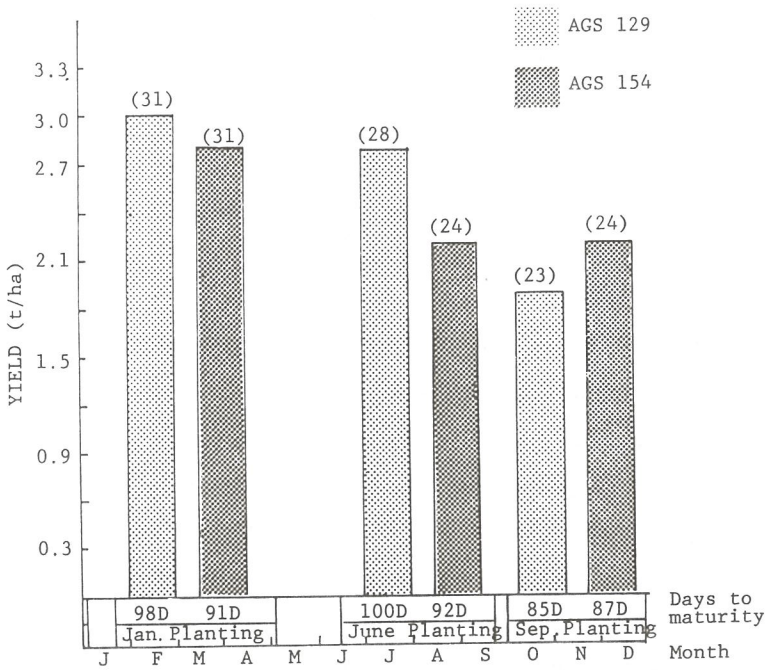


Figure 4. Yield of two soybean selections in three consecutive plantings (values in parentheses are yield/day/ha).

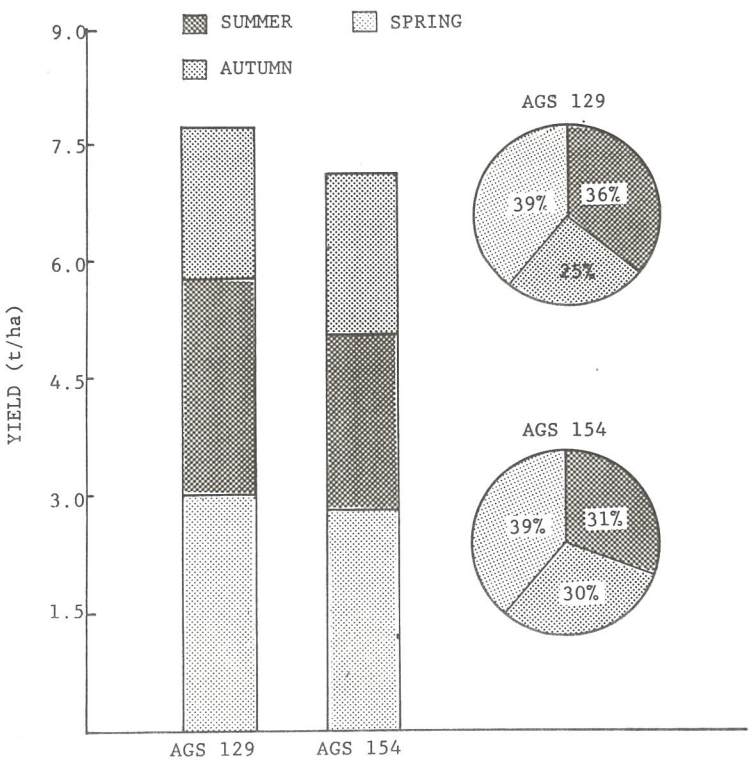


Figure 5. Yield of two soybean selections in continuous cropping for three seasons.

in these seasons to assess the usefulness of paraquat to protect seed quality and hasten generation advance.

Materials and Methods

Two large-seeded genotypes, G 9053 and G 9948 (100 seed weight 25 g) and medium- and small-seeded genotypes AGS 129 and G 10194 (100 seed weight 15 and 11 g, respectively) were chosen as test cultivars. Treatments consisted of 1) spraying with paraquat and harvesting five days later and 2) harvesting untreated plants and hanging them in the shade to air-dry for ten days. Both treatments were performed at 20, 25, 30, 35, 40, and 45 days after first flowering and at maturity. The experiment was conducted in a split plot design with genotype as the main plot, treatment as the subplot, and timing of treatment as the sub-subplot. There were six replications. Plots consisted of 1 m long rows spaced 50 cm apart, with 10 cm between plants and two plants per hill. The experiment was conducted twice, planted on February 24 and July 20, 1982. Seed quality was assessed by a germination test. Yield and 100 seed weight were also recorded.

Results

Seed quality improved with later harvest time but delaying until maturity significantly reduced seed quality (Figure 6). Harvesting 40 to 50 days after flowering gave significantly better results than spraying paraquat.

One hundred seed weight increased with time. The medium- and small-seeded genotypes could be harvested 40 days after flowering (R6.5) with good seed quality in the spring season. The large seeded genotypes in the spring and all genotypes in the summer season could be harvested 50 days after flowering and maintain good seed quality (Figure 7). Percent germination, 100 seed weight, and yield of the four genotypes varied with season (Figures 8 and 9). AGS 129 performed best in both seasons.

Conclusions

If rainfall coincides with maturity, plants can be harvested about 40 to 50 days after flowering (approximately R7 stage) and air dried by hanging the plants in the shade for ten days before threshing to get good quality seeds with little yield loss. This practice can be recommended not only for generation advance but for seed production fields as well.

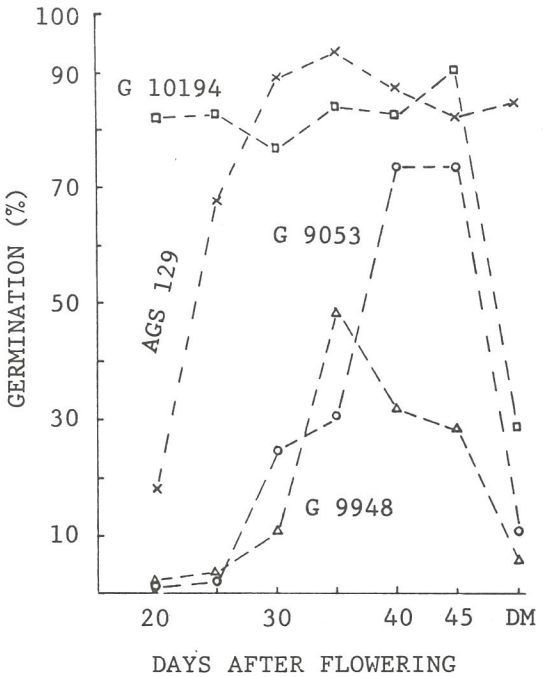


Figure 6. Viability of seeds of four genotypes harvested at different times, no paraquat treatment (air dried for 10 days); spring, 1982.

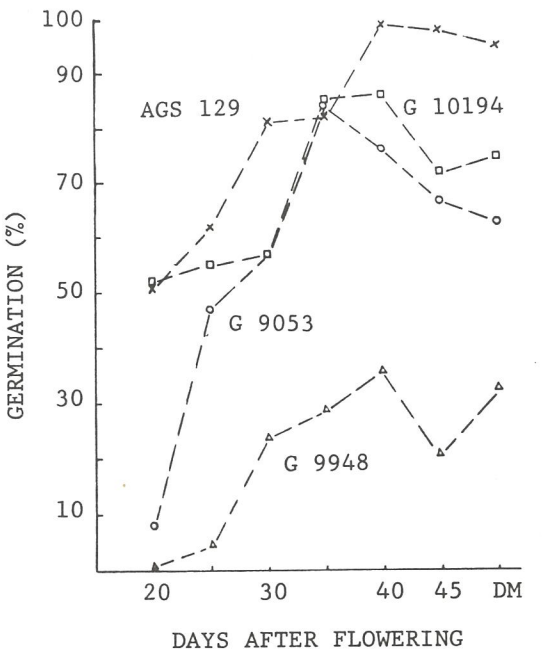


Figure 7. Viability of seeds of four genotypes harvested at different times, no paraquat treatment (air dried for 10 days); summer, 1982.

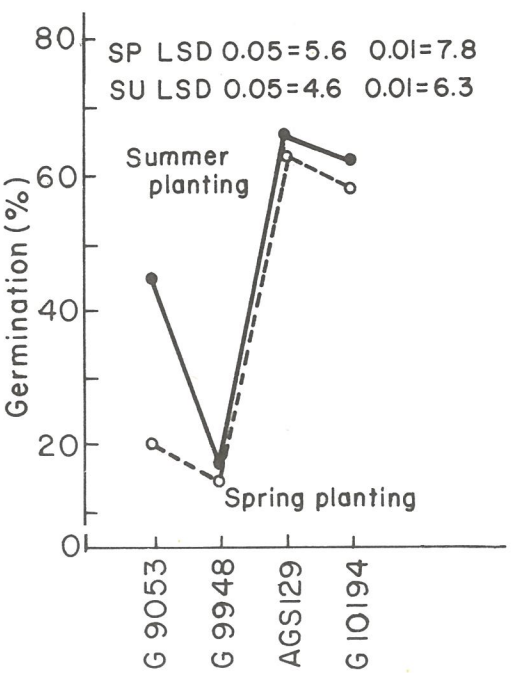


Figure 8. Variation in viability of seeds of four genotypes, spring and summer, 1982.

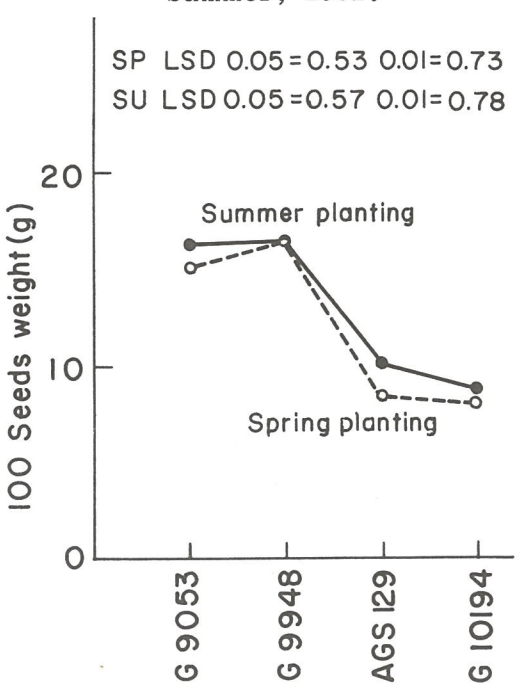


Figure 9. Variation in 100 seed weight of four genotypes, spring and summer, 1982.

Techniques for Determining Soybean Seed Storability

Introduction

Loss of seed vigor and viability during storage is a major soybean constraint in the tropics. Several methods have been proposed to predict the storage potential of soybean seeds. These prediction methods and other storage tests were compared in measuring the seed quality of AVRDC soybean breeding lines that differ in seed size.

Methods and Materials

Six AVRDC selections with different seed sizes harvested from a September, 1981 planting were evaluated (Table 16). Seed quality was first determined using the accelerated ageing technique (T_1), methanol stress (T_2), hot water treatment (T_3), and a control (T_0). (Methods described in: Kueneman, E. A. and H. C. Wien. 1981. Improving soybean stand establishment in the tropics by varietal selection for superior seed storability: Cooperation of National Programs. IITA Research Briefs, Vol. 1, No. 2; and in: Wien, H. C. and E. A. Kueneman. 1981. Soybean seed deterioration in the tropics. 11. Varietal differences and techniques for screening. Field Crops Research 4:123-132.)

Table 16. Seed sizes of genotypes used in seed storage study.

Entry no.	Variety name or cross designation	100 seed wt. (g)
G 9053	Tzurunoku	25
G 9948	Zen Wu #2	33
AGS 129	Shih-Shih x SRF 400	14
AGS 135	Clark 63 x 64-4	14
G 2120	Pure line from PI 86736	8
GC 60011-6-12-6 Br	Clark 63 x TN #4	8

To verify the results of these treatments, a second experiment was conducted using the original seed samples. Seeds were stored for three and six months in a greenhouse at 43 to 47°C (S_1), under cold storage, 15 to 18°C (S_2) and at ambient room temperature, 18 to 26°C (S_3).

A split plot design was used in both cases with four replications. Emergence was tested using 25 seeds/treatment.

Results

Under the accelerated ageing and methanol stress treatments, G 2120 and GC 60011-6-12-6 Br, both small seeded genotypes, exhibited the best seed quality as indicated by percent germination (Table 17). G 2120 is known to have good seed quality. However, in the second experiment all selections lost viability after six months of storage in the greenhouse and at room temperature (Tables 18 and 19). Seed quality was well maintained even after nine months of cold storage but, in contrast to the results of the first experiment, there was no indication that G 2120 and GC 6011-6-12-6 Br store better than other selections (Table 20).

Table 17. Predicting soybean seed storage potential using three different techniques.

Entry no	Percent germination in treatment			
	T_0	T_1	T_2	T_3
G 9053	76	8	41	75
G 9948	89	0	71	64
AGS 129	93	4	80	35
AGS 135	91	3	57	45
G 2120	97	11	96	65
GC 60011-6-12-6 Br	98	33	96	31

T_0: Control.

T_1: Accelerated ageing technique (40°C, 100% R.H. for three days).

T_2: Methanol stress (20% methanol for two hours).

T_3: Hot water treatment (75°C for 80 seconds).

Differences between cultivars and between treatments were significant at the 1% level.

Table 18. Germination of seeds stored in the greenhouse (43 to 47°C).

Entry no.	Before storage	Storage time	
		3 months	6 months
G 9053	76	88	0.0
G 9948	89	78	0.3
AGS 129	93	73	1.0
AGS 135	91	88	-
G 2120	97	87	11.0
GC 60011-6-12-6 Br	98	88	0.3

- = No seed.

Table 19. Germination of seeds stored at room temperature (18-26°C).

Entry no.	Before storage	Storage time	
		3 months	6 months
G 9053	76	87	0.0
G 9948	89	89	0.0
AGS 129	93	86	0.0
AGS 135	91	93	-
G 2120	97	92	0.0
GC 60011-6-12-6 Br	98	91	0.0

- = No seed.

Table 20. Germination of seeds kept under cold storage (15-18°C).

Entry no.	Before storage	Storage time (months)		
		3	6	9
G 9053	76	93	86 b	81 d
G 9948	89	97	87 b	89 ab
AGS 129	93	95	83 b	86 bc
AGS 135	91	97	-	-
G 2120	97	94	84 b	83 cd
GC 60011-6-12-6 Br	98	93	94 a	92 a

- = No seed.

Conclusions

Behavior under methanol stress and the accelerated ageing technique appears to differentiate genotypes for seed quality. However, the conditions under which seeds can store well without deterioration must still be determined. The storage experiment did not corroborate the results of the storability prediction tests.

Evaluation of Korean Soybeans

Introduction

Twelve selected breeding lines were received from the Korean Atomic Energy Research Institute (KAERI) for evaluation under AVRDC conditions.

Materials and Methods

Twelve KAERI selected lines and three check cultivars were tested. The experiment was conducted in a randomized complete block

design with two replications. Plot size was 5 x 1 m. Spacing between rows was 50 cm and two seeds were planted 10 cm apart within rows. The experiment was planted on September 14, 1982.

Results

Attributes of the five highest yielders are given in Table 21. One of the entries, KAS 700-38, gave significantly higher yield than Shih-Shih and KS #9. It also matured as early as Shih-Shih.

Conclusions

Two high yielding, early maturing selections were identified from KAERI lines. They will be evaluated in 1983.

Table 21. High yielding, early maturing Korean selections evaluated in the autumn season.

Entry no.	Yield (t/ha)	Days to maturity	100 seed wt. (g)
KAS 700-38	2.42 a	83.0 g	25.5 ab
KAS 700-18	2.14 abcd	82.5 h	25.1 ab
KS-9 (check)	1.96 bcdef	97.0 a	25.5 ab
TN-15 (check)	2.24 ab	83.0 g	28.5 a
Shih-Shih (check)	1.88 cdef	83.0 g	23.9 abc

Optimum Managment Input for Maximum Economic Yield in Soybean

Introduction

To obtain maximum economic yield, optimum levels of appropriate management inputs should be provided. Appropriate inputs, however, may vary under different environments.

Materials and Methods

Varying levels of five input factors, irrigation, fertilizer, weeding, pest control, and disease control, were studied in an L^{64} orthogonal factorial design using two cultivars, AGS 62 and AGS 144 (Table 22). Plot size was 6 x 3 m. Between row spacing was 50 cm; within row spacing was 10 cm. The experiment was conducted in the spring (February 19 planting), summer (June 21 planting) and autumn (September 9 planting). Two seedlings per hill were used in spring and summer, and three seedlings per hill in autumn. Major agronomic characters were observed. The AVRDC economics section cooperated in collecting the economic data.

Table 22. Different levels of five input factors used in the orthogonal factorial experiment.

Factors	Details of levels
I. Irrigation	1. Normal (as needed) 2. One irrigation, 30 days after planting (DAP) 3. Twice, 30 and 60 DAP 4. No irrigation (control)
II. Fertilizer	1. 60:80:80 = $N:P_2O_5:K_2O$ 2. No fertilizer (control)
III. Weed control	1. Herbicide (Lasso, standard application) + one hand weeding at 60 DAP 2. Herbicide only 3. Hand weeding at 60 DAP 4. No weeding (control)
IV. Pest control	1. AVRDC standard insecticide application 2. No insecticide (control)
V. Disease control	1. Fungicide: Dithan M-45, standard application 2. No fungicide (control)

Results

Data analysis is not yet complete; therefore only trends are provided. Response to inputs varied with genotype and season. Irrigation appeared more effective in spring than in autumn and unnecessary in the rainy summer season. Weed control was most important in the autumn. Response to weed control was similar in spring and summer. Weed control was more important for AGS 62 than for AGS 144. Fertilizer and insect control were deemed unnecessary. The amount and method of fertilizer application did not elicit response. If at all, insect control is useful during the autumn. Disease control appeared important in all the three seasons (Table 23).

Conclusions

To obtain maximum yield, most of the tested inputs are needed (Table 24). Based on the results, fungicide, herbicide, and irrigation appear to be the most important inputs for maximum economic yield (Table 25). For further analysis, see Agricultural Economics: Economic Analysis of Soybean Breeding Experiment.

Table 23. Maximum increase in yield (%) due to each of the factors in different seasons.

Season	Cultivar	Irrigation	Weed control	Fertilizer	Insect control	Disease control
Spring	AGS 62	64	30	-	8	15
	AGS 144	21	10	-	-	47
Summer	AGS 62	-	38	-	12	37
	AGS 144	-	18	-	-	72
Autumn	AGS 62	13	167	14	14	23
	AGS 144	15	84	-	17	25

Table 24. The best input combinations for maximum yield in different seasons.

Season	Combination	Yield (t/ha)
Spring	Normal irrigation + herbicide + hand weeding + insecticide + fungicide	2.39
Summer	One irrigation, 30 DAP + herbicide + hand weeding + insecticide + fungicide	2.74
Autumn	Two irrigations, 30 and 60 DAP + herbicide + hand weeding + insecticide + fungicide	0.934

Table 25. Inputs for maximum economic yield in different seasons (speculation).

Season	Combination	Yield (t/ha)
Spring	One irrigation, 30 DAP + herbicide + fungicide	2.3
Summer	No irrigation + herbicide + fungicide	2.2-2.5
Autumn	Two irrigations, 30 and 60 DAP + herbicide + fungicide + insecticide	0.77-0.81

Soybean Pathology

Survey of Mycorrhizal Fungi in Pingtung County

Introduction

Most important agricultural crops are beneficially associated with vesicular-arbuscular (VA) mycorrhizae. However, the potential of mycorrhizae in tropical farming systems has been neglected. Research is particularly lacking on the distribution and ecology of mycorrhizal species in the paddy rice-legume cropping systems found throughout Southeast Asia.

Methods and Materials

A survey was conducted in ten districts of Pingtung County, the major soybean production area in Taiwan, from May 24 to 26, 1982, immediately after the harvest of the first rice crop. Soybean was the preceding crop in most fields sampled. In each district, ten adjacent fields were sampled, and ten subsamples were randomly collected from the top 18 cm of soil within each field. The ten subsamples from each field were thoroughly mixed and one 100 cm^3 aliquot was withdrawn for examination. Mycorrhizal spores were extracted by wet-sieving and decanting, rice roots were stained in trypan blue lactophenol, and both were examined microscopically.

Results

A total of 16 VA mycorrhizal species and two unidentified species with morphologically similar spores were identified (Table 1). Three species, Glomus mosseae, Gl. etunicatus, and Acaulospora scrobiculata were found in almost all fields (Table 2). Six of the species have previously been reported as mycorrhizal on soybean. Two other species have been reported as non-mycorrhizal on soybean in pot culture. Most of the species occurred over a wide range of soil pH and phosphorous concentrations (Table 3). Both vesicular and arbuscular structures were found inside the rice roots in the ten districts, and external vesicles of Gigaspora spp. were found in the soil.

Table 1. Spores of species of mycorrhizal fungi present in the soil from 100 rice-legume cropping system fields in Pingtung County. Soil samples were collected on May 24, 1982 after the harvest of the first rice crop.

Gigaspora margarita Becker and Hall
Gigaspora gigantea (Nicol. and Gerd.) Gerd. and Trappe
Acaulospora scrobiculata Trappe
A. spinosa Walker and Trappe
A. laevis Gerd. and Trappe
A. trappei Ames and Linder
Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe
Gl. etunicatus Becker and Gerd.
Gl. clarus Nicolson and Schenk
Gl. monosporus Gerd. and Trappe
Gl. m.v. *macrocarpus* Tul. and Tul.
Gl. m.v. *geosporus* (Nicol. and Gerd.) Gerd. and Trappe
Gl. multicaulis Gerd. and Bakshi
Gl. microcarpus Tul. and Tul.
Gl. convolutus Gerd. and Trappe
Sclerocystis clavispora Trappe
Type I (*Acaulospora* sp.)
Type II (*Acaulospora* sp.)

Table 2. The frequency of occurrence of VA mycorrhizal species per 100 cc of soil from 100 rice-legume cropping system fields in Pingtung County. Soil samples were collected on May 24, 1982 after the harvest of the first rice crop.

VA Mycorrhizal Fungi	District name (ten fields per district)										Total Frequency
	Lii Kang	Kan Ding	Lin Luoh	Kao Shu	Chiu Ru	Chour Jou	Chu Tien	Chia Dong	Wan Luen	Nei Pu	
Gigaspora margarita[z]	10	0	6	0	10	4	4	0	10	10	54
Gigaspora gigantea[z]	0	0	6	0	10	0	3	0	10	10	39
Acaulospora scrobiculata[y]	10	10	10	5	10	10	8	10	10	9	92
A. spinosa	1	5	9	1	1	10	3	3	2	9	44
A. laevis[z]	10	0	10	3	6	0	0	0	10	0	39
A. trappei	0	1	5	2	0	4	1	0	0	6	19
Glomus mosseae[z]	10	10	10	10	10	10	10	10	10	10	100
Gl. etunicatus	10	10	10	10	10	10	10	10	10	10	100
Gl. clarus[z]	1	0	0	1	1	0	0	0	2	0	5
Gl. monosporus	3	0	0	0	1	0	0	1	9	0	14
Gl. m.v. *macrocarpus*	0	0	0	0	0	0	0	0	1	0	1
Gl. m.v. *geosporus*[y]	2	3	0	3	4	1	2	5	9	9	38
Gl. multicaulis	0	0	0	0	0	0	0	0	2	0	2
Gl. microcarpus	0	0	0	0	0	0	0	0	1	0	1
Gl. convolutus	0	0	0	0	0	0	0	0	1	0	1
Sclerocystis clavispora	2	0	2	3	3	2	0	0	3	0	15
Type I (*Acaulospora* sp.)	0	3	0	2	1	3	5	7	1	0	22
Type II (*Acaulospora* sp.)	1	0	0	0	0	0	0	1	0	0	2

[z] Species that form mycorrhizae with soybean as demonstrated by other scientists.
[y] Species that were unable to form mycorrhizae with soybean as demonstrated by other scientists.

Table 3. The relationship between the distribution of VA mycorrhizal species in the soils of 100 rice-legume cropping system fields in Pingtung County and the phosphorus content and pH of these soils. Soil samples were collected on May 24, 1982 after the harvest of the first rice crop.

VA Mycorrhizal Fungi	Total frequency	Soil pH range	Olsen P (ppm) range
Glomus mosseae	100	5.00 - 7.65	15.02 - 284.69
Glomus etunicatus	100	5.00 - 7.65	15.02 - 284.69
Acaulospora scrobiculata	92	5.00 - 7.65	15.02 - 284.69
Gigaspora margarita	54	5.00 - 7.40	15.02 - 284.69
Acaulospora spinosa	44	5.80 - 7.65	15.02 - 185.16
Gigaspora gigantea	39	5.00 - 7.10	15.02 - 152.40
Acaulospora laevis	39	5.00 - 7.40	35.19 - 284.69
Glomus m.v. geosporus	38	5.00 - 7.65	15.02 - 141.45
Type I	22	5.20 - 7.65	42.59 - 212.07
Acaulospora trappei	19	5.80 - 7.10	15.02 - 244.35
Sclerocystis clavispora	15	5.05 - 7.40	42.59 - 244.35
Glomus monosporus	14	5.00 - 7.05	35.19 - 284.69
Glomus clarus	5	5.00 - 6.10	35.19 - 210.72
Glomus multicaulis	2	5.00	43.26
Type II	2	6.50, 7.40	50.10, 284.69
Glomus m.v. macrocarpus	1	5.30	36.70
Glomus microcarpus	1	5.30	36.70
Glomus convolutus	1	5.30	36.70

Conclusions

At least 16 species of VA mycorrhizal fungi can survive in the rice-rice-legume cropping system in soils ranging from acidic to weakly alkaline. Most species appear to be tolerant of high phosphorus concentrations. Among the three predominant species, Gl. etunicatus and Gl. mosseae have been previously shown to be mycorrhizal on soybean. However, the high frequency of Gl. mosseae, Gl. etunicatus, and A. scrobiculata occurrence indicates that they are mycorrhizal either on rice or on a legume, probably soybean, or on both. Glomus fasciculatus was not found in any of the soils surveyed. Some of the VA mycorrhizal species form mycorrhizae with rice as evidenced by the formation of arbuscules in the first rice crop.

Mycorrhizal Population Dynamics in Soybean-Rice-Rice and Soybean-Soybean-Rice Cropping Systems

Introduction

The amount of fertilizer applied to legumes in paddy rice based cropping systems in the tropics is often limited by high cost. To maximize yields, therefore, a legume crop must fully utilize the residual fertilizer from the preceding rice crop. Mycorrhizae have potential for maximizing the utilization of limited soil nutrients, provided that efficient strains or species of mycorrhizal fungi are present or can be introduced into the cropping system. This study was conducted to assess the population dynamics of VA mycorrhizal propagules throughout two paddy rice based cropping systems during a complete one-year cycle.

Methods and Materials

Four surveys were conducted at two soybean field sites in Pingtung County, one in Jiha-Dong village and the other at the Kaohsiung Districat Agriculture Improvement Station (DAIS), from October 29, 1981 to October 8, 1982. The cropping system at Jiha-Dong village was fall soybean-spring rice-summer rice and at the Kaohsiung DAIS was fall soybean-spring soybean-summer rice. The first survey was conducted at two to three weeks after planting and the other three at or near crop maturity. Eight to ten soil sampling locations were randomly selected at each site. Four to ten subsamples were collected from the top 18 cm of soil and recombined to form one 50 cm^3 or 100 cm^3 sample for each sampling location. Mycorrhizal spores were extracted by wet-sieving and decanting, and crop roots were stained in trypan blue lactophenol. Both were examined microscopically.

Results

The results are shown in Table 4. At both sites, the VA mycorrhizal spore population was the highest at first soybean maturity on January 11, 1982, then remained constant or gradually decreased through the two subsequent cropping cycles regardless of cropping system. The lowest spore populations occurred in the first survey conducted two to three weeks after the fall soybean crop was planted. The spore populations of three species, *Glomus mosseae*, *Gl. etunicatus*, and *Acaulospora scrobiculata* predominated at both sites. These same

three species were the most prevalent in the survey of 100 rice-legume cropping system fields in Pingtung County. The three predominant species were the only ones that showed a distinctive increase in spore population between the first and second surveys.

Table 4. VA mycorrhizal spore populations represented by each of the species per 50 cc from the top 18 cm of soil recovered throughout the two cropping systems (soybean-rice-rice, soybean-soybean-rice) during a complete one-year cycle from October 29, 1981 to October 8, 1982.

VA mycorrhizal fungi	Sampling site, date, and crop[z]							
	Jiha-dong				Kaohsiung DAIS			
	10/29/81 soybean[y]	1/11/82 soybean[w]	5/24/82 rice[w]	10/8/82 rice[w]	10/29/81 soybean[y]	1/11/82 soybean[x]	5/24/or 6/21/82 soybean[w]	10/8/82 rice[w]
Gigaspora margarita					1.11[t]	11.97[s]	8.86[s]	1.10[u]
Gigaspora gigantea					1.30	3.76	6.30	0.50
Glomus mosseae	1.14[v]	65.95[u]	36.85[u]	55.70[u]	1.15	49.67	41.85	56.60
Glomus etunicatus	6.06	230.07	149.05	116.75	8.13	113.96	88.04	68.50
Glomus monosporus	0.95	9.23	8.75	4.25	?[q]	8.92	7.51	8.25
Glomus m.v. geosporus	3.84	4.97	8.80	1.40	8.47	10.51	8.96	3.90
Glomus clarus	-[r]	2.15	0.30	-	-	0.22	-	-
Glomus convolutus	0.14	-	0.40	-				
Acaulospora scrobiculata	0.67	31.53	19.10	19.55	?	79.22	64.70	50.05
Acaulospora spinosa	0.58	0.97	0.25	0.50	1.55	3.15	1.19	0.85
Sclerocystis clavispora	0.20	-	-	-	0.88	0.88	0.47	-
VAM association	?	M+	M+	M-	?	M+	M+	M-

[z] Data represents the mean spore density per 50 cc soil.
[y] Soybean seedlings two to three weeks after planting.
[x] Soybean were at or near maturity.
[w] Soybean or rice were harvested.
[v] Mean of 12 samples with three subsamples per sample.
[u] Mean of 10 samples with ten subsamples per sample.
[t] Mean of 16 samples with six subsamples per sample.
[s] Mean of 176 samples with three subsamples per sample.
[r] - = no spores were observed.
[q] ? = not evaluated.

A high frequency of arbuscule formation in the fall and spring soybean crops and the spring rice crop during the second and third surveys (1/11/82 and 5/24/82) was observed. However, no arbuscule formation was observed in the summer rice crop at either site during the fourth survey (10/8/82).

Conclusions

Spore population dynamics were similar regardless of cropping system or mycorrhizal species. Soybean planted after soybean did not increase spore populations. Spore population dynamics of mycorrhizal species occurred in two distinct patterns: Those that increased between the first and second survey and those that did not. The three

predominant species were also the most likely species to form mycorrhizal associations with soybean. Primary inocula for the spring soybean crop and the spring and summer rice crops probably include both fungal mycelium from the previous crop and spores. However, spores are apparently the primary inoculum source for the first crop (soybeans) after summer rice.

The Effect of Cropping Systems on Vesicular-Arbuscular Mycorrhizae Inoculum Potential Under Greenhouse Conditions

Introduction

The ability of VA mycorrhizal fungi to enhance plant nutrient uptake varies with crop, cropping history, climatic and edaphic environment, and the quality, quantity, and species of mycorrhizal propagules. These factors must be quantified in order to understand the potential of mycorrhizae in a cropping system. This initial investigation focused on the variation in the VA mycorrhizae inoculum potential of field soil in a paddy rice based cropping system.

Methods and Materials

Field soil was collected from the mycorrhizae population dynamics experimental field in Jiha-Dong village immediately after the harvest of the first rice crop on May 24, 1982. The soil was thoroughly mixed and 35 equal portions were placed in Wagner's 1/2000-a pots for the seven treatments (Table 5) with five replicates per treatment. Two experiments were conducted, the first from June 11 to October 20, approximating the summer rice season, and the second from October 22 to January 11, approximating the fall soybean season. Experiment II utilized the treatments from experiment I without disturbing the soil except to plant the soybean seeds. An additional treatment (T8), using washed second rice crop roots as the mycorrhizae inoculum source, was included in experiment II. All crop treatments receive N:P:K; experiment I received 7:1.6:1.6 g/pot (equivalent to 450:110:110 kg/ha) and experiment II received 3:0.5:1 g/pot (equivalent to 200:40:80 kg/ha). Rhizobium was added to all sterile soil treatments. Mycorrhizae inoculum potential was estimated based on soybean grain yield.

Table 5. Treatments and cropping sequences for the study of VA mycorrhizae inoculum potential under greenhouse conditions.

Pretreatment	Experiment I (6/11 - 10/20/82)				Experiment II (10/22/82 - 1/11/83)			
	Treatment number	Soil treatment	Mycorrhizae inoculum	Crop	Treatment number	Soil treatment	Mycorrhizae inoculum	Crop
Unsterilized field soil	T1	Flooded	Natural	Rice	T1	Unflooded	Natural	Soybean
	T2	Flooded	Natural	Fallow	T2	Unflooded	Natural	Soybean
	T3	Unflooded	Natural	Soybean	T3	Unflooded	Natural	Soybean
	T4	Unflooded	Natural	Fallow	T4	Unflooded	Natural	Soybean
Sterilized field soil	T5	Unflooded	-	Soybean	T5	Unflooded	-	Soybean
	T6	Unflooded	1st rice roots[z]	Soybean	T6	Unflooded	1st rice roots	Soybean
	T7	Unflooded	1st rice roots[z]	Fallow	T7	Unflooded	1st rice roots[y]	Soybean
					T8	Unflooded	2nd rice roots[y]	Soybean

[z] Roots of the first rice crop (spring) collected from the same Jiha-Dong field where the soil was collected. Roots were washed to remove mycorrhizae spores, mycelium, and soil.

[y] Same as [z] except roots were from the second rice crop (summer).

Table 6. The effect of agricultural practices on VA mycorrhizae inoculum potential as measured by soybean grain yield under greenhouse conditions.

Treatment	Experiment I (6/11/82 - 10/20/82)			Experiment II (10/22/82 - 1/11/83)		
	Crop	VAM association	Yield[z]	Crop	VAM association	Yield[z]
Unsterilized (field soil)						
T1 Flooded	Rice	M-		Soybean	M+	3.37
T2 Flooded	Fallow			Soybean	M+	3.88
T3 Unflooded	Soybean	M+	12.06	Soybean	M+	2.83
T4 Unflooded	Fallow			Soybean	M+	3.62
Sterilized (field soil)						
T5 Unflooded,	Soybean	M-	5.04	Soybean	M-	1.82
T6 Unflooded, washed rice roots (1st rice crop)	Soybean	M+	10.08	Soybean	M+	3.27
T7 Non-flooded, washed rice roots (1st rice crop)	Fallow			Soybean	M-	2.00
T8 Non-flooded, washed rice roots (2nd rice crop)				Soybean	M-	-
		LSD (.05)	1.01			0.77

[z] Mean yield per plant, five replications with three plants per replication.

Results

In experiment I the presence of mycorrhizae inoculum, either as spores and mycelium in natural soil or as mycelium in the roots of the first rice crop roots used as inoculum, enhanced soybean grain yield (Table 6). However, mycelium in the first rice crop roots served as effective inoculum only in the soybean-soybean sequence (treatment T6) and not in the fallow-soybean sequence (T7). Roots of the second rice crop were not a source of mycorrhizae inoculum (T8). In experiment II the presence of mycorrhizae increased soybean grain yield. Flooding of non-sterilized field soil did not reduce inoculum potential. However, the presence of a crop in experiment I (T1, T3, T6) reduced the inoculum potential for soybeans in experiment II (Table 7). Arbuscules were absent from the soybean roots at maturity in experiment I and both arbuscules and vesicles were absent from the rice roots.

Table 7. Values of contrasts of treatment means and their "t" values (value divided by its standard deviation).

Constrast of means[z]	Total grain yield (g/plant)	
	value	"t"
Flooded > Non-flooded	0.798	1.50
No previous crop > Previous crop	3.57	2.46[y]

[z] See text for explanation of contrasts.
[y] Significant at P - 0.05.

Conclusions

Mycelium of mycorrhizae in rice roots can serve as primary inoculum for a subsequent soybean crop. Mycorrhizal associations do not form on the second (summer) rice crop or, if they do form, the mycorrhizal species are not mycorrhizal on soybean. Apparently, the mycelium of species that are mycorrhizal on soybean cannot survive a three-month fallow period. Therefore, spores are the primary inoculum source for soybeans after summer rice. Apparently the presence of an intervening crop (experiment I) between the first rice crop and the fall soybean crop (experiment II) reduces mycorrhizae inoculum potential.

Identification of Soybean Rust Races at AVRDC

Introduction

Genes for specific resistance to soybean rust, Phakopsora pachyrhizi, have been identified by several scientists in soybean cultivars PI 200492, PI 462312 (Ankur), PI 230970, and PI 230971, and are suspected in PI 459025 and PI 339871 (Glycine soja). Races of rust with varying numbers of corresponding virulence genes have also been found. Lesion types have been classified as tan (T), reddish-brown (RB), and small necrotic fleck (0) representing susceptible, resistant, and hypersensitive reactions, respectively. The purpose of this study was to determine the predominant races of soybean rust present at AVRDC.

Methods and Materials

The differential hosts used were the soybean cultivars PI 462312 (Ankur), Wayne (G 5446), PI 200492, PI 230970, PI 230971, and PI 459025 and the Glycine soja cultivar PI 339871. Naturally infected leaves with T type lesions were collected from field grown cultivars TK #5, PI 230971 (G 8587), G 4919, and AGS 62, and with RB type lesions from PI 459024, PI 459025, TN #4, G 5524, SRE-Z-13 (AGS 183), and Neonotonia wightii. Uredospores of single uredia from each of the cultivars were transferred to detached leaves of the cultivar TK #5 and multiplied by the transfer of uredospores from a single uredium to a healthy detached leaf of TK #5. Greenhouse-grown differential hosts were inoculated when the fourth trifoliolate leaf was fully expanded. Detached leaves were collected from three-week-old differential hosts at the V2 and V3 growth stages. Inoculated host plants and detached leaves were maintained in a growth room at 25±2°C with a 12 hour photoperiod.

Results

All isolates, regardless of original lesion type, appear to belong to a single race, which corresponds to K. R. Bromfield's race PDRL 4 (Tables 8 and 9). This race can overcome the three proven independent specific resistance genes in the cultivars Ankur, PI 200492, PI 230970, and PI 230971, but not the resistance of PI 459025 and PI 339871. The genetics of resistance in PI 459025 and PI 339871 is not known.

Conclusions

A single rust race with multiple virulence genes is the predominant race at AVRDC. This race has developed in the absence of any known

soybean cultivars possessing all the corresponding genes for specific resistance. Apparently P. pachyrhizi is accumulating virulence genes in advance of any scientific effort to accumulate the corresponding specific resistance genes into a soybean cultivar.

Table 8. Lesion type on detached leaves of differential soybean cultivars inoculated with isolates of the soybean rust fungus (Phakopsora pachyrhizi), June, 1982.

Isolate	Lesion type[z]					
	Ankur	G 5446	200492	230970	230971	249025
AGS 62	T	NU	T	T	T	RB
G 4919	T	T	T	T	NU	RB
G 5524	T	T	T	T	NL	-
G 8587	T	T	T	T	NU	RB
PI 459024	T	T	T	T	NU	RB
PI 459025	T	NU	T	T	NU	RB
TK 5	R,RB	T	T	T	T	-
TN 4	T	-	T	T	T	-
Z-13	T	T	T	T	T	RB
G. javanica	T	NL	T	NL	T	T

[z] T = Tan type; RB = Red-brown type; - = Not tested;
NU = No uredia formation; NL = No lesion formation.

Table 9. Lesion type on plants of differential soybean cultivars inoculated with isolates of the soybean rust fungus (Phakopsora pachyrhizi), July, 1982.

Isolate	Lesion type[z]						
	Ankur	G 5446	200492	230970	230971	459025	G. soja
AGS 62	T	T	T	T	T	RB	RB
G 4919	T	T	T	T	T	RB	RB
G 5524	T	T	T	T	T	RB	RB
G 8587 (230971)	T	T	T	T	T	RB	RB
PI 459024	T	T	T	T	NL	RB	RB
PI 459025	T	T	T	NL	T	RB	RB
TK 5	T	T	T	T	NL	RB	RB
TN 4	T	T	T	T	T	RB	RB
Z-13	T	T	T	T	T	RB	RB
G. javanica	T	T	T	T	T	RB	RB

[z] T = Tan type; RB = Reddish-brown type; - = No lesion.

Resistance to Development of Soybean Rust

Introduction

The presence of rate-reducing resistance to soybean rust has been previously reported and appears to be the most practical form of resistance to deploy against rust in developing countries. The purpose of this study was to determine the extent of variation in the rates of rust development under an induced epidemic.

Methods and Materials

Two soybean populations were evaluated, one consisting of advanced breeding lines, commercial cultivars, and accessions, and the other primarily of germplasm accessions previously selected for rust resistance. The populations were planted in spring (February 23) and fall (September 29) using a split plot design with plant density equivalent to 400,000 plants/ha. However, the germplasm accessions were not evaluated in the fall. Three replications were used in the spring and four in the fall. Main plot treatments were fungicide protected and unprotected and subplots were soybean cultivars. Unprotected plots were inoculated with rust spores when the soybeans reached the V2 to V4 growth stage. Dithane M-45 fungicide was sprayed every two weeks. Standard AVRDC cultural practices were followed. Percent rust affected foliage, percent defoliation, and growth stage were recorded weekly. Rate of rust development was determined from the correlation between total rust- affected foliage (rust affected foliage plus defoliation) and relative life time (RLT) as defined in Tables 10 and 11.

Results

Two advanced breeding lines, SRE-Z-11B (AGS 182) and SRE-Z-15A, had a higher level of rate-reducing resistance than the check cultivar, Shih-Shih, in both spring and fall seasons (Tables 10 and 11). One germplasm accession, G 5095, had a higher level of rate-reducing resistance than Shih-Shih (Table 12). Significant variation in the rates of rust development exists among the cultivars tested. Greater variation and higher rates of rust development occurred in the fall season. Estimated total rust affected foliage at completion of 70% of the soybean life cycle also varies among cultivars but is apparently not related to the rate of rust development.

Table 10. Rates of rust development and estimated total rust affected foliage on advanced breeding lines, commercial cultivars, and accessions; spring, 1982, AVRDC.

Cultivar	Rate of rust development[z]	Rust affected foliage (%)[y]	Cultivar	Rate of rust development	Rust affected foliage (%)
SRE-Z-15A	0.0998[z]	22.8	TN #15	0.1245	26.7
SRE-Z-11B (AGS 182)	0.1014	18.6	KS-741	0.1250	35.9
Shih-Shih[x]	0.1069	23.6	78-067	0.1252	32.1
SRE-Z-11A (AGS 181)	0.1083	24.9	SRE-Z-15C	0.1267	18.5
TK #5	0.1113	40.3	KS-8	0.1276	30.6
SRE-A-16	0.1126	20.4	G 5524	0.1293	16.6
KS-535	0.1154	32.5	78-084	0.1299	26.4
Hua-78-28	0.1163	28.3	AGS-66	0.1311	21.7
AGS 62	0.1210	16.2	TN #4	0.1358	30.6
AGS 129	0.1214	26.9	SRE-Z-13 (AGS 183)	0.1390	27.2
LSD (.05)	0.0016			0.0016	

[z] Regression coefficient of the correlation between total rust affected foliage (rust affected foliage + defoliation) and relative life time (DAP ÷ Days to R8 x 100).
[y] Estimated total rust affected foliage (rust affected foliage + defoliation) when 70% of soybean life cycle is completed.
[x] Check cultivar.

Table 11. Rates of rust development and estimated total rust affected foliage on advanced breeding lines, commercial cultivars, and accessions; fall, 1982, AVRDC.

Cultivar	Rate of rust development[z]	Rust affected foliage (%)[y]	Cultivar	Rate of rust development	Rust affected foliage (%)
SRE-Z-11B (AGS 182)	0.1080	42.2	AGS 66	0.1480	47.1
78-084	0.1182	54.9	KS 535	0.1481	60.8
SRE-Z-11A (AGS 181)	0.1198	39.8	Hua 78-28	0.1497	59.0
SRE-Z-15A	0.1233	43.1	KS-741	0.1504	56.2
SRE-Z-15C	0.1243	51.1	TN #4	0.1509	56.7
TN #15	0.1261	45.5	AGS 62	0.1552	40.8
SRE-A-16	0.1281	52.2	78-067	0.1560	69.4
Shih-Shih[x]	0.1317	50.3	SRE-Z-13 (AGS 183)	0.1586	64.9
TK #5	0.1449	66.8	G 5524	0.1629	49.3
KS-8	0.1449	71.0	AGS 129	0.1632	48.3
LSD (.05)	0.0013			0.0013	

[z] Regression coefficient of the correlation between total rust affected foliage (rust affected foliage + defoliation) and relative life time (DAP ÷ Days to R8 x 100).
[y] Estimated total rust affected foliage (rust affected foliage + defoliation) when 70% of soybean life cycle is completed.
[x] Check cultivar.

Conclusions

Variation in the levels of rate-reducing resistance does exist, although the variation is small. There appears to be an interaction between environment and the levels of rate-reducing resistance. There

also appears to be an interaction between the rate of rust development and the rust intensity when 70% of the soybean life cycle has been completed. This interaction could result if different levels of susceptibility occur at the different plant development stages or if previously unidentified specific resistance is present in some of the cultivars. The rate of rust development alone apparently does not indicate the level of a cultivar's resistance.

Table 12. Rates of rust development and estimated total rust affected foliage on accessions previously selected for rust resistance and reference cultivars; spring, 1982, AVRDC.

Cultivar	Rate of rust development[z]	Rust affected foliage (%)[y]	Cultivar	Rate of rust development	Rust affected foliage (%)
G 5095	0.1060	15.8	G 5525	0.1286	12.3
Shih-Shih[x]	0.1125	16.5	G 4919	0.1299	12.5
SRE-B-19-SL	0.1133	14.1	G 5497	0.1415	7.2
G 5554	0.1173	9.9	TN #4	0.1471	17.1
KS-535	0.1194	23.3	G 5422	0.1499	6.3
G 6154	0.1203	8.6	G 5378	0.1516	4.0
G 5646	0.1247	11.6	SRE-B-15-SL	0.1574	9.0
TK #5	0.1260	25.6	G 5524	0.1735	5.1
LSD (.05)	0.0025			0.0025	

[z] Regression coefficient of the correlation between total rust affected foliage (rust affected foliage + defoliation) and relative life time (DAP ÷ Days to R8 x 100).
[y] Estimated total rust affected foliage (rust affected foliage + defoliation) when 70% of soybean life cycle is completed.
[x] Check cultivar.

Yield of Soybean Cultivars Under Stress From a Rust Epidemic

Introduction

Previous studies have indicated that soybean yield under fungicide protected conditions is not necessarily related to yield under unprotected conditions. It has also been observed that percent yield loss based on fungicide protected yield varies with cultivar and that if cultivars were ranked by percent yield loss, then their rank would remain the same in different epidemics. The purpose of this study was to evaluate the extent of variation in yield and yield loss under stress from a severe soybean rust epidemic.

Methods and Materials

Two soybean populations were evaluated, one consisting of advanced breeding lines, commercial cultivars, and accessions and the other

primarily of germplasm accessions previously selected for rust resistance. Neither population was previously selected for yielding ability under rust stress. The populations were planted in spring on February 23 and in fall on September 29 with a plant density equivalent to 400,000 plants/ha. Three replications were used in the spring and four in the fall. A split plot design was used; main plot treatments were fungicide protected and unprotected and subplots were soybean cultivars. Subplots measured 4 x 4 m with the exception that resistant accessions were planted in 3 x 3 m subplots in the spring experiment. Unprotected plots were inoculated with rust spores when the soybeans reached the V2 to V4 growth stage. The protective fungicide was Dithane M-45 sprayed every two weeks. AVRDC cultural practices were followed. Yield data was converted to 13% moisture content before evaluation. Yield loss is expressed as percent of fungicide protected yield.

Results

The percent yield loss in most of the resistant germplasm accessions was similar to or less than that of the check cultivar in both seasons, and in four accessions was significantly less (Tables 13 and 14). The yield of most of the accessions grown without fungicide protection was similar to or greater than the check cultivar's in both seasons and the yield of one accession, G 4919, was significantly greater. Most breeding lines and cultivars that were higher yielding than the check cultivar under fungicide protection were similar to or lower yielding than the check in the rust stress plots (Tables 15 and 16). Most cultivars that were higher yielding under rust stress in the fall had been previously selected for rust resistance (Table 16) and these same cultivars appeared to be higher yielding under rust stress in the spring (Table 15). However, previous selection for rust resistance did not always assure higher yield under rust stress. No correlation was found in the linear regression between yield in the fungicide protected plots and yield in the unprotected plots. Few cultivars were better yielding than Shih-Shih in both fungicide protected and unprotected conditions.

Conclusions

Within the soybean population there is significant variation in yielding ability under stress from a severe rust epidemic. This variation is not related to yield under fungicide protected conditions

and can be readily exploited by selecting for yielding ability within segregating populations or from among cultivars grown under intense rust pressure. Selection for yielding ability under rust stress should not prevent later identification of high yielding lines under low or no rust stress conditions. Currently, yielding ability can be more easily and accurately assessed than resistance. Yielding ability under rust stress appears to be related to rust resistance but the relationship has yet to be established.

It is recommended that segregating soybean populations first be selected for high yield under severe rust stress and then selected for high yield under fungicide protection; that the cultivar Shih-Shih (G-38) be used initially as the yield check under rust stress conditions; and that the term "tolerance to soybean rust" be used and defined as relative yielding ability of soybeans under stress from a soybean rust epidemic.

Table 13. Yield and yield loss of accessions previously selected for rust resistance and reference cultivars grown during a severe soybean rust epidemic; spring, 1982, AVRDC.

Cultivar	Yield (t/ha)		% Yield loss
	Fungicide protected	Unprotected	
G 5378	2.15 -[y]	1.27	41.0 -
G 5524	2.36 -	1.24	46.9
G 5525	2.17 -	1.18	45.0 -
G 4919	4.00 +	1.57 +	60.7
G 5422	2.43 -	1.22	49.7
G 5497	1.96 -	1.47	24.9 -
G 6154	1.68 -	1.19	28.9 -
G 5095	2.96	1.20	59.5
G 5554	1.69 -	1.29	23.2 -
G 5646	2.33 -	1.18	46.6
SER-B-15-0-0-0-5-BK	2.80	1.44	48.5
SRE-B-19-3-BK-1-1-BK	2.75	1.30	52.9
TK #5	2.64	0.42 -	83.9 +
Shih-Shih[z]	2.95	1.19	60.4
KS 535	3.12	1.02	67.7
TN #4	2.81	0.54 -	81.0 +
LSD (.05)	.337		14.78

[z] Standard check cultivar.
[y] Significantly different ($p > 0.05$) from check cultivar; + = greater than check, - = less than check.

Table 14. Yield and yield loss of accessions previously selected for rust resistance and reference cultivars grown during a severe soybean rust epidemic; fall, 1982, AVRDC.

Cultivar	Yield (t/ha)		% Yield loss
	Fungicide protected	Unprotected	
G 5378	1.91 -[y]	0.60	67.7 -
G 5524	2.35	0.66	71.7 -
G 5525	2.36	0.53	73.6
G 4919	2.90 +	0.75 +	74.1
G 5422	2.57 +	0.53	79.2
G 5497	2.11 -	0.93 +	56.2 -
G 6154	1.99 -	0.68	65.8 -
G 5095	2.43	0.50	79.5
G 5554	1.97 -	0.64	67.4 -
G 5646	2.47	0.62	74.65
KS-8	2.67 +	0.52	80.7
Hua 78-28	2.30	0.40	82.7 +
SRE-C-21	3.22 +	0.40	87.5 +
AGS 17	2.19	0.25 -	88.7 +
KS 535	2.56	0.49	80.9
TN #4[z]	2.32	0.52	77.7
LSD (.05)	.199		4.79

[z] Standard check cultivar.
[y] Significantly different ($p > 0.05$) from check cultivar; + = greater than check, - = less than check.

Table 15. Yield and yield loss of advanced breeding lines, commercial cultivars, and accessions grown during a severe soybean rust epidemic; spring, 1982, AVRDC.

Cultivar	Yield (t/ha)		% Yield loss
	Fungicide protected	Unprotected	
SRE-Z-11A (AGS 181)	2.34 -[y]	1.21	48.0 -
SRE-Z-11B (AGS 182)	2.58	1.33	48.1 -
78-067	2.17 -	0.20 -	90.9 +
78-084	2.57	0.73 -	71.7 +
SRE-Z-13 (AGS 183)	2.56	0.65 -	75.0 +
SRE-Z-15A	2.60	0.78 -	69.8 +
TN #15	2.32 -	0.99	57.5
SRE-A-16	2.55	0.80	68.0
SRE-Z-15C	2.43	0.80	57.0
KS-741	2.89	0.79	72.6 +
KS-8	3.20 +	0.96	69.6 +
Hua-78-28	2.86	0.58 -	80.0 +
G 5524	2.96	1.21	59.3
TN #4	2.85	0.34 -	87.9 +
TK #5	2.12 -	0.18 -	91.3 +
KS 535	3.11 +	0.83	73.5 +
AGS 66	3.24 +	0.67 -	79.3 +
AGS 62	3.16 +	1.18	62.9
AGS 129	3.29 +	0.72 -	78.2 +
Shih-Shih[z]	2.70	1.09	59.4
LSD (.05)	.308		9.83

[z] Standard check cultivar.
[y] Significantly different ($p > 0.05$) from check cultivar; + = greater than check, - = less than check.

Table 16. Yield and yield loss of advanced breeding lines, commercial cultivars, and accessions grown during a severe soybean rust epidemic; fall, 1982, AVRDC.

Cultivar	Yield (t/ha)		% Yield loss
	Fungicide protected	Unprotected	
SRE-Z-11A (AGS 181)	2.23 -[y]	0.93 +	57.7 -
SRE-Z-11B (AGS 182)	2.11 -	0.84 +	60.2 -
78-067	2.27 -	0.22 -	90.2 +
78-084	2.20 -	0.45 -	79.3
SRE-Z-13 (AGS 183)	2.60 +	0.55	79.1
SRE-Z-15A	2.47	0.82 +	66.5 -
TN #15	2.09 -	0.72 +	65.1 -
SRE-A-16	2.37	0.65	72.0
SRE-Z-15C	2.43	0.72 +	70.6 -
KS-741	2.58	0.65	74.4
KS-8	2.79 +	0.51	80.7 +
Hua-78-28	2.48	0.52	79.1
G 5524	2.32 -	0.72 +	68.8 -
TN #4	2.47	0.63	74.5
TK #5	2.42	0.28 -	88.5 +
KS 535	2.59	0.51	80.0
AGS 66	2.41	0.57	75.9
AGS 62	2.49	0.82 +	66.5 -
AGS 129	2.74 +	0.55	79.6
Shih-Shih[z]	2.48	0.59	76.1
LSD (.05)	0.116		4.42

[z] Standard check cultivar.
[y] Significantly different ($p > 0.05$) from check cultivar; + = greater than check, - = less than check.

The Effects of Vesicular-Arbuscular Mycorrhizae on Soybean Mosaic Virus Infected Soybeans

Introduction

The general beneficial effect of mycorrhizae on crops growing in soils with low fertility (i.e. low phosphorus) is well documented. However, information on the effect of mycorrhizae on plant pathogens is scanty and inconclusive. Some cases are reported where mycorrhizae have reduced plant pathogens, particularly those that are soil borne. On the other hand, the opposite effect has been observed with foliar pathogens.

In this study, the effect of mycorrhizae on soybean mosaic virus (SMV) in soybeans was investigated under greenhouse and field conditions.

Materials and Methods

Greenhouse: The experiment consisted of three treatments: Inoculation with mycorrhizae, inoculation with SMV at the VC stage in addition to inoculation with mycorrhizae, and no inoculation (control). Each treatment consisted of ten pots, three plants per pot, with autoclaved (120°C/30 min) soil containing a mean of 9 ppm P_2O_5. Before seeding, each seedhole was inoculated with 1 ml of a solution of crushed soybean nodules containing 7.5 x 10^7 Rhizobium sp. bacteria/ml. The nodules had been surface sterilized (0.1% $HgCl_2$/1 minute) and rinsed in sterile distilled water before crushing. The mycorrhiza treatments received an additional 10 g soil inoculum containing approximately 20 spores of Glomus mosseae per gram soil. Plants were inoculated at the primary leafstage using a homogenate of 1 g fresh SMV (Strain G-1) infected soybean leaves (variety TN-4) in 3 ml 0.1 M phosphate buffer pH 6.5. The virus concentration in SMV infected leaves was measured in the fully expanded leaves of the fifth, seventh, and eighth nodes. Five circular pieces of 27.75 mm^2 were cut from each leaf at the same position: Three pieces from the tip of the middle leaflet and one piece each from the side leaflets. The leaf pieces were pooled and triturated in 1 ml of 0.1 M phosphate buffer pH 6.5. 20 µl of this homogenate was placed on a half-leaf of a fully developed unifoliolate leaf of Phaseolus vulgaris Topcrop, the local lesion host of SMV, and spread out evenly with a glass rod.

Field: A similar experiment using the same three treatments was conducted in the fall season (September) in the field from which the soil for the pot experiments had been taken.

Each treatment consisted of one plot (2 x 5 m) with two beds of two rows per plot. Distance between rows was 50 cm and between hills 10 cm. Three seeds were planted in small paper bags containing 50 g soil. After ten days the seedlings were thinned to two per bag. The mycorrhiza treatments were planted in soil containing 20 g spores of Glomus mosseae per gram soil. All treatments received 1 ml of a solution of crushed Rhizobium sp. containing 7.5 x 10^7 bacteria. SMV inoculation was the same as for the greenhouse experiment.

Results

Results are shown in Tables 17, 18, and 19. In the greenhouse experiment, mycorrhizal infection significantly increased virus

concentration in the seventh and eighth nodes. Mycorrhizal infection also stimulated plant growth to such an extent that plant height, leaf size, pod number, seed number, shoot and root dry weight, and total yield of SMV infected mycorrhizal plants were the same or larger than those of the healthy control plants.

Yield reduction due to SMV in mycorrhizal plants was 39% compared with 64% in SMV infected plants not amended with mycorrhizae.

The field experiment failed to show any significant differences between mycorrhizal and non-mycorrhizal treatments, even though the seeds received 2.5 times as many mycorrhiza spores as the pot experiments. It is possible that the mycorrhizal inoculum was too low for field conditions where mycorrhizae must compete with a very large population of different soil microorganisms, including native mycorrhizae. It is also possible, however, that in agricultural soils effective mycorrhizal colonization of plant roots is not from spores, but from mycorrhizal mycelium.

Conclusions

When considering mycorrhizae as a possible soil amendment to stimulate plant growth in soils with low fertility, it must be taken into account that the techniques which give good results in pot experiments using sterilized soil cannot be directly applied to the field, and that certain foliar pathogens, such as viruses and possibly fungi, may also be stimulated.

Table 17. Effect of mycorrhizae on the virus concentration of SMV infected soybeans.

Treatment	No. of local lesions produced on *P. vulgaris* Topcrop[z]		
	Fifth node leaf	Seventh node leaf	Eighth node leaf
No mycorrhiza	27.9	87.8	33.4
Mycorrhiza[y]	31.2	132.9*	79.0**

[z] Each value represents a mean from 5 x 23.75 mm^2 pieces from one leaf of each of ten plants inoculated on two half leaves of *P. vulgaris* Topcrop.

[y] *: Significantly different from control (no mycorrhiza) at the 5% level.
**: Significantly different from control at the 1% level.

Table 18. Effect of mycorrhizae on SMV infected soybeans (greenhouse experiment).

Treatment	Plant height (cm)	Leaf size[z] (cm^2)	Pod no./ plant	Seed no./ plant	Shoot dry weight (g)	Root dry weight (g)	Nodule no./ plant	100 seed weight (g)	Yield/ plant (g)
No mycorrhizae									
No virus	86.20 b[x]	59.59 c	5.93 b	9.77 b	1.32 b	0.82 a	13.31 b	20.57 a	2.00 b
Virus[y]	62.79 c	39.39 d	2.97 c	4.07 c	0.63 c	0.42 b	7.89 b	17.50 c	0.72 c
Mycorrhizae									
No virus	105.50 a	150.29 a	9.00 a	15.90 a	1.97 a	0.97 a	30.45 a	19.12 b	3.07 a
Virus[y]	81.80 b	103.28 b	7.00 b	10.73 b	1.31 b	0.82 a	8.64 b	17.40 c	1.86 b

[z] Area of sixth node trifoliolate leaf.
[y] Artificial inoculation with SMV-1 at VC stage.
[x] Means within columns followed by the same letter are not sigificantly different (P = 0.05) by DMRT.

Table 19. Effect of mycorrhizae on SMV infected soybeans (field experiment).

Treatment	Plant height (cm)	Leaf size[z] (cm^2)	Pod no./ plant	Seed no./ plant	Shoot dry weight (g)	Root dry weight (g)	Nodule no./ plant	100 seed weight (g)	Yield/ plant (g)
No mycorrhizae									
No virus	49.16 b[x]	--	15.06 a	24.41 a	3.03 a	0.46 a	7.16 ac	16.73 a	7.28 a
Virus[y]	39.33 ab	--	9.07 b	14.22 b	2.08 b	0.34 b	2.50 bc	15.95 a	4.09 b
Mycorrhizae									
No virus	48.41 ab	--	14.44 a	22.98 a	2.77 a	0.45 a	5.21 ab	16.65 a	7.11 a
Virus[y]	38.70 b	--	8.00 b	12.56 b	1.71 b	0.31 b	4.19 bc	15.72 a	4.01 b

[z] All data are the means of three replications and of 40 plants selected at random from each replication.
[y] Artificial inoculation with SMV-1 at VC stage.
[x] Means within columns followed by the same letter are not significantly different (P = 0.05) by DMRT.

Isolation and Characterization of Viruses on Soybean in Taiwan

Introduction

Soybean can be infected by a large number of viruses, often simultaneously. Of these viruses, soybean mosaic virus (SMV) is particularly important, because it is seed transmitted and occurs as several strains. A search for SMV strains was initiated in 1980. In 1981, virus isolates that could all be classified as strain 1 (SMV-1) were recovered from field grown soybeans. The search for other strains of SMV, in particular the more virulent necrotic strains, was continued in 1982 for use in SMV resistance screening.

Materials and Methods

Host range: Leaf samples of soybean plants showing typical virus symptoms, such as chlorosis, mottle, mosaic, and malformation, were collected at AVRDC and Pingtung. The leaf samples were triturated in 0.1 M phosphate buffer pH 7.2 and inoculated to Phaseolus vulgaris Topcrop, the local lesion host for SMV as well as a number of other viruses affecting soybean. To obtain a pure virus sample three single local lesion transfers were made. The viruses were maintained on Glycine max TN-4. For host range studies, three plants each of 22 plant species were inoculated at the cotyledon or true leaf stage and kept in the greenhouse for symptom observation. Symptomless plants were assayed by back-inoculation to P. vulgaris Topcrop.

Electron microscopy: Leafdip preparations stained with 2% potassium phosphotungstate were used for electron microscopic examination of particle morphology.

Results

The results of the electron microscopic examination are shown in Table 20 and host range results in Table 21. The reactions of three SMV-1 isolates (ATCC isolate, AVRDC isolate, and isolate 83, recovered in 1981 from soybean in the Taichung area) are listed for comparison.

In leafdip preparations, flexible rods of approximately 750, 400, and 300 nm (the smaller rods possibly representing fragments of the 750 nm particles) were found in all isolates. In the host range study, isolates 74, PN, and PM reacted similarly to the SMV reference isolates, with the exception that they induced necrotic reactions on several

soybean cultivars and systemic reactions in P. vulgaris cultivars Bountiful and Saxa. Isolates 74 and PN also infected Vigna umbellata systemically and isolate PN also induced necrotic lesions in Vicia faba.

Table 20. Particle morphology of virus isolates recovered from soybean.

Virus isolate	Particle shape and approximate size
ATCC	flexible rod, 650-800 nm
AVRDC	flexible rod, 650-800 nm
83	flexible rod, 700-800 nm
74	flexible rods, 400, 500, 300 nm
PN	flexible rods, 650-800 and 400 nm
PM	flexible rods, 400 and 750 nm

Table 21. Host reaction of some virus isolates recovered from soybean in Taiwan.

Host plant	Symptoms[z]					
	ATCC	AVRDC	83	74	PN	PM
Gomphrena globosa	-	-	-	L/-	L/-	-
Chenopodium amaranticolor	CL/-	-	-	CL/-	CL/-	CL/-
C. quinoa	CL/CL	-	-	CL/CL	CL/CL	CL/CL
Cyamposis tetragonoloba	-/M	-/M	-/M	-/M	-/M	
Dolichos labalab	-	-	-	-/M	-/M	-/-
Glycine max						
TN 4	-/Mal	-/M	-/M	-/M	-/Mal,M	-/M
Rampage	-/M	-/M	-/M	N/M	-/M	-/M
York	-/-	-/-	-/-	N/M,N	N/M,N	N/N
Marshall	-/-	-/-	-/-	-/M	N/M	-/M
Odgen	-/-	-/-	-/-	N/M,N	N/M,N	NL/N
Kwanggyo	-/-	-/-	-/-	-/-	-/M,N	-
Buffalo	-/-	-/-	-/-	-/-	N/M,N	NL/N
Bragg	N/M	N/M	N/M	N/M	N/M,N	VN/M,N
Davis	-/-	-/-	-/-	N/M	N/M,N	N/-
Phaseolus lathyroides	-/M	-/M	-/M	-/M	NL/N	-/M
P. vulgaris						
Bountiful	CS/-	CL/CL	CL/-	CL/Mal	CL/M	CRL/Mal
Kentucky Wonder Wax Pole	NL/N	NL/N	NL/-	NL/N	NL/N	NL/N
Kentucky Wonder Wax Runner Bean	NL/N	NL/N	NL/-	NL/N	NL/N	NL/N
Pinto III	NL/-	NL/-	-/-	-/-	CL/-	-/-
Saxa	CL/-	CL/CL	-/-	CL/Mal	VC/Mal	-/RL,Mal,NL
Topcrop	NL/-	NL/-	NL/-	NL/-	NL/N	NL/-
Pisum sativum Dark Skin Perfection	-/-	-/-	-/-	-/-	-/-	-/-
Vicia faba	-/-	-/-	-/-	-/-	NL/-	-/-
Vigna angularis Sword	-/M	-/M	-/M	-/M	-/M	-/M
V. radiata V 2010	-/-	-/-	-/-	-/-	-/-	-/-
V. mungo Acc. 3115	-/-	-/-	-/-	-/-	-/M	-/M
V. unguiculata						
Black	-/(+)	-/-	-/-	-/-	RL/RL,M	-/-
Early Ramshorn	-/N	-/-	-/-	-/(M)+	RL/M	-/-
Blue Goose	-/+	-/-	-/-	-/M+	-/M	-/-
Black Eye	-/+	-/-	-/(M)	-/(M)+	NRL/M	-/-
V. umbelleta Acc. 4050	-/-	-/-	-/-	-/M	-/M	-/-
Datura stramonium	-/-	-	-	-	-	-
Nicotiana glutinosa	-/-	-	-	-	-	-
N. tabacum Xanthi	-/-	-	-	-	-	-
Physalis floridana	-/-	-	-	-	-	-
Petunia hybrida	-/-	-	-	-	-	CL/-
Cucumis sativus Chicago Pickling	-	-	-	-	-	-
Cassia occidentalis	-/M	-/M	-/M	-/M	-/M	-/M

[z] Format of symptom symbols:
Reaction on inoculated leaves/reaction on non-inoculated leaves.
- = no reaction, no virus recovered by back inoculation to P. vulgaris Bountiful.
+ = virus recovered by back inoculation to P. vulgaris Bountiful.

Conclusions

Although SMV is reported to show a considerable variability in host range, it is not reported to infect P. vulgaris cultivars Bountiful and Saxa systemically. This would suggest that the three isolates 74, PN, and PM are not SMV. These isolates are now undergoing further investigation to establish their exact identity.

Preliminary Yield Trial of Soybean Lines Resistant to Soybean Mosaic Virus

Introduction

AVRDC was approached by Dr. R. M. Goodman of INTSOY to cooperate in a regional preliminary yield trial of INTSOY's soybean mosaic virus (SMV) resistant tropical lines. The primary purpose was to evaluate the yield potential of these lines.

Materials and Methods

Seeds of 19 SMV resistant advanced lines were received from INTSOY, Puerto Rico. The seeds were sown February 22 in a randomized complete block design with three replications. Each plot consisted of four rows 5 m long. Distance between rows was 50 cm and between plants within rows 10 cm. Three seeds per hill were planted and later thinned out to two seedlings. Standard AVRDC cultural practices were followed. The plants were not inoculated with SMV. Yield data were collected from the two inside rows (minus 0.5 m at each end).

Results

The results are presented in Table 22. Generally the lines are not suited for growth in Taiwan's spring cropping season, as most lines do not reach maturity (R8 stage) at the same time as the local cultivars. Some lines do not even reach maturity by 190 DAP. Only one line, PR 140-1, has potential for growth under Taiwan conditions. Although it reaches maturity somewhat later, 141 days as compared to 95 to 121 days for the local check cultivars, its yield (7.25 g/plant) is comparable to that of the local check cultivars (5.18 to 8.85 g/plant).

The plants were observed for naturally occurring virus infection. Conspicuous SMV-like symptoms (strong crinkle and mottle) were observed in a number of lines about six weeks after planting (V5 stage). Several samples were inoculated to Phaseolus vulgaris Topcrop, the local lesion

host of SMV, but in no case did local lesions develop. In all lines the symptoms in the field disappeared five weeks later (R1-R3 stage).

Conclusions

Since the SMV susceptible check cultivar TN-4 did not show any virus symptoms, it was assumed that the virus-like symptoms observed in the other lines were caused by nutrient deficiency in the soil.

Table 22. INTSOY trial OF SMV resistant lines, spring, 1982.

Cross ID	Parentage	Days to maturity	Plant height[z] (cm)	Pod no./ plant[z]	100 seed weight (g)	Yield/ plant[y] (g)	Growth stage at harvest[x]
PR 139-1	Buffalo x HLS	176	107.88	38.96	10.02	3.41	R8
PR 139-2	Buffalo x HLS	154	103.08	32.67	9.54	6.31	R8
PR 140-1	Buffalo x Jupiter	141	80.17	22.75	19.79	7.25	R8
PR 140-2	Buffalo x Jupiter	190	70.63	-	-	-	R2-R5
PR 141-1	PI 324068 x Jupiter	190	91.84	-	-	-	Vn+R2
PR 141-2	PI 324068 x Jupiter	190	86.63	-	-	-	R2-R5
PR 141-3	PI 324068 x Jupiter	190	96.05	24.84	9.74	3.01	R8
PR 141-4	PI 324068 x Jupiter	190	77.05	-	-	-	R2-R5
PR 141-5	PI 324068 x Jupiter	190	89.21	-	-	-	R2-R5
PR 142-1	PI 341242 x HLS	190	88.54	21.59	9.16	2.68	R8
PR 142-2	PI 341242 x HLS	176	89.67	38.63	8.64	3.45	R8
PR 142-3	PI 341242 x HLS	176	87.96	30.92	9.03	2.73	R8
PR 142-4	PI 341242 x HLS	176	93.83	37.13	8.57	2.69	R8
PR 143-1	PI 341242 x Jupiter	190	106.50	-	-	-	R2-R5
PR 143-2	PI 341242 x Jupiter	190	101.67	-	-	-	Vn+R2
PR 143-3	PI 341242 x Jupiter	176	68.50	32.69	11.89	2.77	R8
PR 143-4	PI 341242 x Jupiter	190	81.25	-	-	-	R2-R5
PR 143-5	PI 341242 x Jupiter	190	97.26	-	-	-	R2-R4
PR 143-6	PI 341242 x Jupiter	190	93.32	-	-	-	R2-R5
Shih-Shih (RCK)		95	56.83	27.30	18.63	6.43	R8
AGS 103 (PI 189935 x AGS 2) (RCK)		121	112.59	33.84	12.56	5.18	R8
AGS 129 (Shih-Shih x SRF 400)		112	79.21	22.92	22.07	8.85	R8
KS 8 (CK) (local variety)		112	70.46	17.21	33.31	7.60	R8
TN 4 (SCK)		106	77.46	20.42	24.23	7.09	R8
LSD (5%)			8.10	10.31	2.67	0.62	

[z] Mean of eight plants/replication.
[y] Mean of three replications.
[x] 190 DAP.

Soybean Entomology

Study of Beanfly Resistance Inheritance in Soybean

Introduction

In 1979, four Glycine soja accessions - G 3089, G 3091, G 3104, and G 3122 - were identified as highly resistant to beanflies, Melanagromyza sojae, Ophiomyia centrosematis, and O. phaseoli. AVRDC's soybean breeder crossed one of these accessions, G 3122, with a cultivated soybean cultivar, G 215. Using a decapitation technique in the greenhouse and later field testing in fall, 1981, 161 plants were selected. The seeds of individual plants were bulked. Several plants had seeds segregating for seed coat color. The seeds were separated on the basis of color and the resulting 197 F_5 entries were screened in fall, 1982.

Materials and Methods

Seeds of each entry were planted as a single row on the top of a 5 m long, 0.75 m wide raised bed. The crop was grown using traditional cultural practices except that no insecticide was applied. Six weeks after planting, ten plants were sampled, or 50% of the plants when the number of plants per plot was less than 20. The stem of each was cut open and the number of larvae and pupae within each plant was recorded. The number of beanfly damaged plants in each sample was also recorded. Resistance levels of each entry were judged by a statistical formula based on the mean and standard deviation of the mean number of larvae and pupae of all entries evaluated in the test.

Results

Of 197 entries, four entries did not germinate. Fifty-two entries were found moderately resistant, 48 exhibited low resistance, 79 were rated susceptible, and eight highly susceptible. All moderately resistant entries had varying degrees of beanfly damage but beanfly larvae or pupae were not found in their stems.

There was a considerable variation in plant growth between spring and fall crops. The spring plants were bigger and had broader leaves

almost like cultivated soybean, whereas in the fall all plants were small and had smaller leaves and stem diameters like their Glycine soja resistant parent, despite the fact that seed size and color in both seasons were more like cultivated soybean.

Conclusions

Since beanfly population pressure is considerably higher in Indonesia and Thailand than in Taiwan, moderately resistant entries will be tested in those countries during spring, 1983, to select more resistant materials.

Screening Soybean Germplasm for Resistance to Beanflies

Introduction

In 1979, after 6,775 soybean accessions were screened (some of them several times) four were found with high levels of resistance to beanflies. During the three following years additional germplasm was received. These materials were screened in 1982 along with others that had either been missing from or multiplied inadequately for use in the earlier screening. The 1982 screening was done in the fall when beanfly population is relatively high.

Materials and Methods

A 1 ha field was divided into ten alternating 2.25 m wide insect sources and 7.5 m wide varietal testing blocks. Two weeks before testing, soybean, mungbean, and snap bean were planted in source blocks to maintain the insect population. The test blocks were rototilled and worked into 75 cm wide raised beds. Every week, 225 accessions were planted, 25 accessions/test block. Seeds were planted on the top of 2 m long beds. Planting was sequenced so as to have the first week's accessions in each of nine blocks seeded adjacent to an insect source block. Each subsequent week's entries were planted in the neighbouring row in each test block.

Four weeks after planting, ten plants from each plot were uprooted and dissected, and the number of larvae and pupae found in each plant was recorded. The number of plants with damage was also recorded, as at times maggots died in an early instar, making it difficult to count insect number.

Each week the mean number of insects (larvae + pupae) found per ten-plant sample was subjected to a statistical analysis based on mean ($\bar{x}$) and standard deviation (SD). The accessions that had insect number less than $\bar{X}$ - 2SD were considered highly resistant (HR), between $\bar{x}$ - 1SD and $\bar{x}$ - 2SD moderately resistant (MR), between $\bar{x}$ and $\bar{x}$ -1SD as having low resistance (LR), between $\bar{x}$ and $\bar{x}$ + 2SD susceptible (S), and more than $\bar{x}$ + 2SD highly susceptible (HS). Since the past several studies showed highly significant positive correlation between insect numbers and percent damaged plants, only mean number of insects was used as the criterion for resistance evaluation.

Results

The results of the resistance screening are shown in Figure 1. Of 2,169 accessions screened 32 were rated HR, 315 MR, 82 LR, 938 S, and 63 HS.

Conclusions

Since this was a preliminary, single replicate, one season screening, it is difficult to ascertain the stability of the resistance. Thirty-two HR and 315 MR accessions will be planted in spring, 1983, in Indonesia, Thailand, and possibly Vietnam where beanfly population pressures are higher than at AVRDC. This will allow selection of reliably resistant accessions.

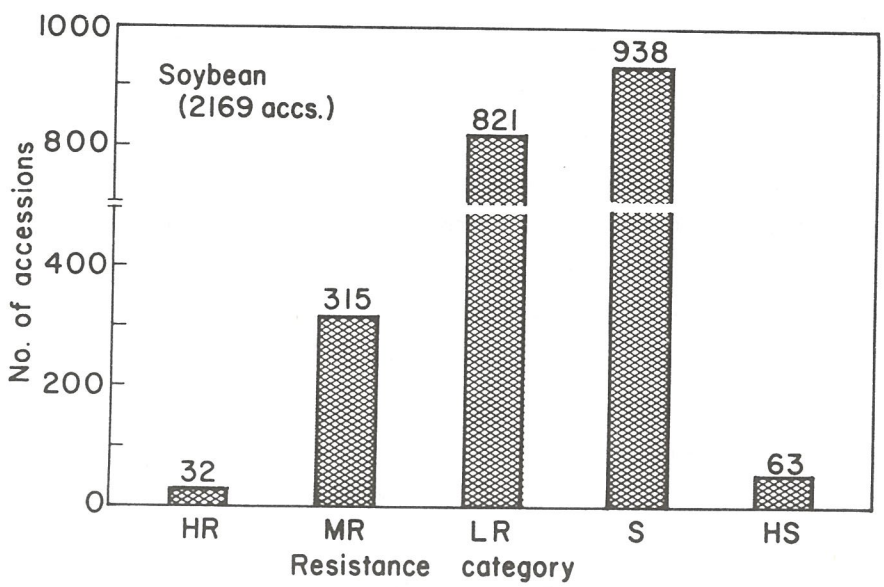


Figure 1. Relative resistance reactions of soybean accessions to agromyzid flies.

Evaluation of Insecticides for Beanfly Control

Introduction

In past AVRDC screenings three insecticides, monocrotophos, dimethoate, and omethoate, sprayed 3, 7, 14, 21, and 28 days after germination, were found to give excellent control of beanflies. Since all three compounds have sufficient water solubility to act as systemics, foliar spray and soil systemic applications were compared for effectiveness in controlling beanflies on soybean. Three new insecticides, isofenphos, flucythrinate, and MK-936, were also included in this test.

Materials and Methods

Details of the experiment's methodology are described in the AVRDC publication "Vegetable Pest Control: Insecticide Evaluation Tests." In brief, nine insecticide treatments and one untreated check were included. Insecticide evaluation was carried out on 10 m^2 field plots each measuring 3.3 x 3 m. The crop was planted in two rows on the top of 1 m wide, 3.3 m long beds. Each insecticide was applied to four replicated plots arranged in a randomized complete block design.

Granular formulations of monocrotophos, dimethoate, and omethoate were prepared in the laboratory using Ottawa sand as a carrier base. These formulations were band applied by hand along the seeds at sowing time with the amount for each plot row having been previously weighed. Emulsifiable formulations were applied with ten 1 air pressure sprayers charged to 2.7 kg/cm^2 (40 psi) for each plot. Each sprayer was individually calibrated with a stopwatch so that specific volumes of spray could be accurately and uniformly delivered to each plot.

A 30-plant sample was taken from each plot five weeks after germination. Stems of each plant were cut open and the number of larvae and pupae found within each stem was recorded. The number of plants with beanfly damage was also recorded, as at times the larva died within the stem in an early instar, making it difficult to count insect numbers. At harvest the seed yield was recorded.

Results

The results are summarized in Table 1. Monocrotophos, dimethoate, and omethoate when sprayed on foliage gave good control of beanflies, but failed to give any beanfly control when applied to the soil as

systemics. MK-936, an antibiotic type insecticide applied as spray, also gave good control of beanflies.

Conclusions

Several reasons could account for the inefficacy of systemic applications. Perhaps the high soil pH (7.5) degrades organophosphate insecticides before sufficient quantity is absorbed by the roots; or these chemicals are not translocated readily within plants or are degraded quickly within plants; or possibly the chemicals are not effective in controlling larvae. The high efficacy of these chemicals against beanflies when sprayed on foliage seems to be due to their action on adult beanflies that visit soybean for feeding and oviposition.

Table 1. Evaluation of insecticides for the control of beanflies on soybean.[z-u]

Insecticides	Rate (kg ai/ha)	No. beanfly maggots +pupae per 30-plant sample	Damaged plants (%)	Plant height	Yield (t/ha)
Monocrotophos 2.5G	2	24.25 a	85.825 a	48.48 cd	1.89
Dimethoate 2.5G	2	21.50 a	82.525 a	50.48 bcd	1.89
Omethoate 2.5G	2	21.00 a	82.525 a	45.69 d	1.82
Isofenphos 50EC	0.5	14.50 b	60.825 b	56.99 a	2.04
Flucythrinate 30EC	0.05	18.25 ab	70.000 b	54.78 a	2.14
MK-936 0.36SL	0.02	0.75 c	2.500 d	55.40 a	1.89
Monocrotophos 55EC	0.5	2.00 c	10.000 d	52.36 abc	1.96
Dimethoate 44EC	0.5	4.50 c	25.850 c	54.88 a	2.11
Omethoate 50EC	0.5	0.75 c	4.175 d	56.06 a	2.01
Check		22.75 a	87.500 a	47.53 cd	1.98

[z] Cultivar: TK5.
[y] Planting date: 10/14/82.
[x] Insecticides sprayed: 10/22, 10/26, 10/29, 11/5, 11/11, and 11/19/82.
[w] Harvest date: 1/12/83.
[v] 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 according to Duncan's multiple range test.
[u] Plot size: 10 m^2.

Host Range of Beanfly Species on Common Legumes

Introduction

In 1975 beanfly infestation of commonly grown legumes was studied in order to determine what other crops are infested by these insects. At that time the AVRDC identification technique was still being perfected. During the intervening period one more species was found - *Ophiomyia centrosematis* - that infests soybean and mungbean. This insect morphologically resembles *O. phaseoli* and causes identical

damage. It is possible that some of the so-called O. phaseoli infestation in the earlier study was actually caused by O. centrosematis. The host range of each of the three species was therefore studied during 1980. A confirmation test was carried out in fall, 1982.

Materials and Methods

Seeds of 14 commonly grown legume crops were planted in the fall season when beanfly population is high, each as a single 5 m long row on the top of a 0.75 m wide raised bed. Each crop was planted in three plots arranged in a randomized block design. Plants were left exposed to infestation by the ambient beanfly population. When five weeks old, 20 to 30 plants in each plot were uprooted and their stems and the upper portion of their roots were dissected. The number of larvae and pupae of each beanfly species found inside was recorded.

Results

Test results are summarized in Table 2.

Table 2. Infestation of common legumes by various beanfly species.

Host plant	Scientific name	No. beanfly larvae+pupae/20 plants		
		Ophiomyia phaseoli	Ophiomyia centrosematis	Melanagromyza sojae
Adzuki bean	Phaseolus angularis	4.3	4.0	11.0
Alfalfa	Medicago sativa	0.7	0.7	9.0
Asparagus bean	Vigna sesquipedalis	0.0	0.0	1.8
Black gram	Vigna mungo	10.6	0.2	1.8
Cowpea	Vigna sinensis	7.7	0	0.5
Clover	Medicago denticulata	0	0.2	2.2
Garden pea	Pisum sativum	0	0.6	15.6
Lima bean	Phaseolus lunatus	14.4	10.3	0
Mungbean	Vigna radiata	15.6	1.2	0
Pigeon pea	Cajanus cajan	0	1.7	1.3
Rice bean	Phaseolus calcaratus	0	0	0.6
Snap bean	Phaseolus vulgaris	46.2	4.4	0.4
Soybean	Glycine max	2.2	8.0	28.0
Sunn Hemp	Crotalaria juncea	0	0	1.3

Chick pea (Cicer arietinum), centrosema (Centrosema pubescens), peanut (Arachis hypogaea), velvet bean (Mucuna nivea), winged bean (Psophocarpus tetragonolobus), and yam bean (Pachyrrhizus erosus) were not infested by any of the three species.

Conclusions

All three species have wide host ranges. Snap bean is the preferred host for O. phaseoli and soybean for M. sojae. O.

centrosematis is a minor pest in most crops. Although Centrosema pubescens is damaged rather heavily by O. centrosematis in Indonesia and Malaysia, at AVRDC no species was found to infest this crop. This could be due to low population pressure or the presence of a different biotype in Taiwan.

Beet Armyworm Resistance in Selected Soybean Accessions

Introduction

Three soybean accessions, PI 171451, PI 227687, and PI 229358, were reported to be resistant to two soybean foliage feeders, Mexican bean beetle (Epilachna varvivestis) (van Dyan et al. 1971. Crop Sci. 11:572-573; 1972. Crop Sci. 12:561-56) and Heliothis armigera, in the United States. Since beet armyworm, Spodoptera exigua, a polyphagous insect, has been causing increasingly serious damage to spring soybean in recent years, these accessions were tested for resistance to beet armyworm in the field. Laboratory tests were conducted on feeding preference, oviposition, and antibiosis to characterize the nature of the resistance.

As leaf structure plays an important role in defoliator damage in all crops, leaves of the resistant plants were examined as well. In soybean, unifoliolate leaves are the first to emerge after germination and their characters could give some idea about the characters of the leaves that emerge later. If some of the unifoliolate leaf characters could be linked to resistance in later stages, they might comprise a useful criterion for selection in the early growth stage. Emphasis was therefore placed on examining the morphological characters of unifoliolate leaves.

Materials and Methods

Resistance screening test: Four soybean accessions, PI 171451, PI 227687, PI 229358, and susceptible GC 30067-0-8, were planted in the field on February 9, 1982. The PI accessions were planted in alternate rows with the susceptible cultivar in 4 x 1 m plots replicated four times, and the crop was exposed to infestation by the ambient beet armyworm population. The insect damage was recorded by counting the damaged leaves and the total leaves from a randomly selected 1 m^2 area of each plot at 7, 10, 19, and 26 days after germination.

Feeding preference test: Leaves of each accession grown in the field were collected and two leaves of each accession were placed in a petri dish at equal distance from the midpoint. Seven third instar beet armyworm larvae were released at the center and the number of larvae feeding on the leaves of different accessions was recorded 0.5, 2, 4, and 24 hours later.

One potted plant each of PI 171451, PI 227687, and GC 30067-0-8, previously grown in a greenhouse for five weeks, were placed in a nylon net cage and 40 first and second instar beet armyworm larvae were released inside. The number of larvae feeding on each plant was recorded 5, 7, and 10 days later.

Oviposition preference study: One branch with nine leaflets was cut from a plant of each of the four accessions and placed in a flask containing water. The flasks were then placed in a nylon net cage and 15 female and seven male adult insects were released inside the cage. The cage was covered with black cloth. The number of egg masses per branch and number of eggs per egg mass were recorded 24 hours after insect release.

Antibiosis study: Two fresh leaves of each accession were confined in a 12 x 3 cm test tube, 20 tubes per accession. Two first instar beet armyworm larvae were released in each tube. The leaves were replaced at one- to three- day intervals. The number of dead larvae were recorded every day. After pupation, the female and male pupae were separated and weighed to judge their growth on each accession. After adult emergence, one pair raised on each accesson was released in a nylon net cage containing a potted plant of the susceptible accession. The number of larvae resulting from oviposition was recorded ten days after the insects were released.

Plant characterization: Various characters of leaves of each accession were studied at 25 and 48 days after germination. Measurements were made of the leaf area, leaf thickness, and number of trichomes on the upper and lower surfaces of unifoliolate leaves at 25 days and trifoliolate leaves at 48 days after germination. Thickness was measured at two points and trichomes were counted at four points of a 1 mm^2 area of each leaf surface. The moisture content of the leaves was determined by weighing 30 leaflets before and after drying.

Results

Resistance screening: The results of the resistance screening field test are summarized in Table 3. Up to seven days after emergence (DAE) there was no difference in leaf damage among the accessions but at ten DAE the PI entries were less damaged than the susceptible accession GC 30067-0-8. Apparently the characters responsible for resistance start developing at a certain period after germination. During later observations the PI accessions were significantly less damaged than the susceptible check.

Feeding preference study: In the feeding preference test, the susceptible check accession was significantly preferred over the PI entries (Table 4). The insects' nonpreference to PI entries was clear within four hours after initiation of infestation. After 24 hours there was no statistically significant difference, possibly because the leaves of susceptible entries were eaten up and the insects moved to other leaves. The leaves of PI 227687 appeared to be the least preferred, however.

Table 3. Leaf damage to various accessions due to beet armyworm.[z-v]

Accession	Damaged leaves (%)			
	7 DAE	10 DAE	19 DAE	26 DAE
PI 171451	0.25	1.25 a	12.5 ab	16.5 a
PI 227687	1.00	2.75 b	11.8 a	13.0 a
PI 229358	0.50	1.25 a	10.5 a	18.3 a
GC 30067-0-8	0.80	2.00 ab	18.0 b	55.3 b

z Planting date: February 9, 1982.
y Emergence: February 20, 1982.
x Plot size and replication: 5 m^2 (5 x 1 m), four replications.
w DAE: Days after emergence.
v Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 4. Feeding preference of beet armyworm on detached soybean leaflets.[z-w]

Accessions	% larvae feeding			
	0.5 HAI	2 HAI	4 HAI	24 HAI[v]
PI 171451	20 a	10 a	15 a	30
PI 227687	16 a	20 a	19 a	12
PI 229358	18 a	10 a	14 a	28
GC 30067-0-8	46 b	60 b	52 b	30

z Infestation: Seven third instar larvae/replication.
y Replication: Seven replicates/accession.
x HAI: Hours after infestation.
w Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
v No statistical difference.

Similar results were obtained when insects were released on potted plants (Table 5). In this test also, PI 227687 was the least preferred entry.

Table 5. Feeding perference of beet armyworm on potted soybean plants.[z-u]

Accessions	% larvae feeding		
	5 DAI	7 DAI	10 DAI
PI 171451	26.0 a	27.3 a	29.3 ab
PI 227687	14.7 a	16.3 a	24.2 a
GC 30067-0-8	59.3 b	56.4 b	46.5 b

[z] Infestation: 40 first to second instar larvae per three potted plants.
[y] Replications: Four.
[x] Growth stage: 36 days after emergence.
[w] DAI: Days after infestation.
[v] Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[u] Due to inadequate seed supply, PI 229358 was not included in this test.

Ovipositional preference test: Table 6 shows the results of the ovipositional preference test. The number of egg masses and number of eggs within egg masses were significantly lower on PI entries than on the susceptible check.

Ovipositional preference is an important mechanism in determining the resistance of plants to insect pests. Nonpreferred plants probably lack stimulants or contain certain repellents which make these plants less attractive to insect pests. With less oviposition, the quantity of insects and insect damage is accordingly low.

Antibiosis test: When beet armyworm larvae were reared on leaves of the four accessions, insects raised on PI 227687 and PI 229358 exhibited a higher mortality rate than those raised on the other two accessions (Figure 2). The three PI entries also limited the growth and development of beet armyworm compared to the susceptible check (Table 7). Insects feeding on PI 227687 suffered increased mortality at the final larval stage just before pupation. This mortality could be due to toxic properties or reduced nutritional qualities of the host plant leaves. PI 171451 did not show as strong an antibiosis effect on insect development as the other PI entries.

Table 6. Ovipositional preference of beet armyworm on soybean accessions.[z-w]

Accessions	No. of egg masses	Avg. no. of eggs/egg mass		Total no. of eggs
		Range	Mean	
PI 171451	1.5 a	5-49	16.0	45.3 a
PI 227687	4.0 ab	1-53	16.6	81.3 a
PI 229358	3.0 ab	4-43	14.4	60.3 a
GC 30067-0-8	7.8 b	8-106	31.0	250.3 b

[z] Infestation: 15 female and seven male adults per replication.
[y] Replications: Four.
[x] Egg laying time: 24 hours in a nylon net cage.
[w] Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

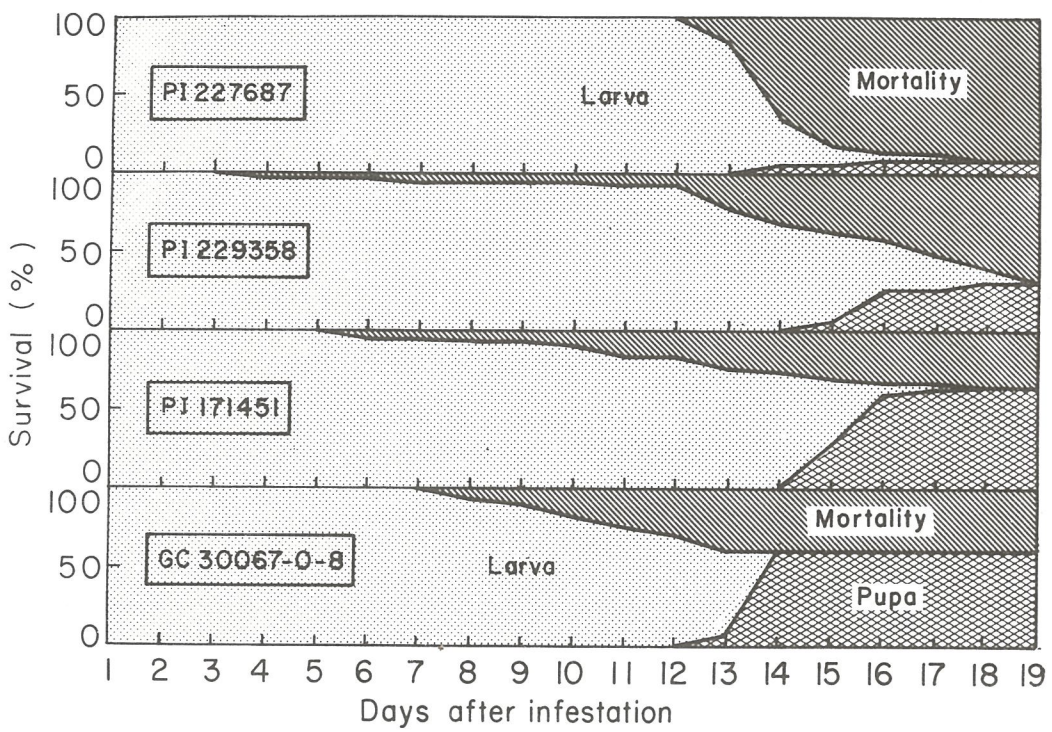


Figure 2. Development of beet armyworm on selected soybean accessions.

Pupal period was generally longer and pupal weight less when insects were fed on PI entries rather than on the susceptible check. Generally pupal period was longer and pupal weight greater in female than in male insects. Insects fed on PI 227687 and PI 171451 were less fecund as evidenced by their production of fewer second generation larvae than insects fed on the susceptible check cultivar produced.

Table 7. Development of beet armyworm on soybean accessions.[z-v]

Accessions	Larval period (days)	Pupal period (days)		Pupa weight (mg)		No. of larvae per pair
		female	male	female	male	
PI 171451	15.6 b	7.4 a	6.1 ab	72.2 a	71.8 a	153.3 a
PI 227687	14.7 c	7.0 ab	6.0 ab	71.6 a	67.8 a	134.4 a
PI 229358	16.2 a	6.8 ab	6.6 a	72.4 ab	70.4 a	293.5 b
GC 30067-0-8	13.9 c	6.6 b	5.4 b	80.5 b	79.6 b	290.7 b

[z] Infestation: two first instar larvae per replication in test tube.
[y] Replication: 20.
[x] Dead larvae were checked daily.
[w] Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[v] Oviposition and feeding on susceptible host plants in a greenhouse.

Plant characterization: Table 8 summarizes morphological characters of unifoliolate leaves. In general the leaves of PI entries were slightly thicker and significantly smaller than the leaves of GC 30067-0-8. On both leaf surfaces, the PI entries had significantly more trichomes than the susceptible check entry, GC 30067-0-8.

Table 8. Characterization of unifoliolate leaves of selected soybean accessions.[z-w]

Accessions	Thickness (mm)	Area (cm^2)	No. trichomes/mm^2	
			lower	upper
PI 171451	0.43 a	28.6 c	18.0 b	17.7 b
PI 227687	0.40 ab	14.0 d	21.7 a	20.2 a
PI 229358	0.42 ab	33.1 b	11.0 c	8.3 c
GC 30067-0-8	0.39 b	38.4 a	7.2 d	4.5 d

[z] Ten leaves of each accession.
[y] Thickness checked at two points per leaflet.
[x] Trichomes counted at four 1 mm^2 points per lower and upper surface of leaflet.
[w] Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Similar characteristics were observed when trifoliolate leaves were studied (Table 9). The leaves of PI entries were significantly thicker than those of GC 30067-0-8. Leaf area varied greatly, and as a result there was no significant difference in this parameter between resistant and susceptible accessions. Trichome density on leaves of PI 227687 was significantly higher than in other entries. There was no difference in leaf moisture content among the entries tested.

Table 9. Characterization of trifoliolate leaves of selected soybean accessions.[z-x]

Accessions	Leaflet thickness (mm)	Leaflet Area (cm^2)	No. trichomes/mm^2 lower	upper	Weight/30 leaflets (g) fresh	dry	moisture (%)
PI 171451	0.55 a	34.5	14.3 b	12.0 b	24.6	7.2	71
PI 227687	0.51 b	50.5	45.5 a	29.6 a	26.1	5.8	78
PI 229358	0.55 a	28.1	15.5 b	10.3 b	21.4	5.9	72
GC 30067-0-8	0.43 c	46.9	14.9 b	7.6 b	22.8	5.5	76

[z] Ten leaflets collected from the field experiment.
[y] Trichomes counted at four 1 mm^2 points per lower and upper surface of leaves.
[x] Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Among all leaf parameters, trichome density seems to be most important in the insect/host plant relationship. Greater trichome densities have been linked to insect resistance in tomato and other crops. Cursory observations indicated that insect larvae had difficulty moving on leaf surfaces with exceptionally high trichome densities.

Conclusions

The field study indicated that the three PI accessions PI 171451, PI 227687, and PI 229358 have moderate to high levels of resistance to beet armyworm. Laboratory studies indicated that the insect does not find these plants attractive to lay eggs or feed on. Certain antibiotic principles in the leaves of PI entries retard growth and cause increased mortality when beet armyworm larvae feed on them. Leaves of the PI accessions have greater trichome density than those of susceptible accessions.

PI 227687 in particular represents a good source of resistance to beet armyworm.

The Effect of Defoliation on Yield and Yield Components of Soybean

Introduction

In spring three prominent polyphagous defoliators, beet armyworm (*spodoptera exigua*) and scarabid green beetles (*Anomala cuprepis* and *A. expansa*) infest soybean in Taiwan. When soybean is planted during the last week of January and the first week of February, it is infested by beet armyworm during the V2 through R2 stages and by green beetle from

the R5 growth stage onwards. The pest damage can result in heavy defoliation. Knowledge of the relationship between a crop's insect damage and yield loss is important for insect pest management. To determine this relationship, plants can be artificially infested in cages or the pest population can be by altered by applying varying rates or kinds of insecticides. Both of these approaches are ineffective in showing true yield relationships, however, because of extraneous factors arising from the influence of cages on the physical environment, such as altered growth characteristics of the plant, modification of insect feeding, and physiological changes in the plant. Therefore another popular method, simulation of insect damage by artificial defoliation, was employed to quantify the relationship between insect feeding and yield loss.

Materials and Methods

The same experiment was conducted in spring 1980 (preliminary), 1981, and 1982. Soybean cultivar GC 30067-0-8 was planted as a single row on the top of 5 m long and 0.75 m wide beds. Two weeks after germination the crop was thinned to equalize the number of plants per plot. The crop was raised by traditional cultural practices including application of insecticides and fungicides at regular intervals to minimize damage by polyphagous insects, as such damage would interfere with the effects of intentional defoliation.

Starting 20 days after germination and once every ten days thereafter, plants were defoliated until 90 days after germination. Individual plot treatments with replications included 10, 25, and 50% defoliations. At each defoliation the phenological growth stage of the plants was recorded. At each interval, in each plot the number of leaflets per plant was counted and the desired number was removed by hand along the entire plant. In cases where a portion of an individual leaflet was to be cut, the desired amount of leaf area was cut from the distal end of a randomly selected leaflet. At harvest all plants in each plot were uprooted and the following data were recorded: plant height, number of branches/plant, pods/plant, and seeds/pod, weight of 100 seeds, total yield, and fat content of seeds.

Results

Results of the 1981 experiment are summarized in Table 10. The results of the 1982 experiment were practically identical.

Table 10. Effects of varying levels of defoliation at various growth stages on soybean yield and yield components.[z-v]

Defoliation %	Single defoliation					Two consecutive defoliations					Three or more consecutive defoliations				
	Growth stage	No. pods per plant	No. seeds per pod	100 seed weight (g)	Yield (kg/plot)	Growth stage	No. pods per plant	No. seeds per pod	100 seed weight (g)	Yield (kg/plot)	Growth stage	No. pods per plant	No. seeds per pod	100 seed weight (g)	Yield (kg/plot)
10	V2	26.2 a-g	2.40 b-e	19.67 a-e	1.249 a-b	V2+V4	22.4 b-k	2.35 c-f	19.50 a-f	1.192 a-e	V2+V4+R2	24.1 b-j	2.43 b-d	18.50 a-k	0.989 a-l
25		22.9 b-k	2.26 c-g	19.17 a-h	1.054 a-i		21.7 c-k	2.32 c-g	19.67 a-e	0.898 d-n		19.8 d-k	2.34 c-g	19.33 a-g	0.855 g-n
50		25.0 a-i	2.33 c-g	19.33 a-g	1.035 a-j		20.0 d-k	2.34 c-g	20.17 ab	1.025 a-j		18.7 f-k	2.33 c-g	18.67 a-j	0.759 i-o
10	V4	23.7 b-j	2.38 b-f	19.17 a-h	1.022 a-j	V4+R2	21.9 c-k	2.41 b-e	19.33 a-g	1.049 a-i	V4+R2+R3	23.8 b-j	2.40 b-e	18.33 a-l	0.994 a-m
25		25.6 a-h	2.41 b-e	19.83 a-d	1.134 a-g		32.3 a	2.09 gh	19.17 a-h	1.149 a-g		18.9 jk	2.36 c-f	17.33 e-o	0.788 h-n
50		20.9 c-k	2.30 c-g	19.17 a-h	1.062 a-i		22.6 b-k	2.37 c-f	19.17 a-h	1.046 a-i		17.7 i-k	2.44 b-d	17.33 e-o	0.686 m-o
10	R2	22.0 c-k	2.36 c-f	19.67 a-e	1.067 a-h	R2+R3	23.5 b-j	2.39 b-f	19.33 a-g	1.169 a-f	R2+R3+R4	19.6 d-k	2.43 b-d	17.50 d-o	0.801 h-n
25		21.8 c-k	2.35 c-g	20.17 a-b	1.123 a-g		18.7 f-k	2.49 bc	18.33 a-l	0.789 h-n		24.5 b-j	2.27 c-g	16.83 h-q	0.695 l-o
50		23.5 b-j	2.34 c-g	18.50 a-k	0.929 c-m		18.0 h-k	2.39 b-f	16.43 j-r	0.732 j-o		17.6 i-k	2.13 f-h	15.00 p-t	0.496 o-q
10	R3	21.6 c-k	2.46 b-c	18.50 a-k	1.024 a-j	R3+R4	23.0 b-j	2.37 c-f	17.83 b-h	0.803 h-n	R3+R4+R5	20.0 d-k	2.38 b-f	16.00 l-r	0.855 g-n
25		25.3 a-i	2.40 b-e	18.83 a-i	0.988 a-m		21.9 c-k	2.24 c-h	16.50 i-r	0.887 e-n		18.5 g-k	2.33 c-g	15.67 m-s	0.498 o-q
50		22.4 b-k	2.31 c-g	17.17 f-p	0.882 f-n		19.5 d-k	2.00 h	13.67 s-u	0.402 pq		20.1 d-k	2.15 e-h	14.33 r-t	0.490 o-q
10	R4	24.1 b-j	2.36 c-f	18.83 a-i	1.040 a-i	R4+R5	26.0 a-g	2.32 c-g	17.67 c-o	1.061 a-i	R4+R5+R6	22.5 b-k	2.39 b-f	16.83 h-q	0.926 c-m
25		24.0 b-j	2.33 c-g	17.50 d-o	0.976 a-m		27.1 a-d	2.32 c-g	18.50 a-k	0.952 b-m		19.4 e-k	2.37 c-f	14.67 q-t	0.621 n-p
50		23.3 b-j	2.25 c-g	17.00 g-p	0.885 f-n		22.4 b-k	2.18 d-h	14.50 r-t	0.627 n-p		26.3 a-f	2.30 c-g	14.67 q-t	0.710 k-o
10	R5	25.0 a-i	2.35 c-g	18.50 a-k	1.037 a-i	R5+R6	22.0 c-k	2.34 c-g	17.67 c-o	0.926 c-m	R5+R6+R7	25.9 a-g	2.72 a	17.83 b-n	1.259 a
25		24.5 b-j	2.35 c-g	16.83 h-q	0.984 a-m		24.3 b-j	2.37 c-f	15.33 o-s	1.011 a-k		22.2 b-k	2.43 b-d	15.83 m-s	0.900 d-n
50		26.7 a-e	2.31 c-g	16.33 j-r	0.715 k-o		19.7 d-k	2.42 b-e	15.33 o-s	0.794 h-n		29.9 ab	2.13 f-h	15.50 n-s	0.846 g-n
10	R6	25.2 a-i	2.32 c-g	19.00 a-h	1.010 a-k	R6+R7	24.4 b-j	2.34 c-g	18.83 a-i	0.962 a-m	V2 to R7	20.7 d-k	2.36 c-f	16.17 k-r	0.716 k-o
25		24.8 b-i	2.41 b-e	18.00 b-m	1.088 a-h		25.7 a-h	2.35 c-f	17.67 c-o	1.224 a-c		18.7 f-k	2.38 c-g	12.83 t-u	0.486 o-q
50		24.7 b-i	2.32 c-g	18.50 a-k	0.982 a-m		26.8 a-e	2.29 c-g	17.67 c-o	1.085 a-h		15.3 k	2.01 h	11.97 u	0.301 q
10	R7	22.7 b-k	2.39 b-f	19.17 a-h	1.152 a-g										
25		28.5 a-c	1.47 b-c	19.17 a-h	1.201 a-d										
50		25.2 a-i	2.40 b-e	20.50 a	1.182 a-f										
Check		26.7 a-e	2.64 a-b	20.00 a-c	1.200 a-d										

[z] Cultivar: GC 30067-0-8.
[y] Planting date: January 29, 1981.
[x] Harvest date: May 7, 1981.
[w] Plot size: 5 x 1 m.
[v] The data are means of three replicates. Means in each vertical column followed by the same letters are not significantly different at 5% according to Duncan's multiple range tests.

Single defoliation: A single 50% defoliation reduced seed yield significantly over the nondefoliated control at the R3, R4, and R5 stages. Yield reduction was greater at R5 than at the two earlier stages. The reduction was due mainly to reduction in seed size in all three cases. A single defoliation at other growth stages did not have any statistically significant effect on yield.

Defoliation at two consecutive stages: Defoliation at the R2+R3 stages at the rates of both 25 and 50%, defoliations of 10, 25, and 50% at stages R3+R4, and of 50% at the R4+R5 and R5+R6 stages reduced soybean seed yields significantly over the nondefoliated control plots. In addition to reduction in seed size, reduction in the number of pods/plant, especially at the 50% defoliation rate, was a principle cause for the yield reduction. The reduction in pod number was especially striking when plants were defoliated at the early reproductive (R2+R3) stages.

Defoliation at three or more consecutive stages: A 50% defoliation at any three consecutive growth stages reduced soybean yields significantly over the nondefoliated control. A 25% defoliation at three consecutive stages also reduced yield significantly over the nondefoliated control except at the R5+R6+R7 stages. A 10% defoliation reduced yield significantly only when this treatment was performed at the R2+R3+R4 and the R3+R4+R5 stages. When defoliation was performed in the early stages such as V2+V4+R2, the yield reduction appeared to be due to reduction in the number of pods/plant and seeds/pod, but in later stages the yield loss was due to reduction in all three yield components, with reduction in 100 seed weight being consistently severe. When plants were consecutively defoliated at all growth stages by 10, 25, or 50%, yield was reduced significantly over the nondefoliated control.

Plant height was not reduced by single defoliation at any stage but was significantly reduced by 25 and 50% defoliation at two or three consecutive early growth stages, V2 through R2. Although certain treatments reduced the number of branches/plant and percent seed lipid content, there was no clear-cut trend in the influence of defoliation on these two plant parameters.

Conclusions

Reproductive stages R2 through R5 are especially sensitive to yield

loss induced by defoliation. A single defoliation of up to 25% at any stage does not reduce yield significantly but a 50% single defoliation or lower rates of defoliation at two or more consecutive reproductive growth stages reduces soybean seed yield significantly.

Chemical Control of Beet Armyworm on Soybean

Introduction

Beet armyworm, Spodoptera exigua, is a polyphagous pest that is becoming an increasingly serious problem on spring soybean in Taiwan. In addition to studies on host plant resistance and the relationship of insect infestation to yield loss, routine insecticide screenings are also conducted to find chemicals or chemical mixtures that will give effective and economical control of this pest. A screening was conducted in spring, 1982.

Materials and Methods

Seeds of soybean breeding line GC 30067-0-8 were sown in 10 m^2 plots with three 1 x 3.3 m beds per plot and two rows per bed.

The crop was raised by traditional cultural practices, excluding the use of designated insecticides.

The insecticides screened were decamethrin 2.8EC, Bacillus thuringiensis, malathion 57EC, BPMC 50EC, MIPC 50WP, and Larvin 75WP. Insecticides were applied either singly or in mixtures according to the same procedures described for beanfly control.

For efficacy evaluation, the number of beet armyworm larvae per square meter at the center of each bed was counted after the first and second insecticide treatments and the number of insect damaged plants was recorded from the same area. Plants were also observed for possible phytotoxicity after each spraying.

Results

The results of the insecticide efficacy evaluation are summarized in Table 11. Decamethrin or decamethrin in combination with Bacillus thuringiensis gave the best control of beet armyworm. B. thuringiensis alone did not give adequate control of the insect and there was no synergism resulting from the combination of the insecticide and the bacteria. Larvin also gave significantly better control than other insecticides. The leaf damage observed was correlated to insect count data. The less the insect population, the less the leaf damage.

Table 11. Evaluation of insecticides for beet armyworm control on soybean.[z-t]

Insecticides	Rate (kg ai/ha)	No. insects/m^2 3/8/82	No. insects/m^2 3/16/82	Damaged leaflets (%) 3/14/82	Damaged leaflets (%) 3/23/82	Damaged leaflets (%) 4/1/82
Decamethrin 2.8EC	0.0125	4.0 ab	0.3 a	2.7 ab	2.7 a	0.4 ab
Bacillus thuringiensis (Bt)	0.5	13.8 abc	3.3 ab	22.2 f	24.4 c	8.7 c
Decamethrin 2.8EC+Bt	0.0125+0.5	2.0 a	0.0 a	1.7 a	1.9 a	0.3 a
Larvin 75WP	0.5	6.3 ab	1.3 a	5.6 abc	3.9 a	1.3 a
Malathion 57EC	1.0	15.8 bc	1.8 a	8.0 abcd	13.8 b	4.4 b
BPMC 50EC	0.8	6.0 ab	5.3 ab	17.5 ef	24.2 c	10.0 c
MIPC 50WP	0.8	7.8 ab	2.0 a	13.9 de	14.1 b	7.8 c
Malathion 57EC+BPMC 50EC	0.5+0.4	7.5 ab	1.0 a	9.5 bcd	14.6 b	2.9 ab
Malathion 57EC+BPMC 50WP	0.5+0.4	9.5 ab	3.5 ab	12.0 cde	15.3 b	4.5 c
Control	-	21.3 c	12.0 b	29.0 g	34.6 d	12.6 d

[z] Cultivar: AVRDC breeding line GC 30067-0-8.
[y] Planting date: February 9, 1982.
[x] Insecticides sprayed March 3, 10, 17, and 24, 1982.
[w] Sampling: Number of insects per 1 m^2 and % damaged leaves.
[v] Data are means of four replicates.
[u] Means in each column followed by the same letter are not significantly different at the 5% level.
[t] Plot size: 10 m^2.

Conclusions

Decamethrin 2.8EC sprayed at the rate of 12.5 g ai/ha once a week during the period of beet armyworm infestation gives satisfactory control of the pest.

Resistance to Lima-Bean Pod Borer in Soybean

Introduction

Lima-bean pod borer (Etiella zinckenella) is one of the most destructive pests of soybean in tropical and subtropical Asia. In 1980, seven soybean accessions were identified with moderate to high levels of resistance to this pest. In 1981 the resistance of these accessions was confirmed. But when these accessions were tested in Indonesia, all of them sustained considerable pod borer damage. Further AVRDC studies indicated that infestation is negatively correlated to days to flowering and maturity. Late maturing accessions had less damage than early maturing ones. At the Center, the population of pod borer caterpillars was observed to be high in October whereas the resistant accessions, when planted in mid to late September, mature in December. They probably escape pod borer infestation as a result. Escape as a resistance mechanism, although useful, is highly location specific. Additional soybean accessions were therefore screened in late 1981 and again in fall, 1982 to identify additional sources of resistance.

Materials and Methods

In the preliminary screening, seeds of each of 2,120 soybean accessions were planted in 2 m long single rows on 0.75 m wide raised beds. The crop was raised using traditional cultural practices except that no insecticide was applied. The crop was exposed to the ambient insect population. At harvest the damaged and healthy pods were counted and percent damage was determined.

In the second screening the 95 least damaged accessions from the preliminary screening, along with seven resistant and three susceptible entries from 1980 experiments, were tested in fall, 1982 at three locations in Taiwan: Hualien (planted August 23), AVRDC (planted September 9), and Pingtung (planted September 23). Each accession was planted as a single 5 m long row on a 0.75 m wide bed. All entries were planted in duplicated plots. At Hualien and Pingtung, accessions were exposed to infestation by the ambient pod border population, whereas at AVRDC laboratory-reared lima-bean pod borer pupae were released once every week for six weeks starting in mid-October. At harvest the pod damage was determined by counting the damaged and healthy pods.

The accessions were categorized with various resistance ratings by the same procedure that was utilized in beanfly resistance screening.

Results

In the preliminary screening a large number of accessions had very little damage, and 95 accessions which had high yield and no pod borer damage were selected. In the second screening the pod borer damage at Hualien and Pingtung was very low, 4.47% and 2.91% respectively, compared to 10.05% at AVRDC. Therefore, only AVRDC data was utilized for evaluation.

Of 101 accessions that could be evaluated, one accession showed high resistance, 20 were moderately resistant, 31 had low resistance, 44 were susceptible, and five were highly susceptible. Six of the seven standard resistant accessions were found moderately resistant and one fell in the low resistance category. Most of the moderately resistant accessions were late maturing.

Conclusions

As in 1981, most resistant accessions were found to be late maturing. It is possible that these accessions escape damage because the pod borer population peaks before the plants reach the pod-filling

and maturity stages. Resistant accessions must therefore be screened in more tropical locations where the pod borer population is relatively uniform and high throughout the season.

In 1983 the oviposition and the nature of damage by this pest will be investigated to determine the ideal planting time for exposing plants to maximum infestation. The resistance screening experiment will be planted in mid-summer and laboratory-reared pod borers will be released until harvest time.

Development of an Artificial Diet for Mass Rearing of Lima-Bean Pod Borer

Introduction

High insect population pressure is an essential requirement for host plant resistance screening research. In Taiwan the lima-bean pod borer infests soybean late in the fall season. Population pressure, however, is not high. In mid-1981, therefore, research aimed at developing an artificial diet for this insect was initiated in order to mass rear pod borer to release in the field for resistance screening work.

Materials and Methods

Pod borer lays eggs on soybean pods and the freshly hatched larva bores through the pod cover and feeds on the developing seeds. Since the larvae first feed on pod covers and then on seeds, dry pod cover and soybean meal are the major ingredients of their diet. Dozens of different diets based on these two main ingredients were tested, each with slight modifications to improve the diet over its predecessor. The major criteria for better diet were: Briefness of larval and pupal periods, low mortality of larvae and pupae, and fecundity of adult insects. Insects were collected from the AVRDC field and reared first on pods and later on the diet. Insects were reared at 30^{o}C and 80±5% RH.

Results

After dozens of diets with various combinations were screened, an effective artificial diet was obtained; its composition is described in Table 12. Insect larvae are now successfully reared on this diet.

Table 12. Composition of artificial diet for mass rearing lima-bean pod borer.

Ingredients	Quantities
A. Water	4000 ml
Agar	100 g
B. Water	2500 ml
Soybean meal (defatted)	850 g
Soybean pod cover, dry, R3 stage	100 g
Choline chloride	20 g
Sorbic acid	5 g
Vanderzant vitamin mixture	150 ml
Wesson salt	70 g
Linseed oil	20.6 g
Methyl parabenzoic acid	15 g
Propionic acid	60 ml
Aureomycin	1 g
KOH, 4N	175 ml

A. dissolve agar in water and boil to obtain clear liquid. Cool to 60°C. Blend ingredients of B together and add to A. Blend A and B thoroughly.

Conclusions

An artificial diet based on soybean meal was developed to mass rear lima-bean pod borer in the laboratory. The development period, natural mortality, fecundity, and percent egg hatch of insects reared on the artificial diet are comparable to those of insects raised on soybean plants as reported in the literature. Lima-bean pod borer has now been reared continuously on the diet for over six generations. Modifications are still being made, however, to reduce the period for larval development and to increase fecundity.

Confirmation of Stinkbug Resistance in PI 227687

Introduction

Three stinkbug species, Nezara viridula, Piezodorus hybneri, and Riptortus clavatus, are important pests of soybean and other legumes in Asia. All three species occur in Taiwan mainly in the summer and their population is low. Therefore, in the past no host plant resistance screening work had been done. Recently, however, several researchers found that one soybean accession, PI 227687, was resistant to Nezara viridula. Preliminary field, greenhouse, and laboratory tests were

therefore conducted to study whether this accession is resistant to all three species under AVRDC conditions.

Materials and Methods

Field tests: All tests were done during the summer when stinkbug is prevalent in Taiwan. Seeds of resistant (PI 227687) and susceptible (GC 30067-0-8) accessions were planted in two parallel rows on 1 x 2 m beds. Since PI 227687 is highly photoperiod sensitive and grows vegetatively for a long time when the photoperiod is longer than 12 hours, plants of both accessions were covered with black cloth-lined cages every day from 5 PM to 6 AM until flowering. Under this treatment both accessions flowered at practically the same time. Soon after flowering the photoperiod treatment was discontinued. When the plants were in the R3 stage they were covered with nylon screen cages as follows. In a free choice test two adjacent plots, one planted with the resistant and the other with the susceptible accession, were covered by one 2 x 2 m cage. In a no choice test, plots planted with resistant and susceptible accessions were covered separately. Stinkbugs were then released inside the cages, one species per cage, and at harvest the stylet sheaths on the pod covers and the stinkbug-damaged seeds were counted.

Greenhouse test: Potted plants of PI 227687 and GC 30067-0-8 at the R5 growth stage were covered with a plastic container and ten first instar nymphs were introduced in each. Two weeks later the number of nymphs and adults and their mortality rates were recorded.

Laboratory test: R6 stage green pods of PI 227687 and GC 30067-0-8 were collected from the field and two first instar nymphs were confined on one pod in a petri dish. The pods were replaced periodically with freshly harvested ones. Stylet sheath marks on each replaced pod and number of moults of each insect species were recorded. The experiment was continued until nymphs feeding on the pods of the susceptible entry reached the adult stage.

Results

Field tests: Results of the field tests are summarized in Table 13. Pods of PI 227687 had considerably fewer stylet sheaths, representing less insect feeding activity, than pods of GC 30067-0-8 in both the free choice and no choice tests.

Seeds of PI 227687 were damaged less than the susceptible variety only when the plants were exposed to Nezara or Piezodorus. Riptortus

caused equal damage to the seeds of both accessions. The stylet sheath count and actual seed damage observations were not in agreement because at times an insect made several probings on one seed and very few on another. Both seeds are counted as damaged but the first had considerably greater number of stylet sheaths than the latter.

Table 13. Infestation and survival of three stinkbug species on resistant and susceptible soybean accessions.[z]

Stinkbug species	Accessions	Stylet sheaths per pod	Damaged seeds (%)	No. insects released	No. insects per cage at harvest
Resistant and susceptible planted together in a cage[w]					
Nezara viridula	PI 227687[y]	12.29	7.99	54	105
	GC 30067-0-8[x]	19.71	14.56		
Piezodorus hybneri	PI 227687	2.96	5.25	29	139
	GC 30067-0-8	30.03	27.50		
Riptortus clavatus	PI 227687	0.50	8.31	82	5.5
	GC 30067-0-8	2.47	4.51		
Resistant and susceptible planted in separate cages[v]					
Nezara viridula	PI 227687	4.07	u	32	11.0
	GC 30067-0-8	6.22	39.4	32	25.5
Piezodorus hybneri	PI 227687	1.36	14.9	15	0.0
	GC 30067-0-8	8.97	37.8	15	141.5
Riptortus clavatus	PI 227687	3.00	8.3	37	0.5
	GC 30067-0-8	6.68	7.4	37	7.5

[z] Two cages per treatment.
[y] Resistant and [x] Susceptible accession.
[w] Cage size: 2 x 2 m and [v] 2 x 1 m.
[u] Very few seeds.

Greenhouse test: The results of the greenhouse test are summarized in Table 14. None of the insect species survived on PI 227687. They died during the nymphal stage, whereas most insects reared on GC 30067-0-8 survived and became adults.

Laboratory test: The results of the laboratory test are shown in Table 15. The stylet sheath count showed that insects fed more on the pods of GC 30067-0-8 than on the pods of PI 227687. Nymphs confined on the pods of GC 30067-0-8 developed normally into adults whereas those confined on pods of PI 227687 either remained in the fourth instar when the experiment was discontinued or, in the case of P. hybneri, developed into abnormal adults.

Conclusions

The preliminary experiments indicate that PI 227687 has a certain level of resistance in the field at least to Nezara and Piezodorus. Riptortus is a very active insect, and with slight disturbance it jumps

great distances. Confining this insect in small cages affects its behavior, and it was frequently observed on the walls of the nylon net cages trying to get out. The free choice experiment showed that despite the availability of the susceptible cultivar, most Riptortus died while the populations of Nezara and Piezodorus increased. Small cages, therefore, are not suitable for screening soybean for resistance to Riptortus.

PI 227687 will be studied in greater detail using bigger cages in the field. This accession is also being field tested in Indonesia where stinkbug, especially Riptortus, population pressure is considerably higher than in Taiwan.

Table 14. Growth and survival of three stinkbug species on resistant and susceptible soybean plants. Greenhouse experiment.[z,y]

Stinkbug species	Accession	Survival (%)	Final growth stage
Nezara viridula	PI 227687[x]	0	4th instar nymph
	GC 30067-0-8[w]	60	Adult
Piezodorus hybneri	PI 227687	0	2nd instar nymph
	GC 30067-0-8	50	Adult
Riptortus clavatus	PI 227687	0	3nd instar nymph
	GC 30067-0-8	40	Adult

[z] R6 stage plants, three potted plants per treatment.
[y] Ten first instar nymphs released on caged plants.
[x] Resistant accession.
[w] Susceptible accession.

Table 15. Growth and survival of three stinkbug species on pods of resistant and susceptible soybean accessions. Laboratory experiment.[z]

Stinkbug species	Accession	Style sheaths on pods in nymphal stage	Final growth stage
Nezara viridula	PI 227687[y]	39.5	4th instar nymph
	GC 30067-0-8[x]	135.0	Adult
Piezodorus hybneri	PI 227687	74.0	Adult[w]
	GC 30067-0-8	155.0	Adult
Riptortus clavatus	PI 227687	21.0	4th instar nymph
	GC 30067-0-8	99.0	Adult

[z] Two first instar nymphs released per pod. Fresh pods were changed periodically and the number of stylet sheaths on replaced pods were recorded.
[y] Resistant accession.
[x] Susceptible accession.
[w] Abnormal.

Soybean Physiology

Effect of Weathering on Maturing Soybean and Mungbean Seeds

Introduction

In the humid tropics, soybean and mungbean are quite often grown during the hot season when their seed maturation is subjected to high temperature and humidity. This experiment examined the extent of seed weathering effects for both crops, and investigated varietal differences in response.

Materials and Methods

Soybeans (G 8285 and AGS 66) and mungbeans (V 2773, V 3476, and VC 1562 A) were sown in the field. A split plot design with four replicates was employed. When soybean reached the R6 stage (June 14), and at mungbean's first flush of full size pods (May 27), they were sprinkled with about 37 mm of water for two hours every afternoon. After pods were mature, they were harvested and dried to 13% moisture content. To examine germination, 100 seeds from each replicate were rolled in paper towels, incubated at 25°C, and counted daily. Seeds without water uptake were considered hard seeds. The experiment was repeated in the fall, with weathering treatments beginning on October 20 for soybean and September 14 for mungbean. The same varieties were tested, with the addition of soybeans G 2120 and G 8707.

An *in vitro* seed weathering test was also conducted. Soybean pods at the R7 stage and mungbean pods at the beginning of darkening were harvested from the field and incubated at 30°C to dry to 13% moisture content. In another treatment, pods were placed in beakers at 30°C with controlled relative humidity at 80% for four days before air drying at 30°C in an incubator.

Results

Field weathering with excess artificial rain did not further reduce germination percentage (GP) and germination rate index (GRI) of soybean. However, both GP and GRI of the three mungbean varieties were reduced by

further seed weathering with artificial rain. Furthermore, both GP and GRI in soybean were lower than in mungbean (Table 1). When the field experiment was repeated, however, neither GP nor GRI of the three mungbean varieties were significantly affected by seed weathering (Table 2). In the second experiment on soybean, both G 8285 and AGS 66 were affected by field weathering. Besides low natural rainfall, the temperature in the second field experiment of soybean was lower than in the first experiment (Table 3). This may account for the high GP and GRI among control groups of soybean and mungbean in the second experiment.

Table 1. Effect of field weathering on germination, germination rate index, and hard seed of soybean and mungbean.

Entry	Germination (%)			Germination rate index			Hard seed (%)		
	Control	Weather	t-value	Control	Weather	t-value	Control	Weather	t-value
Soybean									
G 8285	43	42	0.05	6.5	6.0	0.26	-	-	-
AGS 66	56	57	0.03	12.4	11.9	0.27	-	-	-
Mungbean									
V 2773	65	44	4.28*[z]	18.8	11.6	4.67*	21	27	1.18
V 3476	89	72	3.59*	25.1	20.0	3.18*	5	14	6.63**
VC 1562 A	89	79	2.96+	23.5	19.9	1.68	2	3	0.34

[z] +,*,**: Significant difference between control and weathering at 10, 5, and 1% levels.

Table 2. Effect of field weathering on germination, germination rate index, and hard seed of soybean and mungbean.

Entry	Germination (%)			Germination rate index			Hard seed (%)		
	Control	Weather	t-value	Control	Weather	t-value	Control	Weather	t-value
Soybean									
G 2120	96	98	1.38	15.6	15.8	0.74	-	-	-
G 8707	95	91	1.67	15.3	14.1	2.24	-	-	-
G 8285	95	79	2.48+[z]	13.5	11.6	1.67	-	-	-
AGS 66	94	83	3.23*	16.1	13.9	3.50*	-	-	-
Mungbean									
V 2773	59	65	-	15.9	16.7	-	38	33	-
V 3476	95	98	-	26.9	27.7	-	4	2	-
VC 1562 A	93	88	-	22.2	20.2	-	7	9	-

[z] +,*: Significant difference between control and weathering at 10 and 5% levels.

On the contrary, in vitro seed weathering at 30°C and 80% relative humidity substantially reduced GP and GRI of soybean and mungbean. Seeds of G 8285, G 8707, and AGS 66 were readily affected by in vitro

seed weathering; however, G 2120 stood up well under these conditions. Germination of VC 1562 A was almost completely inhibited by *in vitro* seed weathering. However, 30°C with dry conditions also tended to impose seed hardening in mungbean (see Table 4).

Table 3. Days of field weathering[z], mean maximum and minimum temperature (°C), and total natural rainfall (mm) in two field weathering experiments.

	Soybean		Mungbean	
	1st exp.	2nd exp.	1st exp.	2nd exp.
Days of field weathering	36	26	15	20
Maximum temperature (°C)	32	30	29	32
Minimum temperature (°C)	25	20	23	24
Natural rainfall (mm)	428	19	333	0

[z] The beginning of field weathering for soybean and mungbean was June 14 and May 27 respectively in the first experiment, and October 20 and September 14 in the second experiment.

Table 4. Effect of *in vitro* seed weathering on germination, germination rate, and hard seed of soybean and mungbean.

Entry	Germination (%)			Germination rate index			Hard seed (%)		
	Control	Weather	t-value	Control	Weather	t-value	Control	Weather	t-value
Soybean									
G 2120	75	71	1.20	10.1	9.7	0.63	-	-	-
G 8707	77	56	3.97*[z]	9.5	6.6	3.04+	-	-	-
G 8285	55	33	3.32+	6.8	4.3	3.05+	-	-	-
AGS 66	79	52	4.74*	11.6	7.0	6.03**	-	-	-
Mungbean									
V 2773	30	52	1.62	6.1	10.5	1.73	69	1	11.25**
V 3476	86	61	3.56*	20.6	11.4	4.09*	14	0	10.15**
VC 1562 A	97	8	19.80**	22.6	1.7	19.56**	2	0	2.18

[z] +,*,**: Significant difference between control and weathering at 10, 5, and 1% levels.

Conclusions

High temperature and high humidity during maturation cause seed weathering. The sensitivity of seeds to weathering also depends on the variety. For soybean, small seeded G 2120 withstood weathering comparatively well; however, AGS 66 appeared to be sensitive. The three mungbean varieties behaved differently between field and *in vitro* seed weathering tests. Field weathering in the hot, wet summer reduced germination and vigor of VC 1562 A, V 2773, and V 3476, while *in vitro* weathering inhibited germination of VC 1562 A completely. Hot dry conditions tended to impose seed hardness in V 2773. The laboratory method can be used to assay varietal differences in response to seed weathering.

Effect of Storage Conditions on Germination and Vigor of Soybean

Introduction

The viability of soybean seeds is easily affected by storage conditions in the humid tropics. The effect of seed moisture contents and temperature conditions on seed vigor of four soybean varieties was examined.

Materials and Methods

Seeds of G 2120, G 8285, G 8707, and AGS 66 were tested. All treatments used six-month-old seeds of the same lot. Initial seed moisture content was adjusted to 8, 13 and 18%, and seeds were then placed in vials and sealed. Each moisture content was replicated three times. Germination and respiration measurements were taken before storing in incubators at 10, 20, 30, and 40°C. Samples of each replicate at each temperature and moisture content were taken at 1, 2, and 3 months; and respiration rate, percent germination, and germination rate were measured.

Respiration rate was measured with a Gilson respirometer with five seeds after four hours of imbibition. For the germination test 40 seeds from each replicate were rolled in paper towels, incubated at 25°C, and counted daily.

Results

Germination and germination rate index (GRI) decreased in the four entries regardless of temperature and moisture content when the seeds were stored for one month or more. Germination of G 8285 and AGS 66 decreased more than 50% in one month (Table 5). G 2120 and G 8707 withstood storage conditions better; G 2120 maintained 53% germination at three months. Respiration rate (RR) decreased more in G 8285 and AGS 66 than in G 2120 and G 8707. Increasing the moisture content decreased the germination and GRI of G 2120, G 8707, and G 8285 (Table 6). At 8% moisture, AGS 66 had the lowest germination, GRI, and RR, and increased moisture content did not further decrease these parameters. Germination and GRI of all four entries were reduced by storage at 20°C or higher (Table 7). At 10°C AGS 66 had the lowest values for the three parameters, and 30 and 40°C stopped germination completely. Increasing temperature had the least effect on G 2120 and G 8707 in decreasing the three parameters.

Table 5. Main effects of storage time on viability and vigor of soybean seeds.[z]

Entry	Time (month)	Germination (%)	Germination rate index[y]	Respiration (CO_2 mg/seed/hr)
G 2120	0	96 a[x]	15.7 a	16.6 a
	1	62 b	9.3 b	15.9 a
	2	59 b	8.0 c	14.3 b
	3	53 c	7.5 c	11.8 c
G 8285	0	95 a	15.2 a	48.9 a
	1	37 b	5.2 b	36.1 b
	2	36 b	4.4 c	30.6 c
	3	30 c	3.7 d	25.7 d
G 8707	0	99 a	16.3 a	26.7 a
	1	56 b	8.4 b	25.4 a
	2	55 b	7.6 c	23.3 ab
	3	51 c	6.8 c	22.4 b
AGS 66	0	81 a	13.3 a	24.4 a
	1	13 b	2.0 b	19.2 b
	2	9 c	1.0 c	10.7 c
	3	0 d	0 d	0 d

[z] Data averaged over all storage temperatures and moisture contents.

[y] Germination rate index = $\Sigma\left(\frac{\text{\% of normal seedlings per day}}{\text{Days to counting}}\right)$.

[x] Mean separation in columns by Duncan's multiple range test, 5%.

Table 6. Main effects of storage moisture content on viability and vigor of soybean seeds.[z]

Entry	Moisture (%)	Germination (%)	Germination rate index[y]	Respiration (CO_2 mg/seed/hr)
G 2120	8	79 a[x]	11.6 a	18.2 a
	13	56 b	8.8 b	13.1 b
	18	48 c	6.8 c	11.2 c
G 8285	8	45 a	5.9 a	39.9 a
	13	38 b	5.1 b	29.9 b
	18	34 c	4.7 b	26.7 b
G 8707	8	73 a	10.3 a	29.9 a
	13	51 b	7.4 b	21.5 b
	18	48 b	7.1 b	20.4 b
AGS 66	8	14 a	2.0 a	12.8 a
	13	13 a	2.0 a	9.4 c
	18	12 a	1.8 a	11.0 b

[z] Data averaged over all storage temperatures and times.

[y] Germination rate index = $\Sigma\left(\frac{\text{\% of normal seedlings per day}}{\text{Days to counting}}\right)$.

[x] Mean separation in columns by Duncan's multiple range test, 5%.

Table 7. Main effects of storage temperature on viability and vigor of soybean seeds.[z]

Entry	Temperature (°C)	Germination (%)	Germination rate index[y]	Respiration (CO_2 mg/seed/hr)
G 2120	10	87 a[x]	12.9 a	18.3 a
	20	83 b	11.5 b	18.2 a
	30	41 c	5.9 c	12.6 b
	40	21 d	3.0 d	6.6 c
G 8285	10	60 a	7.8 a	43.7 a
	20	50 b	6.2 b	41.7 a
	30	22 c	2.9 c	26.6 b
	40	5 d	0.7 d	11.1 c
G 8707	10	91 a	13.5 a	31.3 a
	20	77 b	10.4 b	29.8 ab
	30	28 c	3.8 c	26.7 b
	40	20 d	2.7 d	9.9 c
AGS 66	10	19 a	2.6 a	16.1 a
	20	10 b	1.3 b	14.7 a
	30	0 c	0.1 c	6.2 b
	40	0 c	0 c	2.7 c

[z] Data averaged over all storage moisture contents and times.

[y] Germination rate index = $\Sigma\left(\frac{\%\text{ of normal seedlings per day}}{\text{Days to counting}}\right)$.

[x] Mean separation in columns by Duncan's multiple range test, 5%.

Conclusions

High temperature and moisture are unfavorable for storage of soybean seeds. The largest seeded variety (G 8285, Table 8) was most easily affected by high temperature and moisture content. Thick seed coat (e.g. G 8285) did not help storability. The variety with low seed oil content (G 2120) has better storability. The variety that had lowest initial germination (AGS 66), reflecting that seeds had originated from a poor lot, had poor storability. Seeds stored at 10°C and 8% moisture maintained the highest viability for G 2120 and G 8707 over three months storage (Table 9). Respiration rate measurement may be useful in assaying for seed vigor.

Table 8. Hundred seed weight, seed coat thickness, and protein and oil contents of four entries.

Entry	100-seed weight (g)	Seed coat thickness (10^{-3} cm)	% Protein (dry wt. basis)	% Oil (dry wt. basis)
G 2120	6.3	7.8 ± 1.5	44.2	16.8
AGS 66	11.8	8.8 ± 1.4	40.7	22.2
G 8707	19.0	10.6 ± 2.6	44.0	21.8
G 8285	26.3	11.6 ± 1.4	46.4	20.4

Table 9. Germination rate index in G 2120, G 8707, G 8285, and AGS 66 seeds stored under 8% moisture and 10°C.

Entry	Storage time (months)			
	0	1	2	3
G 2120	15.7 a	13.3 a	13.5 a	13.1 a
G 8707	16.0 a	11.7 a	12.0 b	12.7 a
G 8285	14.3 ab	6.0 b	8.0 c	6.9 b
AGS 66	12.7 b	3.7 b	2.8 d	0.0 c

Seed Emergence Under Anoxic Conditions

Introduction

Poor field emergence and seedling establishment has been a major problem in growing vegetables in the wet season of the humid tropics. The problem is partly due to the low oxygen availability of wet soil. The effect of anoxic conditions on the germination and vigor of the seeds of several vegetables was examined.

Materials and Methods

The first experiment involved soybean (G 2120, G 9053), mungbean (VC 1562 A, V 2773), Chinese cabbage (BC-77M(2)-25), tomato (L 1) and rice (Tainan No. 5), four replicates per entry. Seeds were sterilized with 1.5% sodium hypochloride for 10 minutes and wrapped in cheesecloth before immersing in sterile water flushed with air or N_2 for 24 hours. After imbibition seeds were taken out for an emergence test in seedling flats with moist sand as medium. Emergence was examined two weeks after sowing and seedlings with intact roots and primary leaves were considered germinated.

In the second experiment, the same entries, excluding rice, were soaked in sterile water flushed with air for 6 hours and N_2 for 6, 24, 48, and 72 hours before placing in the seedling flats with moist sand. There were three replicates per treatment for each entry. Emergence was investigated daily for two weeks.

Results

Seed imbibition of sterile water regardless of air or N_2 flush resulted in poor emergence of G 9053 (Table 10). Seeds of this entry cracked during 24 hours of imbibition. Dissolved O_2 was depleted rapidly in the water of G 9053, possibly because large seeds (i.e.

34.3 g/100 seeds) require large amounts of O_2 for respiration. N_2 flush reduced dissolved O_2 to 40-60% that of air flushed water, and such low levels of oxygen in the water reduced germination of tomato, but not that of other vegetable or rice seeds.

Table 10. Effect of air or N_2-flushed imbibition on emergence of vegetable seeds.

Entry	Germination before imbibition (%)	Dissolved O_2(%)[z]		Emergence (%)	
		Air	N_2	Air	N_2
Soybean					
G 9053	94	50	6	28 a[y]	37 c
G 2120	93	48	41	96 b	95 a
Mungbean					
VC 1562 A	97	80	25	98 b	94 a
VC 2773	92	96	43	98 b	97 a
Chinese cabbage					
BC-77M(2)-25	100	100	36	99 b	100 a
Tomato					
L 1	92	100	29	94 b[x]	81 b
Rice					
Tainan No. 5	76	100	25	80 b	72 b

[z] Expressed as % of aerated water before imbibition.
[y] Mean separation in columns by Duncan's multiple range test, 5% level.
[x] Significant difference between air and nitrogen treatments at the 5% level.

Six hours of imbibition, regardless of air or N_2 flush, reduced G 9053 emergence to less than 15% (Table 11). Most G 9053 seeds that imbibed for six hours or more were cracked. G 9053 is probably susceptible to an "osmotic effect" due to large seed size. Anoxic imbibition reduced tomato (L 1) emergence. Although emergence rate of VC 1562 A and V 2773 were reduced by anoxic imbibition, the extent of reduction was not as great as in tomato.

Conclusions

Large seeded soybean germination is susceptible to water soaking. Six hours of imbibition regardless of air or N_2 flush reduced emergence and emergence rate of G 9053. Small seeded soybean germinated well after three days of imbibition. Three days of anoxic imbibition slightly reduced emergence rate of mungbean. Tomato is sensitive to anoxic conditions of imbibition. Further studies of varietal

differences in response to imbibition and differentiation between the osmotic water effect and the anoxia effect are still in progress.

Table 11. Effect of imbibition flushed with air or N_2 on emergence and emergence rate.

Entry	Emergence (%)				Emergence rate index			
	Air (6 hr)	N_2 (6 hr)	N_2 (72 hr)	LSD (5%)	Air (6 hr)	N_2 (6 hr)	N_2 (72 hr)	LSD (5%)
Soybean								
G 9053	12	12	4	9	0.8	2.4	1.0	1.8
G 2120	90	88	96	13	26.8	28.0	31.8	5.7
Mungbean								
VC 1562 A	98	100	83	27	30.7	27.9	19.8	8.5
V 2773	98	95	90	16	32.6	27.9	23.8	7.1
Chinese cabbage								
BC-77M(2)-25	80	92	97	19	19.7	28.9	31.1	9.9
Tomato								
L 1	93	87	42	19	14.5	14.1	5.6	2.6
LSD 5%	9	10	10		3.3	3.9	6.9	

Nutrition, Environment, and Management Program

Nutrition Chemistry

Cost Estimate of Manufacturing Mungbean Starch by Air Classification

Introduction

Mungbean seeds contain approximately 50% starch and 25% protein. Traditionally mungbean starch for manufacturing starch noodles has been isolated by a wet process. In this process, about 80% of the mungbean protein is lost in waste water. Air classification, a dry process, was used to separate mungbean starch from protein and other components. The starch obtained from this process was found acceptable for noodle production. The protein recovered by the dry method is in the form of fine powder that can be used for fortification, etc. Calculations were made to estimate the cost of producing this starch on a commercial basis.

Methods and Materials

The air classification process is as follows: Dehulled mungbean seeds are subjected to pin-milling and air classification to obtain starch-rich fraction I (SRF-I) and protein-rich fraction I (PRF-I). The SRF-I is further purified by a second pin-milling and air classification to obtain SRF-II and PRF-II. Trace amounts of protein in SRF-II can be removed by washing with 0.1% NaOH to obtain high quality starch for noodle preparation.

Cost analysis was conducted with the assumption that the starch manufacturer would produce SRF-II and sell it to noodle makers.

Results

The input and output costs of starch production are summarized in Table 1. This estimate, however, is prepared under a few assumptions which lack supporting evidence. The most important assumption is that the noodle maker would agree to buy the SRF at about twice the price of mungbean. Another assumption is that the PRF can be sold at the price of wheat flour.

Dehulling is recommended for the dry process. The current dry dehulling process was found to be less efficient than wet dehulling, and needs further improvement.

The PRF has a bitter taste which limits its application. However, breads made from PRF-fortified wheat flour had no bitter taste according to taste-testers. Fortification with PRF not only increases the protein content of wheat flour but also improves its protein quality (Table 2). The actual utilizable protein increased from 7.15 to 14.4% when wheat flour was fortified with 10% PRF.

Comparisons between starch recovery of SRF-I and the product of wet milling suggested that the low starch recovery of the wet process could be due to large particle size.

Conclusions

If the starch recovery of the wet process is improved, the economical feasibility of the dry method will need reconsideration.

Table 1. Annual cost estimate of air classification of mungbean to produce starch-rich fraction for starch noodle production.

Item	Cost or income (NT$)	Calculation
Input:		
Depreciation	600,000	3,600,000/6(yr)
Building	500,000	3,000,000/6(yr)
Mungbean	42,000,000	21,000/t x 2/3 x (1 t/hr x 10 hr/day x (6 x 52 - 12) day)
Labor	1,180,000	(40,000 + 18,000 + 10,000 x 4) x 12
Water	110,000	6 x 1,500 x 12
Electricity	40,000	4/deg x 0.07 deg/HP x 50 HP/hr x 10 hr/day x 300 day/yr
Total	44,430,000	
Output:		
SRF	42,000,000	42,000/t x (2,000 t/yr x 50%)
PRF	8,000,000	16,000/t x (2,000 t/yr x 25%)
Hull fraction	800,000	2,000/t x (2,000 t/yr x 20%)
	50,800,000	

Based on an air classifier capable of processing 1 ton/hr of mungbean.

Table 2. Protein chemical score of breads fortified with mungbean protein-rich fraction (PRF).[z]

Mungbean	Protein content (%)	Lysine		Methionine + Cysteine	
		% of protein	% of FAO pattern	% of protein	% of FAO pattern
0	13.0	2.3	55[y]	4.4	105
5	14.9	3.3	79[y]	3.9	93
10	16.7	4.1	98	3.6	86[y]
15	18.6	4.7	112	3.3	79[y]
20	20.4	5.2	125	3.1	73[y]

[z] Based on: (1) wheat contains 13% protein with 2.3% lysine and 4.4% methionine + cysteine, (2) mungbean PRF contains 50% protein with 8.3% lysine and 1.7% methionine + cysteine.

[y] Chemical scores.

Supplementary Effect of Sweet Potato and Legume Proteins

Introduction

Sweet potato is often mentioned as a potential staple food. Due to the root's low protein content, a diet consisting primarily of sweet potato needs additional protein from other foods. The supplemental effect of combining sweet potato with soybean and mungbean protein was studied in this project.

Materials and Methods

Sweet potato chips (AIS 35-2) were steamed at 100°C for 45 minutes, dried at 80°C, and ground.

Soybean (AGS 66) and mungbean (VC 1973 A) powders were steamed at 100°C for 45 minutes and dried at 80°C. Experimental diets were fed to six Long-Evans rats per treatment. The protein efficiency ratio (PER) was calculated by measuring the growth of experimental animals from the first to the fifth week after weaning.

The feed composition of each treatment is summarized in Table 3 for soybean and mungbean diets. The protein level of the experimental diet was 10%.

Table 3. Protein distribution of the soybean-sweet potato and mungbean-sweet potato diets.[z]

Test	Soybean or mungbean protein (%)	Sweet potato protein (%)
A	100	0
B	85	15
C	70	30
D	55	45

[z] Final composition of test diet: Moisture 10%, crude protein 10%, carbohydrate 68%, crude fat 5%, salt 4%, fiber 2%, vitamins 1%.

Results

The PER and feeding efficiency (FE), as measured by animals' weight gain, of the soybean-sweet potato diet are summarized in Table 4. No significant difference was detected in PER or FE in diets where sweet potato contributed 30% or less of the protein.

The PER and FE of the mungbean-sweet potato diet are summarized in Table 5. A combination of 85% mungbean protein and 15% sweet potato protein gave better PER and FE than other combinations.

Mungbean-sweet potato combinations all had lower FE values than combinations with corresponding quantities of soybean and sweet potato.

Table 4. The protein efficiency ratio (PER) and feeding efficiency (FE) of the soybean-sweet potato diet.

Protein distribution in test diet	PER	FE
100% SB[z] 0% SP	2.01 ± 0.25	20.16 ± 2.52
85% SB 15% SP	2.26 ± 0.22	23.71 ± 2.23
70% SB 30% SP	2.21 ± 0.29	21.62 ± 2.83
55% SB 45% SP	1.39 ± 0.26	13.30 ± 2.44

[z] SB: Soybean protein.
SP: Sweet potato protein.

Table 5. The protein efficiency ratio (PER) and feeding efficiency (FE) of the mungbean-sweet potato diet.

Protein distribution in test diet	PER	FE
100% MB[z] 0% SP	1.48 ± 0.25	14.09 ± 2.51
85% MB 15% SP	1.81 ± 0.32	17.45 ± 3.25
70% MB 30% SP	1.75 ± 0.20	17.21 ± 2.10
55% MB 45% SP	1.50 ± 0.37	12.83 ± 3.53

[z] MB: Mungbean protein.
SP: Sweet potato protein.

Conclusions

Although the chemical scores of both the soybean-sweet potato diet and the mungbean-sweet potato diet indicate S-containing amino acids to be the limiting amino acids, soybean seems to be a better protein supplement for sweet potato than mungbean.

Development of a High Performance Liquid Chromatography System for Provitamin A Activity Determination

Introduction

Despite the fact that high performance liquid chromatography (HPLC) is relatively new, its potential as a tool for carotenoid analysis has been demonstrated. The recent development of the reverse-phase column further expanded the potential application of HPLC for separating xanthophylls and carotenes in a single-step run. Although a gradient solvent system probably is essential for a complete separation of carotenes and oxygenated compounds in one run, the possibility has been suggested that determination of provitamin A activity can be accomplished by an isocretic solvent system.

An acceptable isocretic solvent system for provitamin A analysis should be able to meet the following requirements: (1) have acceptable resolution among major provitamin A carotenoids and possible interfering pigments, (2) be relatively rapid, (3) be reproducible, (4) be quantitative and sensitive, and (5) have low operating cost. An isocretic solvent that basically meets all the requirements listed was developed and used to analyze provitamin A in plant materials.

Materials and Methods

The HPLC used consists of a Waters 6000A solvent delivery system with a model U6K LC injector attached. The chromatogram was moderated by a Waters 440 absorbance detector at 436 nm and recorded by a Hewlett Packard 3390A integrator.

Anthinic carotenoids, isolated and purified from plant tissues by the conventional method, were used as standard compounds. $E^{1\%}_{1\ cm}$ values of 2800 at 444 nm; 2592 at 453 nm; 3486 at 452 nm; and 3450 at 472 nm in hexane were used for quantitation of α-carotene; β-carotene; β-cryptoxanthin; and lycopene respectively.

All solvents used were LC grade and pretreated according to the recommended procedure. Columns tested included μ-Bondpak C_{18}, RCM cartridge C_{18} 5μ, RCM cartridge C_{18} 10μ, and Merck RP-18 10μ.

Results

A distinct separation of α-carotene, β-carotene, β-cryptoxanthin, and lycopene was considered to be the essential requirement for an acceptable provitamin A analysis system. Lycopene and chlorophylls are the major pigments that might interfere with the separation. Since the separation of chlorophylls from lycopene and cryptoxanthin is difficult, saponification is recommended to avoid interference from chlorophylls. It was found that an isocretic solvent system of a combination of MeOH:AcCN:acetone = 40:40:20 applied on a Merck RP-18 column or RCM cartridge C_{18} 5 μ can resolve lycopene and the major provitamin A carotenoids, α-carotene, β-carotene, and β-cryptoxanthin. relavent

A typical chromatogram of the four major carotenoids is shown in Figure 1. The Merck RP-18 column requires a slower flow rate (0.7 ml/min) than the RCM C_{18} cartridge to obtain a comparable retention time. The retention time and resolutions of the relevant major pigments are listed in Table 6. Peak area was found to be a more stable representation of pigment quantity than peak height. A typical calibration curve of the quantity of pigment injected versus the peak area is shown in Figure 2. The relationship is linear within the range tested and a high correlation coefficient was found ($\gamma = 0.999$).

The chromatogram of spinach extract is shown in Figure 3. Chloroplast xanthophylls such as neoxanthin, violaxanthin, and lutein elute out before chlorophylls. A complete resolution among violaxanthin, lutein, and chlorophyll b was observed. Nioxanthin could not be separated from violaxanthin in this system. The resolution value between these two pigments is only 0.54. Since none of the three chloroplast xanthophylls are provitamin compounds, poor separations of these compounds do not affect the estimation of provitamin A activity.

Conclusions

Operating expense of the solvent system is low due to its slow flow rate. A cost comparison with other solvent systems is summarized in Table 7. The method is sensitive to the 0.1 μg level.

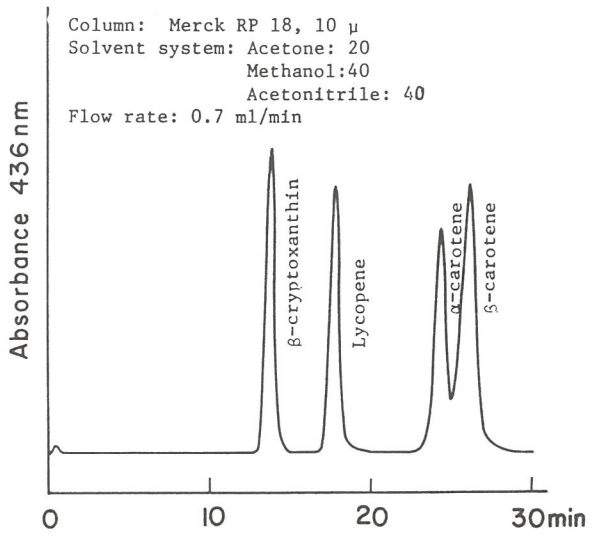


Figure 1.
Typical chromatogram of the four major carotenoids: β-cryptoxanthin, lycopene, α-carotene, and β- carotene.

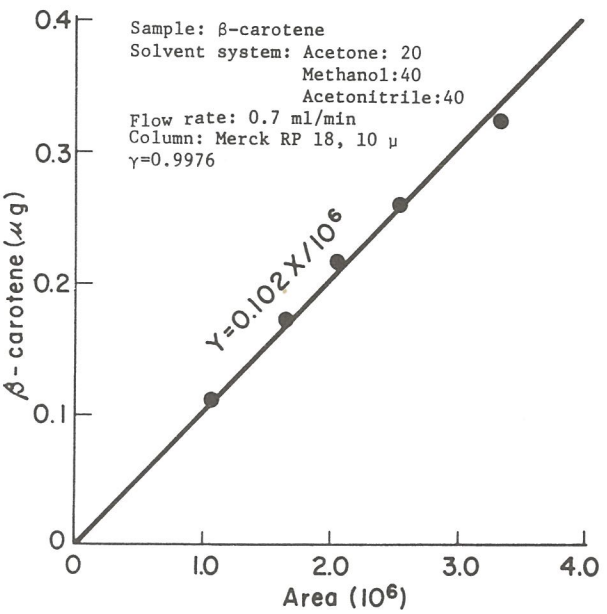


Figure 2.
Calibration curve of β-carotene.

Table 6. Separation of β-cryptoxanthin, lycopene, α-carotene and β-carotene by HPLC.

Carotenoids	Retention time			Resolution		
	mean	S.D.	CV	mean	S.D.	CV
β-Cryptoxanthin	12.69	0.12	0.95	-	-	-
Lycopene	16.26	0.54	3.32	2.52	0.06	2.38
α-carotene	22.08	0.43	1.95	4.07	0.13	3.10
β-carotene	23.64	0.59	2.50	0.86	0.07	8.14
Chlorophyll b	8.99	0.14	1.50	-	-	-
Chlorophyll a	12.21	0.26	2.20	2.59	0.22	8.30

Solvent system: Acetone:methanol:acetonitrile = 20:40:40
Flow rate: 0.7 ml per min.

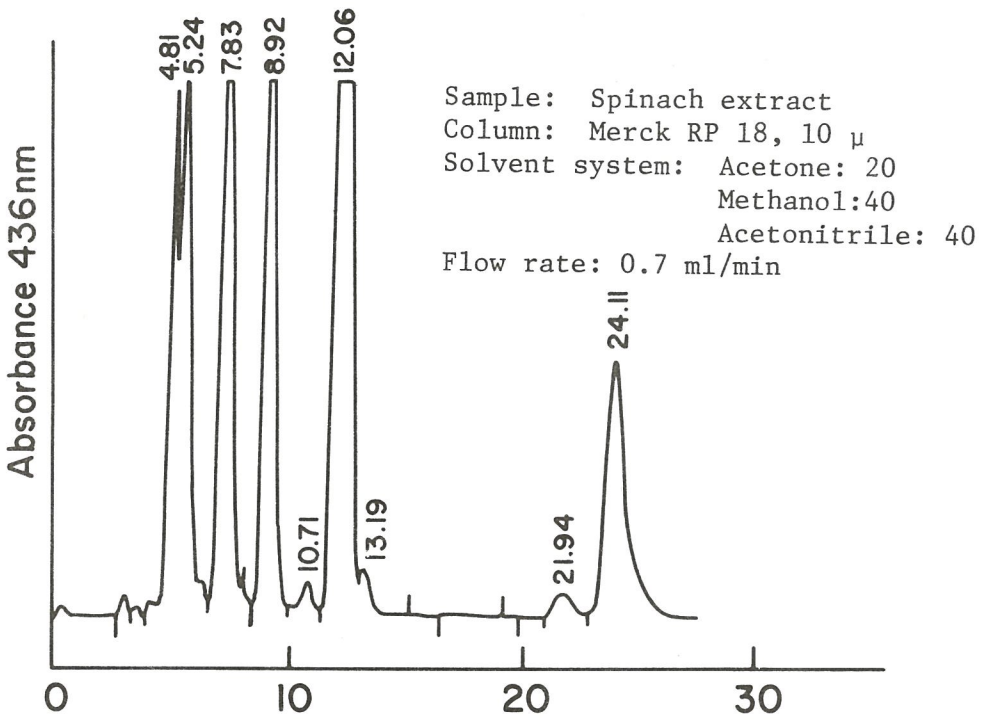


Figure 3. HPLC chromatogram of spinach extract.

Table 7. Comparison of costs of various HPLC solvent systems.

Column	Solvent system	Flow rate ml/min	ml/ analysis	Cost US $	Ref.
Merck RP-18 10µm	Acetone:methanol: acetonitrile = 20:40:40	0.7	30	0.16	Tsou
Partisil-5/ODS 5µm	Chloraform: acetonitrile = 8:92	2.0	17	0.37	Zakaria et. al. 1979
Merck RP-18 10µm	Methanol: acetonitrile = 25:75	1.5	35	0.49	Braumann et. al. 1981
RCM cartridge 5µm	THF:acetonitrile = 10:90	2.0	30	0.31	Tsou and Simpson 1982

Provitamin A Activity of Selected Vegetables and Fruits

Introduction

An accurate determination of provitamin A activity requires separation, identification, and quantification of each individual provitamin A carotenoid weighed by its biological activity. The present AOAC method, which simply separates carotenes from oxygenated compounds and measures the color of the carotene mixture, doe not meet this requirement, and often overestimates the provitamin A activity of plant materials. Provitamin A activity of selected vegetables and fruits was determined with the AOAC method and the more precise HPLC method for comparison.

Materials and Methods

Fresh samples were either purchased from the local market or harvested from AVRDC vegetable gardens. The recommended standard procedure was followed for analysis using the AOAC method. HPLC analysis was carried out on a Waters liquid chromatograph with a Merck RP-18 column. Elution patterns were monitored at 436 nm and recorded with a Hewlett Packard 3390A integrator. Chromatographs were developed with a solvent mixture of acetonitrile:methanol:acetone (40:40:20) with a flow rate of 0.7 ml/min.

Results

The single dominant pigment obtained from green vegetables in the eluents of the AOAC method was β-carotene. Leafy vegetables and green non-leafy vegetables such as green pepper, broccoli, and green peapods all have the same character (Figure 4).

The eluents obtained from yellow or orange color vegetables and fruits using the AOAC method can be classified into two groups: (1) those in which β-carotene is the single dominant pigment (such as sweet potato and tomato), and (2) those containing a mixture of several provitamin A carotenoids (such as carrot, persimmon, pumpkin, and peach) (Figures 5 and 6).

For green vegetables, the AOAC and HPLC methods gave comparable rates of β-carotene recovery (Table 8).

Saponification was found unnecessary for provitamin A analysis of green vegetables but essential to analysis of several yellow and orange colored fruits (Table 9).

Conclusions

The AOAC method overestimates the provitamin A activity of yellow and orange vegetables (Table 9). Modification of the AOAC method for these plant materials should be developed in the future.

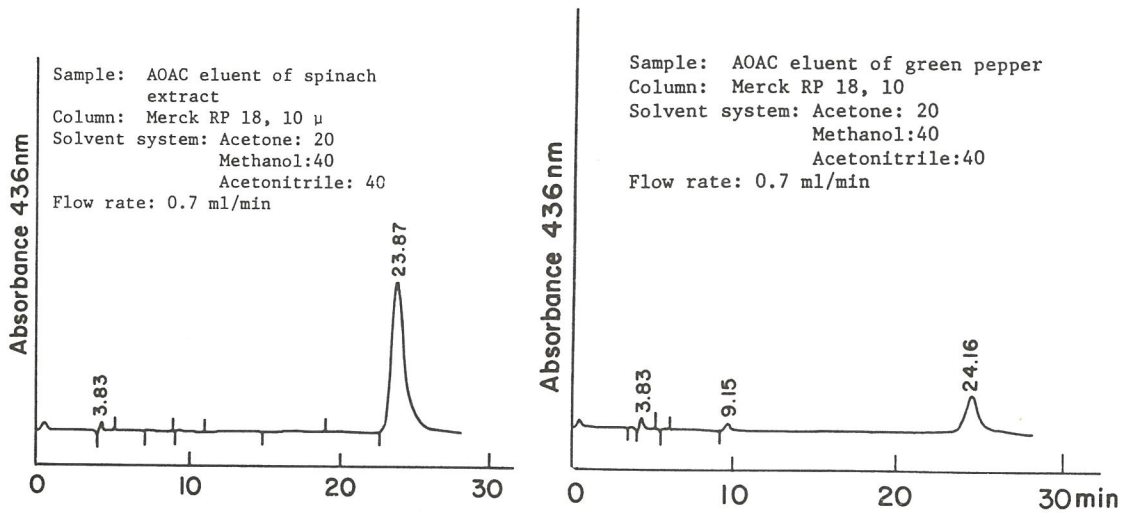


Figure 4. HPLC chromatograms of spinach (left) and green pepper (right).

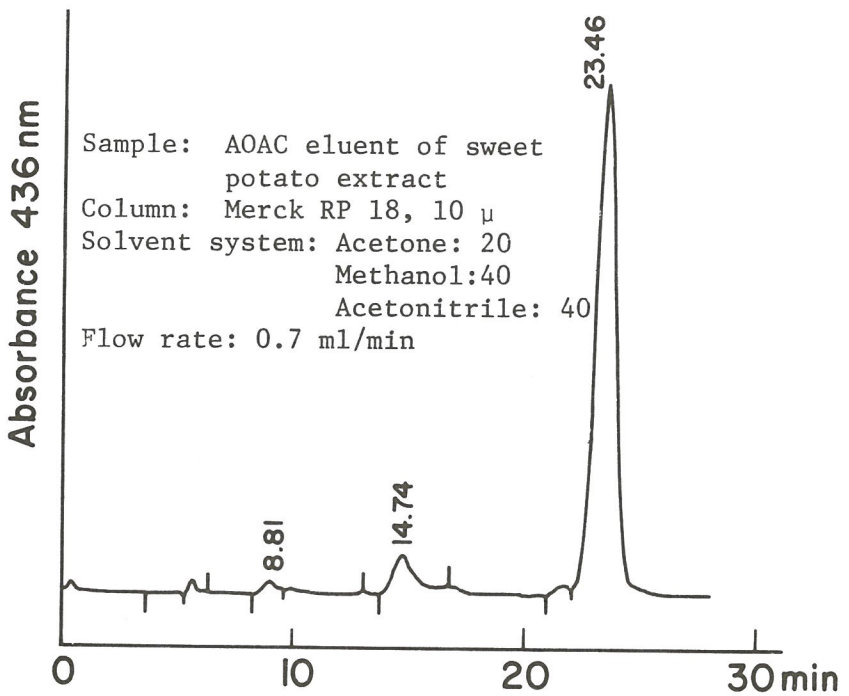


Figure 5. HPLC chromatogram of sweet potato.

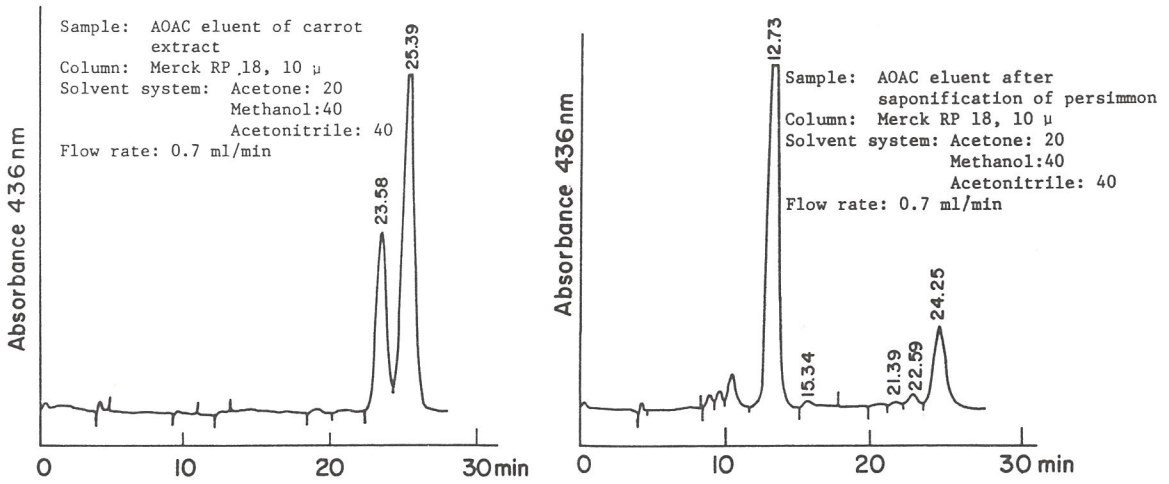


Figure 6. HPLC chromatograms of carrot (A) and persimmon (B).

Table 8. β-carotene content of selected vegetables.

Vegetable	HPLC method	AOAC method		
		I[z]	II[y]	III[x]
	mg/100 g			
Mustard	1.64	1.38	1.80	1.72
Chrysanthemum	1.57	1.43	1.61	1.53
Pai-tsai	1.12	0.71	0.89	0.82
Water convolvulus	3.32	2.73	3.27	3.16
Amaranth	2.14	1.70	2.17	2.11
Lettuce	2.62	1.93	2.91	2.68
Spinach	3.35	2.63	3.55	3.51

[z] Measurement by HPLC.
[y] Measurement at 436 nm $E^{1\%}_{1cm}$ 1960.

[x] Measurement at 452 nm $E^{1\%}_{1cm}$ 2592.

Table 9. Provitamin A activity of selected fruits and vegetables.

Commodity	HPLC Method		AOAC method
	w/saponification	wo/saponification	
	mg/100 g		
Orange	0.73	0.22	2.68
Papaya	0.44	0.20	0.99
Persimmon	0.63	0.30	2.88
Carrot	7.06	9.00	9.87
Pumpkin	5.09	5.24	10.03

Chemical Properties of Vegetable Soybean

Introduction

Because of increasing interest in vegetable soybean, the chemical properties of selected vegetable soybean lines were studied. Although the only difference between vegetable and grain soybean is maturity, they can be considered as two completely different food commodities due to their chemical-physical properties and the ways they are consumed. Since information on the proper way to evaluate vegetable soybean is lacking, the chemical properties considered important to grain soybean were investigated in this study. Comparisons were made between vegetable soybeans and mature seeds for all properties tested.

Materials and Methods

Four varieties (AGS 165, G 8285, G 9053, and G 9948) were selected for this study. Harvested vegetable soybeans were dried with hot air ($45^{o}C$) for two days and kept in a desiccator prior to analysis. Grain soybeans were used directly for analysis without additional treatment.

Available amino acids were determined microbiologically using Streptococcus zymogenes $NCDO_{592}$ as the assay organism. Protein fractionation was carried out based on the solubility of protein in various extraction solvents. Standard analytical procedures were used for other analyses, generally carried out as recommended by the AOAC method without modification.

Results

The chemical composition of vegetable soybeans and mature grain soybeans is summarized in Table 10. The noticeable differences between vegetable soybean and the mature grain seed of the respective varieties are: (1) grain soybean has higher protein content, and (2) vegetable soybean is higher in starch and lower in sugar.

Mineral and phytate contents are listed in Table 11. Vegetable soybean is higher in iron than mature grain soybean. The reverse was found for phosphorus and phytate. In this table the high phytate lines do not all appear to be high in phosphorus. However, a wide variation in mineral and phytate contents was observed in the experiment and may have affected the data.

Content and availability of selected amino acids are summarized in Table 12. The tested amino acid contents per unit protein in vegetable

soybean are not much different from grain soybean. But the availability of leucine and valine seems higher in grain soybean than in vegetable soybean.

The protein fractionation study revealed that vegetable soybean is high in glutelin and non-protein nitrogen but low in albumin and globulin. The high residual protein in vegetable soybean could be the result of the dehydration process.

Conclusions

Vegetable soybean appears to have higher starch, iron, glutelin, and non-protein nitrogen and lower protein, sugar, phosphorus, phytate, albumin, and globulin contents than mature grain soybean. Amino acid contents showed little variation, although the availability of leucine and valine seems higher in grain soybean. A number of chemical and physical properties, such as color, beany flavor, and fatty acids patterns, were not investigated in this study. These will be evaluated in 1983.

Table 10. Chemical composition of soybean.[z]

Material	Variety	Moisture	Protein	Oil	Sugar	Starch	Ash
Vegetable soybean	AGS 165	6.24	37.46	21.66	5.10	10.14	5.22
	G 8285	5.62	41.09	20.95	5.32	7.40	4.96
	G 9053	5.71	38.13	20.53	6.84	10.22	5.41
	G 9948	6.57	35.93	22.24	7.40	10.82	5.37
Grain soybean	AGS 165	9.51	40.80	20.86	12.80	3.27	4.97
	G 8285	10.05	42.31	19.45	12.89	3.09	5.00
	G 9053	10.03	40.25	20.90	13.27	3.13	5.32
	G 9948	9.81	37.98	21.37	11.90	3.06	5.32

[z] Data, with the exception of moisture expressed as percentage on a dry weight basis.

Table 11. Mineral and phytate contents of soybean (dry weight basis).[z]

Material	Variety	Phosphorus	Calcium	Magnesium	Iron	Manganese	Zinc	Copper	Phytate[y]
Vegetable soybean	AGS 165	676.72	84.82	236.21	15.80	3.94	5.49	2.55	3.42
	G 8285	519.02	53.93	205.80	14.18	3.03	4.95	2.63	2.9i
	G 9053	507.75	58.42	195.48	14.35	2.89	4.64	2.75	2.11
	G 9948	576.94	62.78	241.72	13.54	2.76	5.30	2.88	2.17
Grain soybean	AGS 165	670.82	73.82	239.20	8.79	2.83	5.19	2.11	3.60
	G 8285	627.70	47.56	210.05	10.30	2.60	5.37	2.34	3.12
	G 9053	623.63	56.65	208.90	11.24	2.65	4.87	2.56	3.08
	G 9948	649.26	58.43	210.54	10.41	2.51	4.71	2.87	3.80

[z] Unit: mg/100g sample.

[y] Unit: Fe^{+3} precipitated/g of sample.

Table 12. Results of modified microbiological assay for available amino acid index determination in soybean.

Material	Variety	Leucine			Valine			Methionine		
		total content (%)[z]	available content (%)[z]	availability index (%)[y]	total content (%)[z]	available content (%)[y]	availability index (%)[y]	total content (%)[z]	available content (%)[z]	availability index (%)[y]
Vegetable soybean	AGS 165	7.73	4.08	52.80	6.36	3.42	53.83	1.88	0.83	44.01
	G 8285	8.16	4.49	55.01	6.16	3.28	53.33	1.69	0.84	49.46
	G 9053	8.01	4.57	57.06	6.41	3.51	54.75	1.76	0.88	50.86
	G 9948	7.95	6.10	76.70	6.53	4.91	75.25	1.70	0.90	52.86
Grain soybean	AGS 165	8.33	5.53	66.37	6.32	4.23	66.81	1.78	0.70	39.64
	G 8285	8.20	5.62	68.53	6.35	3.57	56.13	1.77	0.75	42.58
	G 9053	8.33	5.76	69.18	6.89	4.31	62.50	1.87	0.92	49.34
	G 9948	7.88	5.89	74.74	5.75	5.09	75.50	1.91	0.69	35.89

[z] Data expressed as percent of total protein.

[y] Availability index = $\frac{\text{Available amino acid content}}{\text{Total amino acid content}}$

Garden Programs

School Garden

Introduction

It is common knowledge that schoolchildren need energy foods and body-building protein foods to meet the demands of their growing bodies. They also require vitamins and minerals, which vegetables can provide. A small amount of cooked vegetables added to the ricebox lunch that many children bring to school throughout Southeast Asia could significantly contribute to the child's daily needs for certain vitamins and minerals.

The objective of this project was to develop a garden that could be grown at a school to provide ½ cup (approximately 113 g edible portion) of nutritious vegetables to each of 80 children, five days per week, during a school year growing and harvesting period.

Materials and Methods

Four "seasonal" gardens were planted during the one year period, in a 10 x 18 m plot consisting of twelve raised beds (10 x 1.5 m, 24 cm high). During the 1981-82 season, 27 vegetables were grown based on their nutritional value and cultural acceptability. Low input agricultural procedures were practiced, with minimum use of pesticides. Where possible, hand weeding and hand pest control were practiced.

The yield was recorded for each vegetable in each planting period. The vegetables were also analyzed for their content of protein, calcium, iron, and vitamins A and C. The contribution that 113 g of cooked vegetables would make to the daily recommended dietary allowance (RDA) of an average 10-year-old schoolchild was also calculated.

Results

The yield and nutritional composition of the vegetables in the four seasonal school gardens are shown in Tables 1 through 4. During the year the school garden produced an average of 15.18 kg of nutritious, culturally acceptable vegetables per day. This translates to one hundred thirty-four 113 g servings per day, exceeding the objective of providing

for 80 children. The yield corresponds to an average over the year of 325.7 g protein, 19,759.5 g calcium, 555.1 mg iron, 45,465.5 µgRE vitamin A, and 7012.3 mg vitamin C per day.

Table 1. Yield and nutrient contribution of school garden I, June to September, 1981, 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	Chinese mustard	61	41.0	0.67	2	13.4	817.4	16.1	1788.9	656.6
3-4	Amaranth	96	113.7	1.18	5	35.4	3433.8	168.7	2324.6	354.0
5-6	Water convolvulus	113	192.8	1.71	6	58.1	2599.2	102.6	5591.7	820.8
7-8	Leaf lettuce	61	96.9	1.59	5	35.0	1860.3	116.1	6360.0	381.6
	Chinese mustard	44	27.8	0.63	2	15.1	1121.4	12.6	1984.5	718.2
9-10	[Lima bean[z]	118	1.0	0.01	1	0.8	2.5	0.2	9.0	3.0
	[Pai-tsai	53	68.8	1.30	6	23.4	2197.0	44.2	2314.0	962.0
11	Sweet potato tips (TN 64)[y]	129	26.9	0.21	5	8.4	256.2	9.9	331.8	98.7
12	[Yard-long bean	97	47.2	0.49	10	13.7	249.9	8.8	163.2	137.2
	[Sweet potato tips (AIS 35-2)	62	8.8	0.14	2	5.2	301.0	9.4	203.0	54.6
Total			624.9	7.93		208.5	12838.7	488.6	21070.7	4186.7

[z] Damaged.
[y] Under a trellis; winged bean growing on the trellis was not harvested in this period.
[= Intercropped.
Additional: Sweet corn growing on the sides of the garden as a windbreak.
Garlic and shallot planted around the edges of beds.

Table 2. Yield and nutrient contribution of school garden II, October to December, 1981, 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	Radish[z]	65	33.0	0.51	4	5.1	137.7	2.0	0	214.2
1	Cabbage (S.A. 633)	58	38.6	0.67	3	9.4	281.4	2.7	15.4	272.0
2	Cauliflower (F.E. No. 2)	58	18.1	0.31	4	8.0	117.8	3.4	20.8	157.1
3	Broccoli (F.G. No. 1)	64	31.7	0.50	5	15.0	175.0	4.0	1165.0	248.0
4	Broccoli	64	30.3	0.47	5	14.1	164.5	3.7	1095.1	233.1
3-4	Garland chrysanthemum	44	93.9	2.13	6	63.9	3280.2	227.9	7348.5	287.6
5-6	Carrot 531	93	41.9	0.45	2	4.5	162.0	9.5	7321.5	46.4
7	Cauliflower (F.E. No. 2)	72	37.7	0.52	4	13.5	197.6	5.7	34.8	263.7
8	Cabbage 633	63	44.3	0.70	4	9.8	294.0	2.8	16.1	284.2
7-8	Cauliflower[y]	37	6.7	0.18	1	4.6	68.4	2.0	12.1	91.2
	[(F.E. No. 2)									
	[Spinach	34	10.3	0.30	2	3.6	273.0	9.0	1629.0	72.9
9-10	[Spinach	46	38.7	0.84	5	10.0	764.4	25.2	4561.0	204.1
	[Sweet pepper	77	75.5	0.98	4	12.3	117.6	8.6	2854.3	1009.4
	[Pai-tsai	31	71.0	2.29	2	32.1	3389.2	59.5	5282.3	1419.8
11	Winged bean younger pods[z]	72	6.9	0.10	3	3.8	81.0	1.6	64.2	21.9
	[Sweet potato tips (TN 64)[z]	122	7.9	0.06	2	2.0	66.6	4.6	164.0	35.4
12	[Cucumber	68	48.2	0.71	8	2.9	99.4	2.2	17.8	49.0
	[Sweet potato tips (AIS 35-2)	107	2.2	0.02	2	0.7	43.0	1.3	29.0	7.8
	Pai-tsai[x]	35	25.2	0.72	5	10.1	1065.6	18.7	1346.6	446.4
	Total		662.1	12.46		225.4	10778.4	394.4	31977.7	5364.2

[z] Continued from garden I.
[y] Damaged.
[x] Intercropped with broccoli, which was not harvested during this period.
[= Intercropped.
Additional: Cassava planted around the edges of the garden.
Sweet corn growing on the sides of the garden as a windbreak; 38.2 kg harvested.
Garlic and shallot planted around the edges of beds; 38.5 kg harvested.

Table 3. Yield and nutrient contribution of school garden III, January to March, 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	Cabbage	60	13.6	0.23	3	3.3	96.6	1.0	5.3	93.3
	[(S.A. 633) Amaranth	88	19.9	0.23	3	7.6	542.8	20.7	821.1	116.6
2	Cauliflower[z]	35	11.1	0.32	2	8.3	121.6	3.5	21.4	162.3
	[(F.E. No. 2) Pai-tsai	36	77.0	2.14	7	45.0	3980.4	53.5	4964.8	1112.8
	[(ching-chiang)[z] Head lettuce	52	71.0	1.37	2	30.2	1602.9	100.0	5480.0	328.8
3-4	Broccoli	70	62.8	0.90	5	27.0	315.0	7.2	2097.0	446.4
	[(F.G. 162) Kale	38	22.6	0.59	1	10.0	1121.0	23.6	3232.8	150.5
	Pai-tsai (ching-chiang 601)	19	10.2	0.54	1	11.4	1004.4	13.5	1252.8	280.8
5-6	Carrot 533[z]	19	43.8	2.31	2	23.1	831.6	48.5	37583.7	237.9
	Kale	56	84.6	1.51	2	31.7	3790.1	72.5	3775.0	1416.4
7-8	Spinach[z]	29	32.6	1.12	6	28.1	1008.0	28.1	5353.6	417.8
	Broccoli	47	6.3	0.13	1	3.9	45.5	1.0	302.9	64.4
	[(F.G. No. 162) Pai-tsai (ching-chiang 606)	26	15.7	0.60	2	13.8	1272.0	28.8	1692.0	541.8
9-10	[Pai-tsai[z]	11	12.0	1.09	1	16.4	1994.7	19.6	1744.0	497.0
	[Sweet pepper[z]	75	37.3	0.50	6	6.5	60.0	4.5	1458.3	515.0
	[Lettuce	48	24.0	0.50	1	7.0	305.0	16.0	885.0	115.0
	Chinese mustard	16	3.5	0.22	1	5.3	391.6	4.4	693.0	250.8
11	Winged bean younger pods[z]	20	3.3	0.17	1	6.5	137.7	2.7	108.5	37.2
	Winged bean tubers[z]	225	5.8	0.026	1	1.5	9.6	0.3	trace	12.0
	[Sweet potato tubers (TN 64)[z]	225	1.4	0.006	1	0.1	4.3	0.1	8.7	1.0
	[Pai-tsai	35	48.8	1.39	3	20.9	2543.7	25.0	2224.0	633.8
	[Head lettuce	43	18.5	0.43	1	5.2	236.5	9.5	1225.5	154.4
12	Broccoli	66	26.4	0.40	3	12.0	140.0	3.2	932.0	198.4
	[(G.K. No. 70) Chinese mustard	25	3.6	0.14	1	2.8	170.8	3.4	373.8	137.2
	[Pai-tsai Chinese mustard	27	24.4	0.90	3	13.5	1647.0	16.2	1440.0	410.4
		27	4.5	0.17	1	3.4	207.4	4.1	453.9	166.6
Total			684.7	17.93		344.5	23580.2	510.9	78129.1	8498.6

[z] Continued from garden II.
[= Intercropped.
Additional: Snake gourd and sweet corn growing on the sides of the garden as a windbreak.
Garlic and shallot planted around the edges of beds; 57.5 kg harvested.

The 113 g portion can contribute significantly to the daily diet of a ten-year-old schoolchild, especially in terms of iron and vitamins A and C (Table 5).

Conclusions

A 10 x 18 m school garden can provide 134 children with 113 g of vegetables per day. If there are fewer children in the school, the garden size can be reduced; otherwise the children can take the excess vegetables home to their families or the school can sell the vegetables as an income-generation scheme. In all three cases the school garden becomes a means of cheaply increasing the availability of vitamins and minerals in the school's community.

Table 4. Yield and nutrient contribution of school garden IV, April to June, 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	[Spinach[z]	35	26.0	0.74	5	8.9	673.4	22.2	4018.2	179.8
	[Head lettuce[z]	31	37.0	1.19	2	36.9	1428.0	55.9	652.1	148.8
	[Yard-long bean	81	39.1	0.48	13	13.4	244.8	8.6	159.8	134.4
	[Chinese mustard	33	5.0	0.15	1	3.6	267.0	3.0	472.5	171.0
3-4	Head lettuce[z]	36	52.5	1.46	2	45.3	1752.0	68.6	800.1	182.5
	[Common cabbage	59	92.2	1.56	4	21.9	655.2	6.3	35.9	633.3
	[Kale	23	5.1	0.22	1	4.6	552.2	10.5	550.0	206.3
	Pai-tsai	32	28.3	0.88	4	14.1	1135.2	28.1	1364.0	607.2
5-6	Pai-tsai (ching-chiang)	24	13.5	0.56	2	15.1	1299.2	21.3	2139.2	433.4
	[Head lettuce	35	44.1	1.26	1	39.1	1512.0	59.2	690.5	157.5
	[Kale[z]	27	7.5	0.28	1	5.9	702.8	13.5	700.0	262.7
	Pai-tsai	28	52.6	1.88	4	26.3	2782.4	48.9	3515.6	1165.6
	Amaranth	28	19.2	0.69	1	16.5	1787.1	58.7	3367.2	446.5
7-8	[Pai-tsai	30	42.0	1.40	4	22.4	2338.0	49.0	3822.0	812.0
	[Head lettuce	31	19.8	0.64	2	19.9	768.0	30.1	350.7	80.0
	Water convolvulus	75	102.4	1.37	5	42.5	2616.7	68.5	6822.6	637.1
9-10	Pai-tsai[z] (ching-chiang)	17	17.0	1.0	1	27.0	2320.0	38.0	3820.0	774.0
	[Broccoli	45	23.5	0.52	3	15.6	182.0	4.2	1211.6	257.9
	[Rape greens	62	142.1	2.29	5	48.1	3343.4	75.6	9457.7	1014.5
11-12	Water convolvulus[z]	43	9.5	0.22	1	6.8	420.2	11.0	1095.6	102.4
	[Head lettuce[z]	43	81.7	1.90	3	58.9	2280.0	89.3	1041.2	237.5
	[Chinese mustard	24	16.0	0.67	1	13.4	817.4	16.1	1788.9	656.6
	[Pai-tsai	24	19.2	0.80	2	12.8	1336.0	28.0	2184.0	464.0
	Kale[y]	49	12.3	0.25	3	5.2	627.5	12.0	625.0	234.5
Total			907.6	22.41		524.2	31840.5	826.6	50684.4	9999.5

[z] Continued from garden III.
[y] Intercropped with broccoli, which was not harvested during this period.
[= Intercropped.
Additional: Snake gourd and sweet corn growing on the sides of the garden as a windbreak; 115.0 and 13.2 kg harvested, respectively.

Table 5. Percentage of a 10-year-old child's RDA[z] contained in 113 grams 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	2.43	147.46	4.14	339.29	52.33
Contribution of 113 g to the RDA of a 10-year-old (%)	6.39	22.69	59.14	59.01	261.65

[z] Recommended dietary allowance. Source: Food and Agriculture Organization. 1974. Handbook on Human Nutritional Requirements. FAO, Rome.

Home Gardens

Introduction

Vegetables, especially the green leafy types, contain nutrients (e.g. calcium, iron, and vitamin A) that are lacking in the diets of many people in Southeast Asia and other parts of the world. If rural people can be shown how to grow small home gardens containing recogniz-

able and nutritious crops, the outputs from these gardens can make a significant contribution towards alleviating their nutritional problems.

The objective of this project was to develop small home gardens that contain an intercrop of nutritious vegetables (and a few fruits) which are culturally acceptable in Southeast Asia, and that provide for a family of five (two adults and three children) 40% of the recommended daily dietary allowance (RDA) of calcium and iron, 80% of the RDA of vitamin A, and 100% of the RDA of vitamin C, plus measurable amounts of protein. Home gardens have been developed at AVRDC for Indonesia, the Philippines, and Thailand. A "vitamin A garden" has also been developed to see how much of this nutrient (deficient in many Southeast Asian diets) can be produced in a small plot.

Materials and Methods

In each of the four types of gardens, a culturally acceptable intercrop of vegetables and a few fruits was planted in a 4 x 4.5 m plot consisting of three raised beds (4 x 1.5 m, 25 cm high). Garlic, shallot, and hot pepper were planted around the edges of beds in all gardens. The gardens were planted four times during the year, with variations that reflect the slight seasonal changes in the AVRDC environment. Garden I (hot season) was grown from June to September; garden II (hot to cool season) from October to December; garden III (cool season) from January to March; and garden IV (cool to hot season) from April to June. Low input agricultural procedures were practiced, such as hand weeding, hand insect removal, and the use of rice straw as mulch.

During the seasonal growing periods data were collected on the yield of each crop in each garden; samples of each crop were analyzed for content of the five select nutrients - protein, calcium, iron, and vitamins A and C; the RDA for a family of five was obtained from the literature (Table 6); and from these data the percentage of the RDA available for a family of five was determined from each crop and for each garden.

Results

The yield and nutritional composition of the vegetables in the four seasonal gardens are shown for the Indonesia (Tables 7 to 10), Thailand (Tables 11 to 14), Philippines (Tables 15 to 18), and vitamin A gardens (Tables 19 to 22). The four season mean contribution of each type of

garden is summarized in Table 23. The output of all of the gardens in all seasons surpassed the objectives set for them, both in terms of yield and in terms of percent contribution to the RDA for a family of five. The average yield per day of the four Indonesia gardens, for example, was 1.66 kg, which is probably more than the average Asian family of five would consume. However, if they ate only half of the garden's daily output the nutritional objectives would still be met, and the other half could be distributed to extended family or friends or sold.

Conclusions

Small home gardens are feasible and can contribute significantly toward the alleviation of specific nutritional deficiency problems in Asia.

Table 6. 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 7. Yield and nutrient contribution of Indonesia home garden I, June to September, 1981.

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	75	36.0	0.48	5	14.9	561	14.4	1872	197
2	Amaranth	99	15.1	0.15	5	3.9	540	7.1	410	80
3	[Winged bean[z]	134	2.8	0.02	2	0.8	16	0.3	13	4
	[Sweet potato tips (AIS 35-2)	134	5.5	0.04	3	1.1	61	6.3	84	18
	Cassava tips[y]	92	13.5	0.15	4	11.5	350	6.7	909	34
	Yard-long bean	95	7.5	0.08	9	2.2	41	1.4	27	22
Total			80.4	0.92		34.4	1569	36.2	3315	335
RDA for a family of five						149.0	3100	49.0	2625	140
% of RDA contributed by garden						23.1	50.6	73.9	126.3	253.6

[z] Winged bean growing on a trellis; sweet potato under the trellis.
[y] Yard-long bean growing on an edible cassava fence.
[= Intercropped.

Table 8. Yield and nutrient contribution of Indonesia home garden II, October to December, 1981.

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	Cabbage 633	69	17.5	0.25	3	3.5	105.0	1.0	6	101.5
	Pai-tsai[z]	34	15.8	0.46	3	7.4	593.4	14.7	713	317.4
	Garlic and shallot[y]	34	2.25	0.07	1	1.3	58.8	1.1	60	17.1
						0.4	18.2	0.4	22	2.3
2	Broccoli (G.K. No. 70)	68	7.22	0.11	3	3.3	38.5	0.9	256	54.6
	Kale	22	8.0	0.36	1	6.1	684.0	14.4	1972	91.8
	Garlic and shallot[y]	34	2.25	0.07	1	1.3	62.7	1.1	64	18.2
						0.3	14.6	0.3	18	1.8
3	[Winged bean[x]	63	5.0	0.08	5	3.1	64.8	1.3	51	17.5
	[Sweet potato tips[x] (AIS 35-2)	71	1.6	0.02	2	0.5	35.6	3.3	64	6.4
Total			59.6	1.42		27.2	1675.6	38.5	3226	628.6
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						18.3	54.1	78.6	122.9	449.0

[z] Intercropped with broccoli, which was not harvested in this period.
[y] Growing around the edges of beds.
[x] Continued from garden I.
[= Intercropped.
Additional: Edible cassava fence.

Table 9. Yield and nutrient contribution of Indonesia home garden III, January to March, 1982.

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	[Broccoli[z]	61	9.9	0.16	3	4.8	56.0	1.3	373	79.4
	[Chinese mustard	49	2.8	0.06	1	1.4	106.8	1.2	189	68.4
	Pai-tsai (ching-chiang 606)	42	8.0	0.19	4	5.1	440.8	7.2	726	147.1
	[Chinese mustard	21	1.0	0.05	1	1.2	89.0	1.0	158	57.0
2	Kale	28	9.9	0.35	1	6.0	665.0	14.0	1918	89.3
	[Pai-tsai	39	22.5	0.58	2	8.7	1061.4	10.4	928	264.5
	[Head lettuce	42	6.9	0.16	1	1.9	88.0	3.5	456	57.4
3	[Winged bean[z]	20	2.6	0.13	1	4.9	105.3	2.1	83	28.5
	[Sweet potato tips[z] (AIS 35-2)	20	1.1	0.06	1	1.5	106.8	9.9	193	19.3
	[Head lettuce	35	9.8	0.28	1	3.9	170.8	9.0	496	64.4
	[Spinach	35	5.4	0.15	2	1.8	136.5	4.5	815	36.5
	Garlic and shallot[y]	50	4.05	0.08	1	1.44	67.2	1.2	68	19.5
						0.42	20.8	0.4	26	2.6
Total			84.0	2.25		43.1	3114.4	65.7	6429	933.9
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						28.9	100.5	134.1	244.9	667.1

[z] Continued from garden II.
[y] Growing around the edges of beds.
[= Intercropped.
Additional: Sweet potato growing on an edible cassava fence.

Table 10. Yield and nutrient contribution of Indonesia home garden IV, April to June, 1982.

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	101	29.2	0.29	4	9.0	339.3	8.7	1131	118.9
2	[Spinach	35	3.1	0.09	2	2.3	121.5	2.0	448	37.2
	[Head lettuce	39	14.8	0.38	2	5.3	231.8	12.2	673	87.4
	Kale	33	4.8	0.15	3	3.2	376.5	7.2	375	140.7
	Pai-tsai (ching-chiang 606)	24	5.0	0.21	1	5.7	487.2	8.0	802	162.5
	[Pai-tsai	24	2.7	0.11	1	1.7	177.6	3.1	224	74.4
3	[Head lettuce	44	13.3	0.30	1	4.2	183.0	9.6	531	69.0
	[Amaranth	47	10.6	0.23	5	7.6	542.8	20.7	821	116.6
	[Sweet pepper	72	1.9	0.03	2	0.4	3.6	0.3	88	30.9
	[Chinese mustard	28	2.3	0.08	1	1.9	142.4	1.6	252	91.2
	Rape greens	30	6.1	0.20	3	4.4	306.6	6.9	867	93.0
Total			93.8	2.07		45.7	2912.3	80.3	6212	1021.8
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						30.7	93.9	163.9	236.6	729.9

[= Intercropped.
Additional: Sweet potato growing on an edible cassava fence.

Table 11. Yield and nutrient contribution of Thailand home garden I, June to September, 1982.

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	47	7.2	0.15	3	2.1	222	3.9	280	93
	[Chinese mustard	96	19.0	0.20	3	4.6	338	3.8	598	217
2	Pai-tsai	68	37.3	0.55	3	7.7	814	14.3	1029	341
	Pai-tsai (ching-chiang 606)	45	13.0	0.29	3	6.1	539	7.3	673	151
3	[Yard-long bean[z]	94	22.0	0.23	9	6.4	117	4.1	77	64
	[Sweet potato tips (TN 64)	134	6.3	0.05	3	1.8	52	3.2	71	20
Total			104.8	1.47		28.7	2082	36.6	2728	886
RDA for a family of five						149.0	3100	49.0	2625	140
% of RDA contributed by garden						19.3	67.2	74.7	103.9	632.9

[z] Yard-long bean growing on a trellis; sweet potato under the trellis.
[= Intercropped.
Additional: Hyacinth bean and ipil-ipil trees growing on a bamboo fence.

Table 12. Yield and nutrient contribution of Thailand home garden II, October to December, 1982.

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	Cauliflower (F.E. No. 2)	72	6.6	0.09	3	2.3	34.2	1.0	6	45.6
	Pai-tsai	31	9.0	0.29	2	4.6	374.1	9.3	450	200.1
	Garlic and shallot[z]	31	2.25	0.07	1	1.3 0.3	62.7 14.6	1.1 0.3	64 18	18.2 1.8
2	Amaranth	92	20.1	0.22	4	7.3	519.2	19.8	785	111.5
	Garlic and shallot[z]	32	2.43	0.08	1	1.5 0.3	71.7 16.6	1.3 0.3	73 20	20.8 2.1
3	[Cucumber[y]	68	19.57	0.29	6	1.1	39.2	0.8	7	19.3
	[Sweet potato tips (TN 64)	44	2.1	0.05	1	1.7	55.5	3.8	136	29.5
Total			62.05	1.09		20.4	1187.8	37.7	1559	448.9
RDC for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						13.7	38.3	76.9	59.4	320.6

[z] Growing around the edges of beds.
[y] Cucumber growing on a trellis; sweet potato under the trellis.
[= Intercropped.
Additional: Hyacinth bean and ipil-ipil trees growing on a bamboo fence.

Table 13. Yield and nutrient contribution of Thailand home garden III, January to March, 1982.

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	[Cabbage 633	65	19.0	0.29	1	4.1	121.8	1.2	7	117.7
	[Chinese mustard	28	3.4	0.12	1	2.9	213.6	2.4	378	136.8
	Rape greens[z]	33	3.5	0.11	1	2.3	160.6	3.6	454	48.7
2	Kale	28	17.5	0.63	1	10.7	1197.0	25.2	3452	160.7
	Pai-tsai	30	9.4	0.31	1	4.7	567.3	5.6	496	141.4
3	[Chinese mustard	39	4.4	0.11	2	2.2	134.2	2.6	294	107.8
	[Spinach	39	4.6	0.12	1	1.4	109.2	3.6	652	29.2
	Garlic and shallot[y]	41	4.95	0.12	1	2.2 0.6	100.8 31.2	1.8 0.6	103 38	29.3 3.9
Total			66.8	1.81		31.1	2635.7	46.6	5874	775.5
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						20.9	85.0	95.1	223.8	553.9

[z] Intercropped with head lettuce, which was not harvested in this period.
[y] Growing around the edges of beds.
[= Intercropped.
Additional: Sweet potato and ipil-ipil trees growing on a bamboo fence.

Table 14. Yield and nutrient contribution of Thailand home garden IV, April to June, 1982.

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	[Head lettuce[z]	42	15.7	0.37	1	11.5	444.0	17.4	203	46.3
	[Spinach	28	1.4	0.05	1	0.6	45.5	1.5	272	12.2
	Amaranth	75	12.4	0.17	4	6.6	756.5	11.4	813	71.6
2	[Water convolvulus	42	4.8	0.11	1	3.4	210.1	5.5	548	51.2
	[Head lettuce	28	6.2	0.22	1	6.8	264.0	10.3	121	27.5
	[Chinese mustard	26	3.9	0.15	1	3.6	267.0	3.0	473	171.0
	[Pai-tsai	26	2.9	0.11	1	1.7	201.3	2.0	176	50.2
	Kale	49	3.9	0.08	3	1.7	200.8	3.8	200	75.0
3	[Pai-tsai	28	6.3	0.23	2	3.7	296.7	7.4	357	158.7
	[Head lettuce	43	9.8	0.23	2	7.1	276.0	10.8	126	28.8
	Yard-long bean	72	8.7	0.12	8	3.4	61.2	2.2	40	33.6
Total			76.0	1.84		50.1	3023.1	75.3	3329	726.1
RDA for a family of five						140.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						33.6	97.5	153.7	126.8	518.6

[z] Continued from garden III.
[= Intercropped.
Additional: Sweet potato and ipil-ipil trees growing on a bamboo fence.

Table 15. Yield and nutrient contribution of Philippines home garden I, June to September, 1981.

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	Chinese leek	130	6.1	0.05	5	1.2	24	1.0	68	14
2	[Eggplant	127	23.3	0.18	12	3.4	34	2.0	27	11
	[Pai-tsai	47	6.5	0.14	3	2.2	234	4.9	382	81
3	[Snap bean	134	3.5	0.03	3	0.6	6	0.2	6	6
	[Sweet potato (I-426)	69	3.2	0.05	4	0.9	60	4.4	85	15
Total			42.6	0.45		8.3	358	12.5	568	127
RDA for a family of five						149.0	3100	49.0	2625	140
% of RDA contributed by garden						5.6	11.6	25.5	21.6	90.7

[= Intercropped.
Additional: Hyacinth bean and malunggay growing on a bamboo fence.

Table 16. Yield and nutrient contribution of Philippines home garden II, October to December, 1981.

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	Chinese leek[z]	24	7.0	0.29	1	8.7	252.3	6.4	2683	101.5
	Garlic and shallot[y]	35	3.4	0.10	1	1.8 0.5	84.0 26.0	1.5 0.5	86 32	24.4 3.3
2	[Sweet pepper	61	3.3	0.05	3	0.7	6.0	0.5	146	51.5
	[Kale	24	7.2	0.30	1	5.1	570.0	12.0	1644	76.5
	Garlic and shallot[y]	36	2.9	0.08	1	1.4 0.4	67.2 20.8	1.2 0.4	68 26	19.5 2.6
3	Cowpea[x]	63	1.9	0.03	2	1.4	15.0	0.5	6	9.3
	Sweet potato tips (I-426)	69	3.5	0.05	2	1.1	75.5	5.5	106	18.7
Total			29.2	6.90		21.1	1116.8	28.5	4797	307.3
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						14.2	36.0	58.2	182.7	219.5

[z] Continued from garden I.
[y] Growing around the edges of beds.
[x] Cowpea growing on a trellis; sweet potato under the trellis.
[= Intercropped.
Additional: Hyacinth bean and malunggay growing on a bamboo fence.

Table 17. Yield and nutrient contribution of Philippines home garden III, January to March, 1982.

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	Chinese leek[z]	57	16.5	0.29	2	8.7	252.3	6.4	2683	101.5
2	[Chinese mustard	31	2.7	0.09	1	2.2	160.2	1.8	284	102.6
	[Sweet pepper	64	18.8	0.29	6	3.8	34.8	2.6	846	298.7
	Shallot[y]	50	9.0	0.18	1	3.8	187.2	3.6	230	23.6
3	[Chinese mustard	38	3.9	0.10	2	2.0	122.0	2.4	267	98.0
	[Rape greens	38	5.5	0.14	3	2.9	204.4	4.6	578	62.0
	Garlic and shallot[y]	45	5.2	0.12	1	2.3 0.5	107.5 25.0	1.9 0.5	109 31	31.2 3.1
Total			61.6	1.21		26.2	1093.4	23.8	5028	720.7
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						17.6	35.3	48.6	191.5	514.8

[z] Continued from garden II.
[y] Growing around the edges of beds.
[= Intercropped.
Additional: Hyacinth bean, malunggay, and sweet potato growing on a bamboo fence.

Table 18. Yield and nutrient contribution of Philippines home garden IV, April to June, 1982.

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	Chinese leek[z]	131	29.5	0.23	3	6.9	200.1	5.1	2128	80.5
2	Sweet pepper	32	1.0	0.03	1	0.4	3.6	0.3	88	30.9
	[Common cabbage	63	6.2	0.10	2	1.4	42.0	0.4	2	40.6
	[Rape greens	48	31.1	0.65	3	27.1	1883.4	42.5	5327	571.4
3	[Pai-tsai	29	7.7	0.27	3	3.8	399.6	7.0	505	167.4
	[Head lettuce	28	4.5	0.16	1	5.0	192.0	7.5	88	20.0
	[Chinese mustard	26	3.0	0.12	1	2.9	213.6	2.4	378	136.8
	[Pai-tsai	26	2.3	0.09	1	1.4	164.7	1.6	144	41.0
	Kale	49	4.2	0.09	3	1.9	225.9	4.3	225	84.4
	Sweet potato tips[y] (I-426)	30	4.4	0.15	2	3.3	226.5	16.5	318	56.0
Total			93.9	1.89		54.1	3551.4	87.6	9203	1229.0
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						36.3	114.6	178.8	350.6	877.9

[z] Continued from garden III.
[y] Growing on a bamboo fence.
[= Intercropped.
Additional: Hyacinth bean and malunggay also growing on the bamboo fence.

Table 19. Yield and nutrient contribution of vitamin A home garden I, June to September, 1982.

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	42	0.9	0.28	1	5.0	473	9.5	498	207
	[Tomato[z]	38	10.8	0.02	3	0.2	3	0.1	222	5
2	Tomato[z]	42	0.5	0.01	1	0.1	2	0.1	111	2
3	Leaf lettuce	54	14.2	0.26	4	4.4	224	17.7	1269	62
	Chinese mustard	34	6.8	0.20	1	4.8	356	4.0	630	228
	Pai-tsai	22	8.2	0.37	1	7.8	688	9.3	858	192
Total			41.4	1.14		22.3	1746	40.7	3588	696
RDA for a family of five						149.0	3100.0	49.0	2625	140
% of RDA contributed by garden						15.0	56.3	83.1	136.7	497.1

[z] Damaged.
[= Intercropped.
Additional: Mango and papaya trees growing around a bamboo fence.

Table 20. Yield and nutrient contribution of vitamin A home garden II, October to December, 1982.

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	107	24.6	0.23	5	7.1	439.3	11.5	1145	107.0
	Garlic and shallot[z]	38	2.57	0.07	1	1.3	62.7	1.1	64	18.2
						0.3	14.6	0.3	18	1.8
2	Carrot 531	98	21.42	0.22	3	2.2	79.2	4.6	3579	22.7
	Garlic and shallot[z]	35	1.9	0.05	1	0.9	42.0	0.8	43	12.2
						0.3	13.0	0.3	16	1.6
3	Kale	25	18.5	0.74	2	12.6	1406.0	29.6	4055	188.7
	[Spinach	41	3.9	0.10	1	2.6	135.0	2.2	498	41.3
	[Broccoli	76	8.93	0.12	2	3.6	42.0	1.0	280	59.5
	Garlic and shallot[z]	35	2.66	0.08	1	1.4	67.2	1.2	68	19.5
						0.4	20.8	0.4	26	2.6
Total			84.5	1.61		32.7	2321.8	53.0	9792	528.1
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						22.0	74.9	108.2	373.0	377.2

[z] Growing around the edges of beds.
[= Intercropped.
Additional: Mango and papaya trees growing around a bamboo fence.

Table 21. Yield and nutrient contribution of vitamin A home garden III, January to March, 1982.

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	Amaranth	46	8.3	0.18	2	5.9	424.8	16.2	643	91.3
	Shallot	46	5.22	0.11	1	2.3	114.4	2.2	141	14.4
2	[Pai-tsai	49	17.6	0.36	4	5.4	658.8	6.5	576	164.2
	[Tomato	89	5.9	0.07	3	0.6	11.9	0.4	78	16.4
3	[Spinach	56	7.3	0.13	2	1.6	118.3	3.9	706	31.6
	[Chinese mustard	30	3.2	0.11	1	2.6	195.8	2.2	347	125.4
	Pai-tsai [(ching chiang 606)	30	5.4	0.18	2	4.1	381.6	8.6	508	162.5
	[Head lettuce	18	4.2	0.23	1	2.8	126.5	5.1	656	82.6
	Garlic and shallot[z]	50	5.04	0.10	1	1.8	84.0	1.5	86	24.4
						0.5	26.0	0.5	32	3.3
Total			62.2	1.47		27.6	2142.1	47.1	3773	716.1
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						18.5	69.1	96.1	143.7	511.5

[z] Growing around the edges of beds.
[= Intercropped.
Additional: Mango, papaya, and passion fruit trees growing around a bamboo fence.

Table 22. Yield and nutrient contribution of vitamin A home garden IV, April to June, 1982.

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	Amaranth[z]	29	6.5	0.22	2	8.6	979.0	14.7	1052	92.6
	Water convolvulus	80	18.0	0.23	3	5.5	255.2	17.2	554	107.8
2	Tomato 601[z]	21	10.9	0.52	7	4.7	88.4	2.6	577	121.7
	Amaranth	80	22.8	0.29	4	12.2	1380.4	17.1	1662	135.7
3	Head lettuce	39	7.1	0.18	1	5.6	216.0	8.5	99	22.5
	Kale	28	2.9	0.14	3	2.9	351.4	6.7	350	131.3
	Pai-tsai (ching chiang)	24	6.2	0.26	1	7.0	603.2	9.9	993	201.2
Total			75.4	1.84		46.5	3873.6	76.7	5287	812.8
RDA for a family of five						149.0	3100.0	49.0	2625	140.0
% of RDA contributed by garden						31.2	125.0	156.5	201.4	580.6

[z] Continued from garden III.
Additional: Mango, papaya, and passion fruit trees growing around a bamboo fence.

Table 23. Expected versus actual results from four AVRDC home gardens, June 1981 to June, 1982. Means over four seasons.

	Yield/ day (kg)	Percent contribution to RDA[z]: Protein	Calcium	Iron	Vitamin A	Vitamin C
Expected		measurable	40	40	80	100
Indonesia garden	1.66	25.3	74.8	112.6	182.7	524.9
Thailand garden	1.55	21.9	72.0	100.1	128.5	506.5
Philippine garden	1.11	20.6	49.4	77.8	186.6	425.7
Vitamin A garden	1.51	21.7	81.3	111.0	213.7	491.6

[z] Recommended daily dietary allowance.

Market Garden

Introduction

Today, the pure subsistence farm is a rarity. More often than not small farms in developing countries are a mixture of subsistence by farming and subsistence through cash purchases of goods. In poor rural areas it is frequently difficult to earn cash due to a lack of employment opportunities. However, on-farm income generating schemes can be one answer to the employment-cash-subsistence problem.

The objective of the market garden is to increase the income of the rural poor in developing countries (households existing on less than US $1,000 per annum) by at least 30% by developing small income-generating gardens to grow salable crops that are in demand at local markets.

Materials and Methods

Surveys were first conducted at local markets to find out which vegetables in the coming months would be low in supply and high in demand, and could therefore command a good price. The most promising of these vegetables were grown in a 10 x 20 m plot consisting of 13 raised beds (10 x 1.5 m, 25 cm high). Standard AVRDC cultural practices were followed. During the 1981-82 season 23 crops were planted in a total of four seasonal gardens. At harvest time the vegetables were sold wholesale at local markets.

Results

The yield of each vegetable in each garden and the corresponding wholesale market prices were recorded for the year (Tables 24 to 27). A summary of these results (Table 28) shows that the market garden produced 2,356 kg of vegetables which sold at the wholesale market for NT $18,394 (US $460). Deducting input costs (seeds, fertilizer, and pesticide) of NT $2,596, the market garden made a net profit of NT $15,798 (US $394). Labor costs are not included under the assumption that household members will do the labor.

Conclusions

The market garden more than met its objectives in the first year of operation. It demonstrated that it could increase the per annum net income of a poor rural household by more than 30%. This percentage could be increased by selling the produce directly to the consumer, instead of to wholesalers as in the case of the experimental garden.

These data can be useful for agricultural ministries in developing countries that are charged with the responsibility of planning and implementing income-generating food production projects for the rural poor.

Table 24. The yield and price record of market garden I, July to September, 1981.

Plot	Crop	Seed source	Times harvested	Total yield (kg)	Market price (NT$)	Growing period (Days)
1-2	Chinese cabbage (No. 62)	AVRDC	3	27.0	375	48
3-4	Tomato (1131-0-0-38-4-0)	AVRDC	8	33.1	291	88
5-6	Chinese mustard	Local	2	22.2	603	29
7-8	Radish	Thailand,local	4	45.6	347	55
	Chinese mustard	Local	2	25.8	632	31
9-10	Eggplant	Local	9	49.9	788	83
11-12	Cucumber	Indonesia,local	8	97.0	470	68
Total				300.6	3506	

Table 25. The yield and price record of market garden II, October to December, 1981.

Plot	Crop	Seed source	Times harvested	Total yield (kg)	Market price (NT$)	Growing period (Days)
1-2	Broccoli (G.K. 70)[z]	Known You	7	34.1	869	61
	Spinach[y]	Local	5	42.0	655	44
3-4	Cabbage (S.A. 633)	Known You	6	101.0	858	58
5-6	Common cabbage	Local	2	48.7	901	71
	Broccoli (F.G. 2)[x]	Local F_1	8	52.8	243	65
7-8	Chinese mustard	Local	2	25.8	632	31
	Sweet pepper	Known You	7	20.0	498	73
9-10	Eggplant[z]	Local	6	31.1	482	13
9	[Cauliflower (F.E. 2)	Known You	6	28.0	258	69
10	[Broccoli (F.G. 2)[z]	Local F_1	7	32.7	233	75
11-12	Yard-long bean[z]	Known You	9	42.2	625	65
	Spinach[w]	Local	3	54.3	236	38
13	Chinese leek[z]	Local	3	18.6	327	148
	Kale	Local	1	6.7	27	24
Total				538.0	6844	

[z] Continued from garden I.
[y] Intercropped with cabbage, which was not harvested in this period.
[x] Intercropped with carrot, which was not harvested in this period.
[w] Intercropped with broccoli, which was not harvested in this period.
[= Intercroppped.

Table 26. The yield and price record of market garden III, January to March, 1982.

Plot	Crop	Seed source	Times harvested	Total yield (kg)	Market price (NT$)	Growing period (Days)
1-2	[Cabbage (S.A. 633)	Known You	3	93.5	150	68
	[Chinese mustard	Local	3	12.0	28	54
	[Pai-tsai	Local	3	44.0	71	27
3-4	[Garland chrysanthemum[z]	Local	7	100.0	448	73
	[Sweet pepper[z]	Known You	1	3.5	30	103
	[Head lettuce	Local	1	11.0	61	32
5-6	[Carrot (531, ideal)[z]	Known You	2	35.5	72	95
	[Broccoli[z]	Local F_1	5	23.5	186	56
7-8	[Kale[z]	Local	2	29.0	117	30
	[Broccoli[z]	Local F_1	4	53.5	531	62
	[Head lettuce	USA	2	27.0	74	46
9-10	[Pai-tsai	Local	5	50.6	166	31
	[Chinese mustard	Local	2	26.6	137	23
	[Head lettuce	USA	4	45.5	154	42
	[Pai-tsai (ching-chiang)	Local F_1	3	13.5	12	27
11-12	Broccoli[z]	Local F_1	4	59.9	462	64
	Pai-tsai (ching-chiang 606)	Known You	3	31.5	41	23
13	Chinese leek[z]	Local	2	23.7	254	55
Total				683.8	2994	

[z] Continued from garden II.
[= Intercropped.

Table 27. The yield and price record of market garden IV, April to June, 1982.

Plot	Crop	Seed source	Times harvested	Total yield (kg)	Market price (NT$)	Growing period (Days)
1-2	Head lettuce[z]	USA	4	58.0	166	45
	[Yard-long bean	Local	9	43.6	349	83
	[Chinese mustard	Local	1	5.5	63	27
3-4	Sweet pepper[z]	Known You	2	4.0	30	17
	[Cauliflower	Known You	4	13.0	159	44
	[Rape greens	Local	3	12.5	118	29
	[Kale	Local	1	10.0	120	25
	[Rape greens	Local	3	48.1	175	35
5-6	[Spinach[z]	Local	3	46.5	519	40
	[Common cabbage[z]	Local	1	71.5	174	55
	[Kale	Local	1	1.2	38	16
	Pai-tsai[y]	Local	2	32.2	139	30
7-8	Celery[z]	Local	1	26.0	74	40
	Pai-tsai	Local	3	38.5	189	30
	Pai-tsai[x]	Local	3	41.4	201	35
9-10	[Garland chrysanthemum[z]	Local	5	94.5	352	53
	[Cucumber	Local	8	66.5	941	48
	Rape greens[w]	Local	3	55.5	210	35
11-12	Water convolvulus[z]	Local	1	14.5	55	42
	[Broccoli	Local F_1	4	15.7	169	49
	[Kale	Local	1	0.5	19	16
	[Chinese mustard	Local	3	64.5	315	30
	[Rape greens	Local	4	19.1	56	36
13	Chinese leek[z]	Local	3	51.5	419	116
Total				834.3	5050	

[z] Continued from garden III.
[y] Intercropped with cauliflower, which was not harvested in this period.
[x] Intercropped with welsh onion, which was not harvested in this period.
[w] Intercropped with common cabbage, which was not harvested in this period.
[= Intercroppped.

Table 28. Yield and profit of AVRDC market gardens, July, 1981 to June, 1982.

	Yield (kg)	Wholesale market price (NT$)	Input costs (NT$)	Net profit (NT$)
Garden I	300.6	3506	697	2809
Garden II	538.0	6844	885	5959
Garden III	683.8	2994	480	2514
Garden IV	834.3	5050	534	4516
Total	2356.7	18394	2596	15798 (US $394)

Soil Science

Nitrogen Application for Chinese Cabbage

Introduction

The recommended practice of splitting nitrogen application for Chinese cabbage four times (all seasons) is inconvenient and costly. Experiments have been conducted for four years to evaluate the effect of concentrated fertilization and to propose a new fertilization regimen for Chinese cabbage.

Materials and Methods

In March, 1982, Chinese cabbage cultivar Fong Luh was planted in a randomized complete block design with four replications. Various N fertilizer treatments were tested, consisting of basal applications only and split applications ranging from 80 to 200 kg/ha. P_2O_5 and K_2O were applied in the recommended amounts (80 kg and 100 kg split 50-50, respectively).

In an autumn experiment, the effect of rice straw composts containing ammonium sulfate, chicken manure, and various rates of crotalaria was examined. Fong Luh, transplanted October 27, was treated with 80-170 kg/ha of nitrogen, 20 t of five kinds of compost, and 10 t of compost + 40 kg/ha of N.

Results

The amount and method of nitrogen application did not significantly affect the marketable yield of Chinese cabbage compared with the present recommended fertilization technique (Figure 1). The natural supply of nitrogen, which was estimated from the yield of the no-nitrogen plot, was judged insufficient to produce high yields. In addition, the efficiency of basal dressing was found to be higher than that of top dressing (Figure 2). In the fall experiment, unmatured compost caused a decrease in yield.

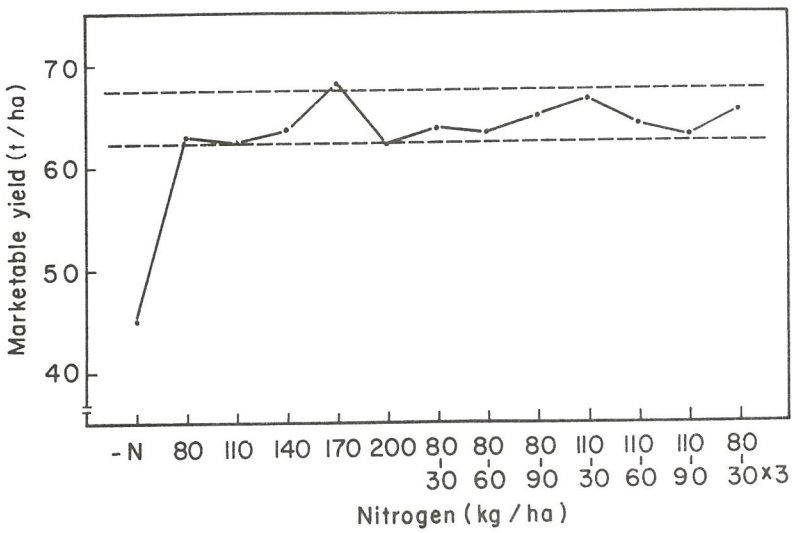


Figure 1. Effect of nitrogen fertilizer on yield of Chinese cabbage.

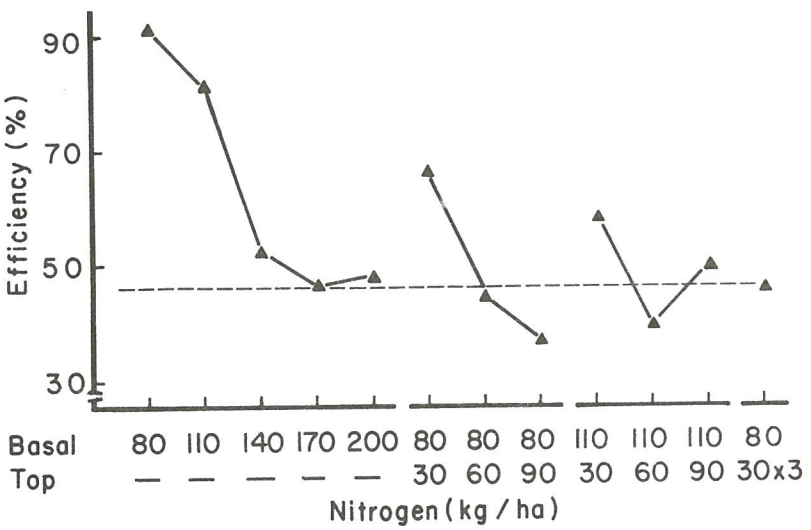


Figure 2. Efficiency of nitrogen fertilizer for Chinese cabbage.

Conclusions

Since four years of experiments supported the conclusion that nitrogen rates do not affect marketable yield, and basal dressing was found more efficient than top dressing, a single basal application of 110-140 kg/ha is now recommended for Chinese cabbage in all seasons. In addition, mulching with 5 t/ha of rice straw is advised, especially in the rainy season.

Field Preparation to Minimize Continuous Cropping Hazard for Mungbean

Introduction

A practical measure is necessary to eliminate the common stunting of mungbean grown after various upland crops. Since mungbean growth is usually normal after rice cultivation, submergence treatments with and without the addition of organic matter were tested under field conditions to determine the effects of anaerobiosis on mungbean growth.

Materials and Methods

A 10 x 10 m plot was prepared, after a previous cropping, with and without the incorporation of organic matter such as rice straw, soybean stalks, and compost. Treatments were also divided by non-flooding, flooding, and flooding with puddling (Tables 1 and 2).

Mungbean was sown after one month of the above treatments and yield data were collected.

Table 1. Nutrient contents of the organic additives (%).

	Total N	Total C	P_2O_5	K_2O	Ca	Mg
Rice straw	0.58	37.51	0.30	1.33	0.17	0.13
Soybean stalks	1.87	40.85	0.51	0.91	0.82	0.37
Compost	1.08	9.42	0.77	0.90	2.56	0.78

Table 2. Experimental treatments.

Additives		Land Preparation[z]
a. None (check)		Flooding + Puddling
b. Rice straw	10 t/ha	
c. Soybean stalks	5 t/ha	
d. Mushroom compost	10 t/ha	
a. None		Flooding
b. Rice straw	10 t/ha	
c. Soybean stalks	5 t/ha	
d. Mushroom compost	10 t/ha	
a. None		None
b. Rice straw	10 t/ha	
c. Soybean stalks	5 t/ha	
d. Mushroom compost	10 t/ha	

[z] All plots were rotovated at the beginning of the experiment and once every three weeks thereafter.

Results

Yield was very poor in the unflooded treatments (Figure 3). Yields more than doubled, however, after one month of flooding. Puddling during flooding favored succeeding mungbean growth. Yield in the soybean stalks treatment improved to 1 t/ha.

Conclusions

The treatments tested did not effectively eliminate the continuous cropping hazard. However, combination of various treatments may prove more effective.

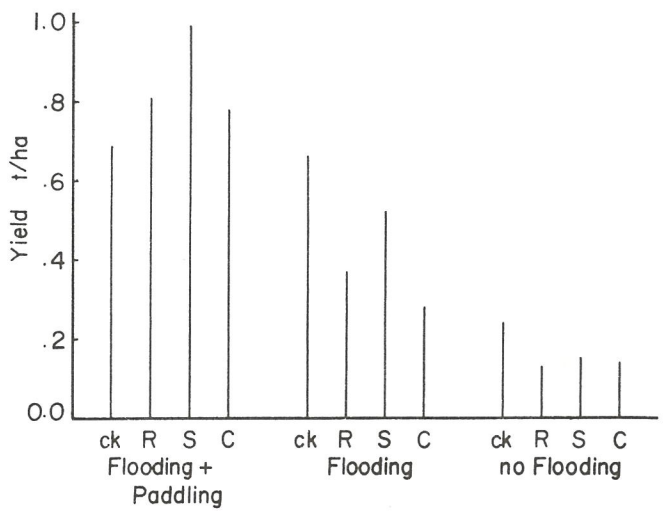


Figure 3. Effect of flooding pretreatments with incorporation of different kinds of organic matter on mungbean yield.

The Effect of Organic Materials on Nodule Activity and Yield of Soybean

Introduction

If available nitrogen in the soil is abundant, soybean prefers to absorb it with consequent retardation of nitrogen fixation. Nodule formation in legumes decreases sharply with increased nitrogen application. Application of carbonacious organic matter decreases mineral nitrogen in soils, however, and can be utilized to encourage soybean nodulation. A more economical utilization of available nitrogen in the soil was sought through the application of organic matter as a mediator of nitrogen.

Materials and Methods

Nine root boxes (10 x 30 x 50 cm) were prepared with glass on one side and packed with 23 kg of sieved fresh soil which had been treated with various amounts of nitrogen and organic matter (rice straw and crotalaria). Soybean isolines To1-0 (non-nodulating) and To1-1 (nodulating) were sown close to the glass and root boxes were placed diagonally for observation of root development and nodule formation.

In a corresponding field experiment, To1-1 and To1-0 were grown from July 15 to September 18, 1982, in 3 x 4 m plots with three replications. Soybeans were planted on 1 m beds with two rows per bed, 5 x 50 cm between hills, and two plants per hill. Treatments 1 through 3 received N applications (NH_4SO_4) of 0, 30 kg/ha (basal), and 60 kg/ha (30 kg/ha basal, 30 kg/ha at flowering) respectively; in treatments 4 through 6 the same N applications were supplemented with 10 t/ha of rice straw. In addition, plots received basal applications of KCl and Ca-Superphosphate, 60 kg/ha each.

Results

In the root box experiment, fertilizer nitrogen favored increases in pod fresh weight, seed number, and seed dry weight (Figure 4). Application of 10 g rice straw decreased these three characteristics due to a lack of nitrogen. They were recovered by the addition of 0.24 g N. Crotalaria application gave a better yield than rice straw application.

Nodule fresh weight was smallest with a heavy application of nitrogen but nodule number was smallest with rice straw alone (Figure 5). Both nodule weight and number were recovered by application of 0.24 g N. Average nodule weight was largest in the treatments of rice straw alone and rice straw (20 g) with 0.48 g N.

In the field, yields of the two isolines responded differently to the increase of nitrogen fertilizer (Table 3). The non-nodulating isoline responded well to applied nitrogen with and without rice straw. Yields of To1-1 were two to three times higher than those of To1-0, but did not increase in proportion to nitrogen application even in rice straw application plots.

Conclusions

Application of rice straw to fertile soils accelerates nodule formation of nodulating soybean. The relationship between nodule activity and yield was not determined.

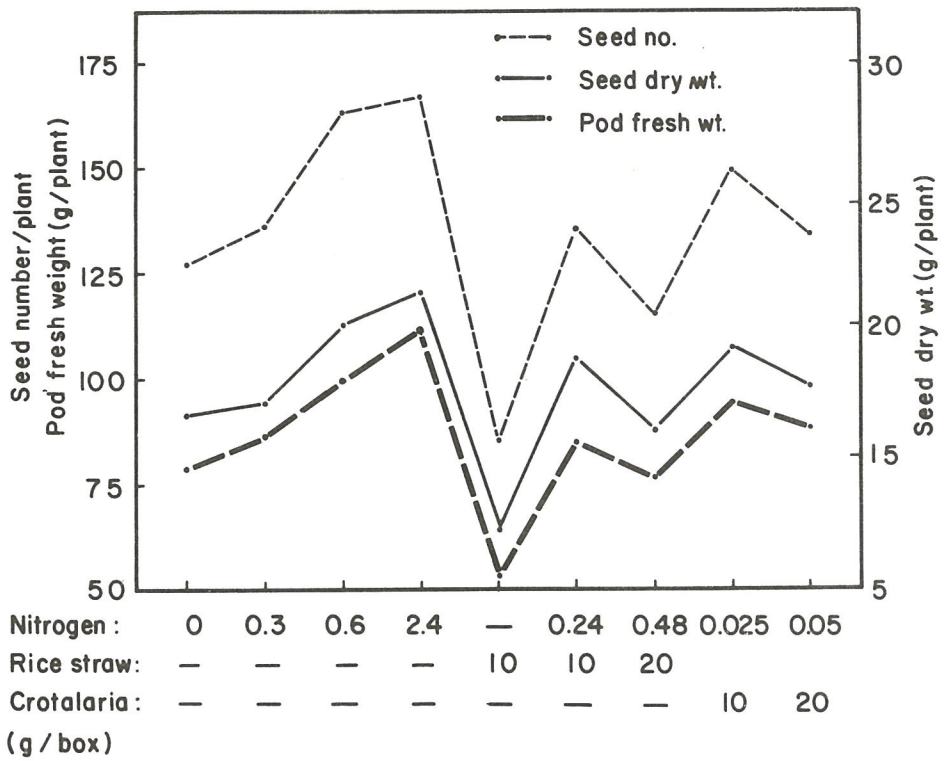


Figure 4. Effect of nitrogen and organic matter applications on soybean growth in a root box.

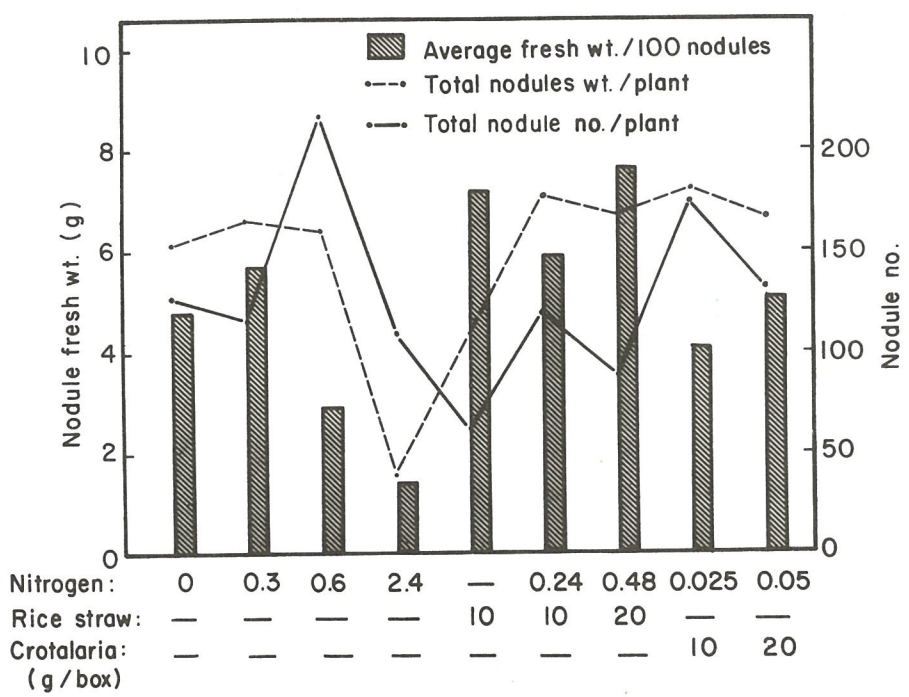


Figure 5. Effect of nitrogen and organic matter applications on nodulation of soybean grown in a root box.

Table 3. The effect of varying initial nitrogen status on the yield of soybean isolines.

Treatment (t/ha)[z]		Yield (t/ha)	
		Tol-1	Tol-0
1. N-0	RS-0	3.473 b	1.053
2. N-30	RS-0	3.483 b	1.645
3. N-30-30	RS-0	3.426 b	1.855
4. N-0	RS-10	3.280 b	0.930
5. N-30	RS-10	3.545 b	1.370
6. N-30-30	RS-10	3.830 a	1.607
Mean		3.484	1.410
L.S.D. (0.05)		0.280	

[z] RS = rice straw.

Fertility Comparisons of Taiwan Soils

Introduction

Three alluvial soils of different origins - salt affected alluvial soil from the west coast, latosol, and hill soils - were collected as representative of the main soils in Taiwan. The fertility of these soils was compared with AVRDC soil in a pit experiment.

Materials and Methods

In 1981-82, soils were collected from the surface 15 cm layer of six different fields: Kaohsiung DAIS (alluvial soil, slate origin), Tainan DAIS and AVRDC field #29 (both alluvial soil, sandstone and shale origin), a Yuensui farm (salt-affected alluvial soil, sandstone and shale origin), Chiayi TARI (latosol), and Fongshan THES (strongly acidic hill soil). Soils were packed into 0.5 m deep, 1 m^2 pits, and a mungbean-rice-soybean cropping sequence was planted.

Results

Relevant nutrient contents of the soils are shown in Table 4.

Due to strong acidity (pH 4.35), mungbean did not germinate in Fongshan hill soil (Table 5). Mungbean yield was highest in Chiayi latosol and lowest in the saline Yuensui soil. The highest 1,000 seed weight and pod number were recorded in Kaohsiung DAIS soil. Legumes grown on AVRDC soil produced the fewest pods.

Rice production was also best in Chiayi latosol soil. In AVRDC soil, plant height was low.

Soybean production tended differently than mungbean. Yields on the alluvial soils of the Kaohsiung and Tainan DAIS were significantly better than on the other soils due to greater pod number.

Conclusions

Soils with different chemical and physical properties showed different fertility and crop growth response. The relation between soil properties and crop yield must therefore be checked more precisely.

Table 4. General characteristics of various Taiwan soils.

Soil origin	pH	EC mmho/cm	Total N %	P_2O_5 ppm	K_2O ppm	CaO ppm	MgO ppm
Kaohsiung DAIS	5.68	0.48	0.221	64	52	1869	290
Tainan DAIS	6.01	0.09	0.061	139	156	493	84
Fongshan THES	4.35	0.19	0.085	26	124	148	51
Chiayi TARI	5.64	0.12	0.080	46	113	842	132
AVRDC field #29	7.47	0.64	0.067	72	45	2843	315
Yuansui	8.40	0.82	0.112	72	76	4434	764

Table 5. Yield and seed weight of crops grown on various Taiwan soils.

Soil origin	Mungbean VC 3476 Yield	Mungbean VC 3476 1000 seed wt.	Rice Tainan No. 5 Yield	Rice Tainan No. 5 1000 seed wt.	Soybean AGS 62 Yield	Soybean AGS 62 1000 seed wt.
Kaohsiung DAIS	2.76 ab (101)	45.4 a	4.72 b (119)	22.2	4.34 a (123)	17.0 a
Tainan DAIS	2.34 bc (85)	42.2 ab	4.82 b (122)	22.9	4.19 a (118)	15.5 b
Fongshan THES	-	-	2.54 c (64)	22.2	3.29 b (93)	16.5 ab
Chiayi TARI	2.92 a (107)		5.91 a (149)	22.7	3.36 b (95)	16.4 ab
AVRDC field #29	2.74 ab (100)	45.0 a	3.96 b (100)	22.4	3.54 b (100)	16.1 ab
Yuansui	1.99 c (73)	39.8 b	4.34 b (110)	22.7	3.40 b (96)	15.8 b
Mean	2.55	43.3	4.38	22.5	3.68	16.2

- = Mungbean did not germinate due to the strong acidity of the soil. Numbers in parentheses are yield indexes based on yields on AVRDC #29 soil.

Crop Management

Seedling Age and Yield of Transplanted Tomato

Introduction

If tomato seedlings are transplanted too young, they may fail to withstand the field environment. On the other hand, old seedlings may face a greater risk of transplanting shock. In both cases, low yield may result. The objective of this study was to determine the best seedling age for transplanting using yield as the means of evaluation.

Methods and Materials

A split-plot design with four replications was employed. Main plots consisted of three tomato selections, CL 1561-6-0-19-1-4, CL 1591-5-0-1-2-0, and CL 1591-5-0-1-7-6, while the subplots had seedlings of different ages; i.e. 15, 20, 25, 30, and 35 days old. All seedlings were transplanted on the same day.

Results

Yields were significantly affected by the age of the seedling (Table 1). Yields increased substantially as the seedling age increased from 20 days to 25 days (from 69.87 t/ha to 81.85 t/ha). Yields from the older seedlings (30 and 35 days) were practically the same as those of the 25-day-old seedlings. Yield difference was attributed to difference in number of fruits/plant. Fruit size was not affected by seedling age.

Table 1. Effect of the age of tomato seedlings on marketable yield, fall, 1981.

Cultivar	Seedling age, days					Mean
	15	20	25	30	35	
	t/ha					
CL 1561-6-0-19-1-4	68.62	67.75	94.79	91.45	88.20	82.16
CL 1591-5-0-1-2-0	54.15	68.54	77.87	86.53	73.56	72.13
CL 1591-5-0-1-7-6	69.96	73.31	72.90	85.08	82.39	76.56
Mean	63.96	69.87	81.85	87.69	81.38	
L.S.D. (0.05):	Cultivar = NS Seedling age = 8.65 cv. x age = NS					

Conclusions

The results suggest that of the seedling ages tested, the best age for transplanting is between 25 and 35 days old.

Cultural Practices for Summer Tomato

Introduction

Growing tomato during the summer in the tropical lowlands is not profitable, as yields are very low due to high temperature. To overcome this problem, appropriate cultural practices are being studied.

Materials and Methods

The cultural practices employed during summer, 1982 included shading tomato plants with either nylon net or rows of corn and spraying tomato flowers with plant hormones Tomafix, Tomatotone, and Tolerone. Heat sensitive tomato CL 1561-6-0-5-1-3 was used as a test crop. The experiment was carried out in a randomized complete block design with four replications.

Results

All tomato plants were destroyed by a typhoon 54 days after transplanting. Although it was not possible to take yield data, yield attributes - number of fruits/plant and number of clusters which bore fruit - were recorded to be indicative of the treatments. Neither the number of fruits/plant nor the number of clusters was affected by shading. But both were significantly increased by the plant hormone treatments. The number of fruits/plant and clusters/plant, respectively, were: 10.93 and 6.39 for Tomafix, 5.03 and 3.38 for Tomatotone, and 2.96 and 1.83 for Tolerone. The control had 0.08 fruits/plant and 0.08 clusters/plant (Table 2).

Conclusions

Because typhoon damage prevented yield observations, the results of the experiment are inconclusive.

Herbicide Screening for Tomato

Introduction

Results from previous trials indicated that metribuzin was the best herbicide for transplanted tomato, whereas the effect of oxyfluorfen has

been erratic. These herbicides were re-evaluated in 1982; napropamide was also included in this trial.

Materials and Methods

The experiment was planted October 9 in a randomized complete block design with four replications. Individual 3 x 6 m plots consisted of three rows of tomato spaced at 0.3 m within rows and 1 m between rows. Treatments included applying metribuzin, oxyfluorfen, and napropamide at various rates. All herbicides were applied preemergence; metribuzin was also applied postemergence.

Table 2. Effect of cultural practices on yield attributes of tomato grown in summer (1982).

Treatment[z]	Clusters with fruit	Fruit Development
	----------no./plant----------	
Control	0.08	0.08
Corn shading		
0-30 DAT	0.11	0.14
0-40 DAT	0.13	0.13
0-45 DAT	0.08	0.09
0-50 DAT	0.09	0.12
Tolerone (0.1%)		
A	1.83	2.96
B	0.08	0.11
Tomatotone (1.0%)		
A	3.38	5.03
B	0.00	0.00
Tomafix (1.0%)		
A	6.39	10.93
B	0.19	0.28
Nylon shading		
C	0.07	0.11
D	0.01	0.11
L.S.D. (0.05)	0.82	1.92

[z] A = sprayed when cluster had 2-4 flowers open.
B = sprayed on every cluster at 50 days after transplanting (DAT)
C = 35-40% light reduction.
D = 60-65% light reduction.

Results

Yield and weed fresh weight are summarized in Table 3. Oxyfluorfen controlled broadleaf weeds but allowed heavy grass infestation. The reverse was true for napropamide. Moreover, serious crop injury occurred with the napropamide treatments. Consequently, yields from the plots treated with these two herbicides were as low as the weedy check. Metribuzin at rates higher than 0.5 kg/ha controlled both grasses and broadleaf weeds effectively when applied either pre- or postemergence. But crop injury was observed at the early growth stage with the postemergence treatments, especially with application rates higher than 0.5 kg/ha. However, this phytotoxicity disappeared at the later growth stage. Yields of the metribuzin-treated crops slightly surpassed the weed-free check.

Conclusions

Metribuzin is recommended for transplanted tomato.

Table 3. Tomato yield and weed fresh weight as affected by herbicides.[z]

Herbicide	Rate (kg/ha)	Yield (t/ha)	Weed fresh weight (t/ha)	
			Grass	Broadleaf
Weedy check	-	40.25 cde	9.67 a	0.50 c
Weed-free check	-	50.34 abc	0.00 e	0.00 c
Metribuzin (preemergence)	0.50	54.02 ab	4.33 bc	0.00 c
	0.75	59.61 a	3.21 cd	1.08 c
	1.00	56.61 ab	2.67 cd	0.50 c
Metribuzin (postemergence)	0.50	52.14 abc	3.04 cd	0.33 c
	0.75	54.04 ab	2.50 cde	0.12 c
	1.00	56.62 ab	1.50 de	0.08 c
Oxyfluorfen	0.12	38.38 de	5.96 b	2.25 bc
	0.24	44.50 bcde	6.00 b	0.33 c
	0.36	46.50 abcd	4.67 bc	0.58 c
Napropamide	1.00	49.12 abc	3.08 cd	2.71 bc
	2.00	42.94 bcde	2.50 cde	7.79 a
	3.00	32.78 e	2.54 cde	2.67 bc
	4.00	34.08 de	2.21 cde	5.92 ab
4-6 WAT Weed-free	-	47.30 abcd	1.08 e	0.42 c

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Seedling Nursery Methods for Transplanted Chinese Cabbage

Introduction

Loss of Chinese cabbage yield due to transplanting shock is substantial. To avoid this loss, seedlings have been raised in pots, a costly and time-consuming method. In order to reduce transplanting shock and the labor cost of the polyethylene (PE) pot nursery methods, a new technique was devised - slot planting. This method involves partitioning seedling flats with polyvinyl chloride (PVC) strips to confine the roots of individual seedlings in small slots and hence avoid injury during transplanting. The objective of this study was to evaluate the effectiveness of the slot technique as compared to the traditional flat and PE pot methods.

Materials and Methods

The experiment was conducted in a randomized complete block design with five replications. Treatments involved raising Chinese cabbage seedlings in different types of containers, namely plastic flats (conventional method), plastic pots, and flats partitioned into slots with PVC strips. Chinese cabbage cultivar Bing Luh was used as a test crop. Twenty-day-old seedlings were transplanted on September 29. The plants were harvested on November 10 and November 15.

Results

Development of the seedlings raised in flats, as measured by the above-ground fresh weight, was significantly retarded while plants raised in pots and slots were more vigorous. The difference was due to transplanting shock caused by root injury to the seedlings raised in flats. Marketable yield was significantly affected by the different seedling nursery methods. The slot treatment gave the highest yield of 27.5 t/ha while the flat treatment yielded the lowest (Table 4). Yield difference was due to difference in head weight.

Conclusions

The slot treatment can prevent transplanting shock and hence sustain high crop yield. This technique is simpler and less time-consuming than the pot method, taking into account the time used to prepare containers for seeding and transplanting time.

Table 4. Effect of different seedling methods on yield, fresh weight, and number of nonwrapper leaves of Chinese cabbage, fall 1982.[z]

Nursery method	Yield (t/ha)	Total plant weight (kg/plant)	Head weight (kg/head)	Nonwrapper leaves (no./plant)
Flat	24.2 b	2.11 b	0.91 b	15.4 a
Pot	26.0 ab	2.22 ab	0.97 ab	16.1 a
Slot	27.5 a	2.31 b	1.03 a	15.4 a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Leaf-tying and Shading for Summer Chinese Cabbage

Introduction

Chinese cabbage head development is sensitive to temperature. The optimum temperature for head formation is about 15-16°C. In the tropics, the most suitable environments for this crop are found in the highlands year-round and during winter in the lowlands. The objective of this study was to identify measures that could enhance head formation of Chinese cabbage grown during the hot summer in the lowland tropics.

Materials and Methods

A field experiment employing a split plot design was conducted during the summer of 1982. The main plot consisted of two cultivars, Bing Luh and Wen Wu; the subplot treatments were leaf-tying and three levels of shading (light intensity reduction of 35-40%, 50-55%, and 60-65%).

Results

Heading rates were significantly affected by the tying treatment (Table 5). Leaf-tying gave highest heading rates of 95% and 97.5% for Bing Luh and Wen Wu, respectively. This was 17.6% higher than the control for Bing Luh and 21.9% higher for Wen Wu. Heading rate was not affected by shading. Head weight was also increased by leaf-tying while shading caused no effect. Yields of Bing Luh and Wen Wu were 48.7% and 33.4% higher than the control when leaves were tied (Table 5). The higher yield was due to higher heading rate and heavier or firmer head.

Conclusions

Leaf-tying effectively increases the heading rate and head weight of heat sensitive Chinese cabbage grown during the summer in the lowland tropics.

Table 5. Marketable yield and heading rate as affected by leaf-tying and shading, summer, 1982.

Cultivar	Treatment					Mean
	Control	Leaf-tying	Shading-light reduction, %			
			35-40	50-55	60-65	
	Marketable yield t/ha					
Wen Wu	25.04	33.41	16.80	19.76	17.46	22.49
Bing Luh	19.14	28.46	20.67	16.85	16.64	20.35
Mean	22.09	30.94	18.74	18.31	17.05	
L.S.D. (0.05)	Treatment means					4.05
	Treatments for the same cultivar					6.36
	Heading rate %					
Wen Wu	80.00	97.50	71.60	76.70	72.50	79.70
Bing Luh	80.80	95.00	85.00	80.00	75.80	83.30
Mean	80.40	96.20	78.30	78.40	74.20	
L.S.D. (0.05)	Treatment means					11.69
	Treatments for the same cultivar					16.53

Herbicide Screening for Chinese Cabbage

Introduction

Weed interference can cause substantial Chinese cabbage yield loss. To address this problem, a herbicide screening study was initiated in 1982.

Materials and Methods

The experiment was conducted using a randomized complete block design. Five herbicides - pendimethalin, nitralin, DCPA, butralin, and alachlor - at various application rates were evaluated. All treatments were applied prior to transplanting and replicated four times.

Results

The results are presented in Table 6. Yield reduction due to weed interference was 26.8% (19.7 and 14.42 t/ha for the weed-free and weedy

check, respectively). Crops were significantly affected by herbicide application. The alachlor treated crop gave the lowest yield (14.56 t/ha), because the herbicide severely injured the crop. Although the pendimethalin, nitralin, and butralin treated crops yielded as high as the weed-free check, the herbicides caused some plant injury during the early growth stage. (This effect was more obvious in the preliminary trial during the spring season.) The DCPA treated crop was uninjured and also yielded as high as the weed-free check. Yield reduction was due to smaller head size.

Conclusions

The results show that DCPA may be the best herbicide for Chinese cabbage. It will be further tested against pendimethalin, nitralin, and butralin in different planting seasons. Alachlor, however, is not a suitable herbicide for Chinese cabbage.

Table 6. Yield, total weight, and head weight of Chinese cabbage following herbicide application, fall, 1982.[z]

Herbicide application (kg/ha)	Yield (t/ha)	Plant weight	
		Total (t/ha)	Head (kg/head)
Weedy check	14.42 b	1.14 b	0.62 cd
Weed-free check	19.70 a	1.67 a	0.75 ab
Pendimethalin			
0.50	18.60 a	1.56 a	0.71 bc
1.00	19.40 a	1.66 a	0.73 abc
1.50	18.54 a	1.50 a	0.70 bc
Nitralin			
0.75	20.16 a	1.60 a	0.80 ab
1.00	20.72 a	1.78 a	0.79 ab
1.25	21.06 a	1.74 a	0.80 ab
DCPA			
2.50	19.95 a	1.52 a	0.76 ab
5.00	20.59 a	1.60 a	0.77 ab
7.50	21.92 a	1.71 a	0.85 a
10.00	20.40 a	1.69 a	0.80 ab
12.50	21.93 a	1.74 a	0.82 ab
Butralin			
1.00	20.86 a	1.70 a	0.79 ab
2.00	20.24 a	1.68 a	0.76 ab
Alachlor			
2.00	14.56 b	1.17 b	0.56 d

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

N Scheduling and Rate for Sweet Potato

Introduction

In order to use N for sweet potato production efficiently, a field trial was carried out to determine the best scheduling for applying N fertilizer.

Methods and Materials

A randomized complete block design with five replications was employed using sweet potato selection I 57 as a test crop. Every treatment, except the control, received total N of 90 kg/ha. The treatments included all N applied at planting; 1/2 N at 0 and 20 DAP, 0 and 30 DAP, 0 and 40 DAP, and 0 and 50 DAP; 1/3 N at 0, 20, and 80 DAP, 0, 30, and 80 DAP, 0, 40, and 80 DAP, and 0, 50, and 80 DAP.

Results

The results are presented in Table 7. Yields were significantly affected by both scheduling and rate of N application. When N was split, applied at planting and either 30, 40 or 50 DAP, the yield was higher than the control. On the other hand, when N was applied at planting only or split into three applications, the yield was not better than the control. Among the different N schedulings, applying half of the fertilizer at planting and the other half at 50 DAP resulted in the highest yield.

Table 7. Sweet potato root yield[z] as affected by N scheduling and rate, 1982.

Time of application (DAP)	Yield (t/ha)	
	Total	Marketable
Control	11.48 c	9.67 c
90 kg N		
0	11.55 c	9.72 c
45 kg N/application		
0, 20	13.28 abc	11.48 abc
0, 30	14.68 ab	13.02 a
0, 40	14.52 ab	12.53 ab
0, 50	15.62 a	13.37 a
30 kg N/applicaton		
0, 20, 80	12.77 abc	10.15 bc
0, 30, 80	12.68 abc	10.80 abc
0, 40, 80	13.40 abc	11.35 abc
0, 50, 80	12.12 bc	9.85 bc

[z] Means within a colum followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Conclusions

Timing of N fertilizer application is important for maximum benefit. Under the environmental conditions of this study, splitting N into two applications gave better yields than single or three-way split applications. The best strategy was to apply half of the fertilizer at planting and the other half 50 DAP.

Sweet Potato Yield and Planting Dates

Introduction

It has been observed that the vegetative growth of sweet potato grown during summer is very vigorous whereas the root yield is extremely low. On the other hand, yield during the cool season is quite high. Obviously, temperature is one of the factors affecting root development. The objective of this study was to determine the suitable time for planting sweet potato using temperature as the determinant factor.

Methods and Materials

A split plot design with three replications was used. The main plots consisted of three sweet potato cultivars while the subplots employed different planting dates (at 10 day intervals from August 7 to November 25). Plants were harvested at 130 days.

Results

Accumulated temperatures from different growing periods, i.e. 0-30, 0-60, 0-130, 30-130, and 60-130 days after planting (DAP), were calculated and correlated with yield for each planting. The results showed that the accumulated temperature of 0-60 DAP gave the best correlation with yield. Yield and the accumulated temperature of the 60 DAP are presented in Table 8. Yields were reduced when the accumulated temperatures were either too high or too low. The lowest yields of 7.69 and 7.58 t/ha resulted from the August 17 and November 25 plantings when the accumulated temperatures were 1043.9 and 452.1°C-days, respectively.

Conclusions

The data indicate that the best planting period was between September 16 and October 16 or when the accumulated temperature was between 689.9 and 918.5°C-days. With high temperature, top growth was increased and number of roots/plant was reduced. With low temperature, top growth and average root weight were reduced.

Table 8. Root yield of sweet potato and accumulated temperature (base 10°C) of the first 60 days after planting following different planting dates, AVRDC, 1981.[z]

Planting date	Yield (t/ha)	Accumulated temperature (°C-days)
August		
7	8.24 c	1073.0
17	7.69 c	1043.9
27	11.04 bc	1000.7
September		
6	14.37 b	975.4
16	19.38 a	918.5
26	11.29 bc	872.1
October		
6	14.27 b	774.4
16	18.22 a	689.9
26	13.42 b	607.4
November		
5	14.60 b	557.0
15	12.71 b	517.5
25	7.58 c	452.1

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Herbicide Screening for Mungbean

Introduction

For many years, butralin has been used as a herbicide for mungbean on the AVRDC farm. However, in 1981, when used in summer planting for the first time, butralin failed to control weeds satisfactorily, while metolachlor and Galex 500 (metolachlor + metobromuron) were more effective. This indicates that one herbicide cannot be recommended for year-round use and that season-specific herbicides should be recommended instead. Accordingly, butralin, metolachlor, and Galex 500 were tested for their effectiveness in three different planting seasons (spring, summer, and fall).

Methods and Materials

The experiments were carried out in a randomized complete block design with four replications. Varying rates of the three herbicides

were employed as treatments. Mungbean line VC 1628 A was used as the test crop.

Results

The results are presented in Table 9. Weed infestation during the spring planting was much higher than during the summer and fall plantings. Weed interference resulted in yield losses of 79.3%, 47.7%, and 3.8% for spring, summer, and fall, respectively. The best treatment for spring was Galex at 3.0 kg/ha, which gave the highest yield and controlled both grasses and broadleaf weeds as effectively as the weed-free check. In summer, both Galex and metolachlor (at application rates higher than 1.5 kg/ha) gave better control of broadleaf weeds than butralin. Yields in all treatments were higher than the weedy check. Due to very low weed pressure in the fall planting, yields of all treatments were equal. Yield differences in spring and summer were due to differences in plant stand and number of pods/plant.

Table 9. Seed yield of mungbean and weed fresh weight as affected by herbicide applications, 1982.[z]

Treatment kg ai/ha	Yield (t/ha)		
	Spring	Summer	Fall
Weedy check	0.40 d	0.68 b	1.26 a
Weed-free check	1.93 ab	1.30 a	1.31 a
Butralin			
2.0	1.29 bc	1.20 a	1.44 a
Metolachlor			
1.0	1.16 bc	1.42 a	1.42 a
1.5	1.17 bc	1.28 a	1.40 a
2.0	1.08 cd	1.25 a	1.40 a
2.5	1.42 bc	1.38 a	1.29 a
Galex[y]			
1.5	1.55 abc	1.44 a	1.43 a
2.0	1.87 ab	1.49 a	1.28 a
2.5	1.60 abc	1.34 a	1.47 a
3.0	2.22 a	1.43 a	1.36 a

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

[y] Galex = Metolachlor + Metobromuron at equal rate of 250 g + 250 g/l.

Conclusions

The best herbicide for weed control in mungbean during the spring season, when the major weeds included both broadleaf weeds and grasses, was Galex at the rate of 3.0 kg/ha. Although all herbicides were equally effective during the summer trial, based on the results of a 1981 trial only Galex and metolachlor can be recommended for summer mungbean.

Weed Competition in Mungbean

Introduction

To minimize the labor cost of hand weedling in the cultivation of mungbean, a study was initiated in spring, 1982 to determine the critical period of weed competition.

Methods and Materials

A randomized complete block design with four replications was employed. Mungbean was kept weed-free or allowed to be infested with weeds for different lengths of time after planting. The crop was spaced 10 cm apart within each row and 25 cm between rows. The crop was harvested twice and the total growing duration was 87 days.

Results

Previous results had shown that the critical period of weed competition was between 30 and 60 days after planting when mungbean was planted 20 cm apart within each row and 25 cm between rows. The results of the present trial are presented in Table 10. Mungbean kept weed-free for 30 days after planting (DAP) yielded as high as the weed-free check (2.06 vs 1.76 t/ha). No additional yield was gained when mungbean was kept weed-free longer than 30 DAP. Crops left weed infested longer than 30 DAP showed significant yield reductions.

Conclusions

Mungbean was able to tolerate weed infestation for up to 30 DAP without yield loss. Therefore, when mungbean is planted 10 cm apart within rows, only one weeding 30 DAP is needed to minimize labor costs and suffer no significant yield loss.

Table 10. Effect of weed interference on yield and plant stand of mungbean, spring, 1982.[z]

Duration of weed interference (DAP)	Seed yield (t/ha)	Plant stand (no./m^2)
Weed-free		
15	1.22 cde	13.30 e
30	2.06 a	22.35 bc
45	2.16 a	26.60 a
60	1.98 a	24.30 ab
75	2.02 a	26.65 a
to harvest	1.76 ab	24.70 ab
Weed-infested		
15	2.00 a	25.55 ab
30	1.91 ab	24.25 ab
45	1.54 bc	16.75 d
60	1.04 de	14.75 d
75	1.35 cd	20.20 c
to harvest	0.89 e	11.65 e

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Herbicide Screening for Soybean

Introduction

Alachlor controls grasses effectively and has been extensively used for weed control in soybean. Under heavy weed infestation, however, its performance is unreliable. In 1981 a screening trial was initiated to find a more effective herbicide to replace alachlor. In summer, 1981, metolachlor and Galex were found promising. These treatments were further evaluated in spring and summer, 1982, under the different types of weed infestation of the two seasons.

Methods and Materials

The herbicides tested were alachlor, oxyfluorfen, metolachlor, pendimethalin, and Galex. All herbicides were applied preemergence. The experiment was conducted in a randomized complete block design with four replications. Plot size was 2 x 6 m.

Results

Results are summarized in Table 11. For the spring trial, the major weeds were broadleaf types. Although statistically these weeds were controlled by all herbicides, some were not supressed by

metolachlor resulting in yield reduction compared to the weed-free check. Yields under other treatments except alachlor were as good as the weed-free check.

Grasses were the major weeds during the summer. They were well controlled by metolachlor and Galex and poorly controlled by oxyfluorfen. The effect of pendimethalin and alachlor was moderate. Only yields from metolachlor and Galex were comparable to the weed-free check.

Conclusions

Galex and pendimethalin appear to be good herbicides for the spring season whereas metolachlor and Galex perform the best in summer.

Table 11. Effectiveness of herbicides for soybean, 1982.[z]

Herbicide rate (kg/ha)	Spring			Summer		
	Yield	Grass	Broadleaf	Yield	Grass	Broadleaf
	t/ha					
Weedy check	1.52 e	1.12 a	12.05 a	1.24 f	5.52 a	0.05 bc
Weed-free check	3.12 a	0.00 b	0.00 b	3.37 a	0.00 d	0.00 c
Alachlor						
2.0	2.41 bc	0.05 b	1.57 b	2.28 cd	2.76 bc	0.01 b
Oxyfluorfen						
0.12	3.18 a	1.15 a	0.87 b	1.45 ef	5.62 a	0.02 bc
0.23	3.19 a	0.45 ab	0.00 b	1.67 ef	3.65 ab	0.00 c
Ala. + Oxy.						
2.0+0.12	3.30 a	0.00 b	0.00 b	2.78 abc	2.78 bc	0.01 bc
2.0+0.23	3.46 a	0.00 b	0.00 b	1.96 de	5.47 a	0.01 bc
Metolachlor						
1.0	1.69 de	0.12 b	2.62 b	3.12 ab	1.66 bcd	0.03 bc
1.5	1.79 de	0.00 b	2.72 b	3.27 ab	0.30 d	0.21 a
2.0	1.90 cde	0.00 b	3.08 b	3.38 a	0.32 d	0.02 bc
2.5	2.20 ce	0.00 b	2.52 b	2.99 ab	0.26 d	0.04 bc
Galex						
1.5	3.00 a	0.12 b	0.00 b	3.25 ab	0.95 cd	0.15 ab
2.0	2.92 ab	0.00 b	0.00 b	3.08 ab	0.88 cd	0.02 bc
2.5	2.91 ab	0.00 b	0.00 b	3.15 ab	0.34 d	0.04 bc
3.0	3.33 a	0.00 b	0.00 b	3.17 ab	0.15 d	0.01 bc
Pendimethalin						
1.0	3.06 a	0.38 ab	0.00 b	2.66 bc	2.07 bcd	0.08 abc
1.5	3.22 a	0.00 b	0.00 b	2.88 ab	1.62 bcd	0.01 bc
2.0	3.22 a	0.18 b	0.00 b	2.25 cd	2.12 bcd	0.00 c

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Weed Competition in Soybean

Introduction

In order to use weeding labor economically, a study was carried out in spring, 1982, to determine the critical period of weed competition for soybean.

Methods and Materials

A randomized complete block design with four replications was utilized. Soybean was kept weed-free, or allowed to be infested with weeds, for varying lengths of time after planting. Soybean was spaced 10 cm apart within rows and 25 cm between rows. Plants were harvested 108 days after planting.

Results

Seed yields were significantly affected by weed interference (Table 12). Soybean kept weed-free for 30 days after planting (DAP) yielded as high as the weed-free check (2.61 vs. 2.29 t/ha). Among the weed-infested treatments, yields were significantly reduced when the duration of weed infestation was longer than 30 DAP. Yield reduction was due to fewer number of pods/plant and fewer branches.

Conclusions

To minimize labor costs without significant yield reduction, soybeans planted with 10 x 25 m spacing can be hand weeded only once, 30 DAP.

Table 12. Effect of weed interference on yield and yield components of soybean, spring 1982.[z]

Duration of weed interference DAP	Yield (t/ha)	Yield components (no./plant)	
		Pods	Branches
Weed-free			
15	1.88 b	16.45 cd	1.25 bc
30	2.61 a	24.08 ab	1.88 ab
45	2.60 a	24.12 ab	2.02 a
60	2.58 a	23.68 ab	2.00 a
75	2.36 ab	20.05 bc	2.20 a
to harvest	2.29 ab	21.85 ab	1.78 abc
Weed-infested			
15	2.60 a	25.35 a	2.15 a
30	2.26 ab	22.52 ab	2.02 a
45	1.90 b	19.45 bc	1.15 c
60	1.24 c	10.98 e	0.18 d
75	1.09 c	13.10 de	0.22 d
to harvest	1.21 c	12.38 de	0.15 d

[z] Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Agricultural Economics

Socioeconomic Feasibility of AVRDC's Gardening System in Asia

Introduction

The cultivation of consumption and/or income generation gardens by the Asian rural poor can increase overall farm production and lead to more available cash, higher quality food, better nutrition, and a subsequent increase in the quality of life. However, as farmers must first be shown how consumption or income-generation gardens can actually contribute to their well-being, more research of an economic nature must be done. An analytic method must be designed to study both the gardens and their associated farming/family living systems (either part-time or full-time farming operations) so that particular gardens can be recommended.

This study aimed to develop methodologies to evaluate the economic performance of the garden enterprises; to evaluate the impact of a garden on an overall farming/family living system; and to design worksheets for the transfer of these microeconomic methodologies to Thailand.

Materials and Methods

Evaluation of gardens: By pricing the products and costing the inputs involved in the garden enterprise the gross income (value of production), the cash costs of inputs, and the hours of labor used for each crop included in the AVRDC home, school, and market gardens were computed individually.

The input cost of each nutrient type by crop and cropping pattern was calculated by dividing the total production cost by each nutrient component. Crops and cropping patterns were ranked in ascending order of cost to determine their comparative advantages.

To compare the generation of income, the comparative value of each crop or cropping pattern was determined by calculating the yield, price,

cost, and labor. The yields and prices of each crop displayed seasonal fluctuations while costs remained more stable. A potential yield was established for each crop according to past experience in the AVRDC home, market, and school gardens during the study year. This potential yield or "break-even marketable yield" divided into the total production cost was used to determine the average unit cost, which could then be taken as a "break-even market price". The two break-even indicators could be used to design plans for increasing farm earnings from the gardens.

In order to evaluate whether it is costly for farmers in Taiwan to acquire their recommended daily allowance (RDA) of selected nutrients from their gardens, the "relative nutrient cost" (AVRDC. 1979. Progress Report for 1978, Shanhua, Taiwan, ROC. p. 119) was calculated to estimate the overall nutritional value of the food products based on the Taiwan Food Balance Sheet and food prices.

If the input cost of each nutrient provided by each vegetable crop, cropping pattern, or garden is less than the relative nutrient cost in Taiwan, it may be worthwhile to extend the garden project to the rural poor in Taiwan.

Evaluation of farming/family living systems: A simplified ten-step sequential process in the comparative (block) hand budgeting procedure (University of Missouri, Columbia, College of Agriculture - Extension Division. 1981. Missouri Farm Planning Handbook, Manual 75, June, pp. II-3 to II-12; III-12 to III-35; IV-2 to IV-30) was used to evaluate the economic consequences of adopting one of the recommended garden units in an existing farming/family living system. A retrospective analysis was conducted from existing data that AVRDC had previously collected on a Taiwan farmer, farmer Chiu. A one-year survey had been made for the Chius' family farm in 1976.

The comparative budgeting procedure provides evaluation measures for the resource (input) requirements of a system, the system's profitability, and the cash-flow feasibility for the farm family's resources. First the land, capital, and labor resources needed for each complete system were quantified, then profits such as farm business and total family profit were calculated. From this profit figure the returns to capital and the returns to family labor and management per hour (or man-day) were computed.

Cash-flow feasibility of the system was calculated by adding to the net cash farm income all outside sources of family income - investments, non-farm business and crafts, off-farm labor income, etc. From this total net cash family income, the cash obligations - for family living, taxes, interest and principal payments on debts, etc. - were deducted to derive the net cash available to the family. This net figure is useful for comparing one system with another.

Results

Evaluation of gardens: the AVRDC school garden shows the lowest unit cash variable cost and highest economic efficiency (net cash income per family labor). The Taiwan wage rate is NT $31.25/hr, so only the Thailand home and school gardens have positive net returns. The six types of gardens all require low per-day family labor (Table 1).

Table 1. Economic evaluation of AVRDC home, market, and school gardens, June 1981 - May 1982.

	Home garden				Market garden	School garden
	Indonesia	Thailand	Philippines	Vitamin A		
Area (m^2)	18.0	18.0	18.0	18.0	195.0	180.0
Total cash variable cost (NT$/$m^2$)	46.3	51.4	30.3	45.3	28.5	24.9
(NT$/kg)	3.0	3.3	2.9	3.6	2.6	1.6
Family labor required (hrs/day)	0.2	0.2	0.2	0.2	1.4	1.4
Net cash income per family labor (NT$/hr)	29.0	32.5	19.5	24.4	23.7	48.8
Vegetable intensity index (%)[z]	127.2	136.4	116.5	114.3	133.3	129.1
Total cash variable cost/value of family labor (%)	38.2	44.8	27.8	35.7	34.5	29.8

[z] Defined as "percent of ha-months cropped to vegetables within the study year."

The costs of nutrient production under different cropping patterns were calculated and ranked in ascending order of cost to determine the comparative advantage of each. The vegetable intensity index, a time-weighted land use index based on percent of ha-months cropped to vegetables within the study year, was calculated for each cropping pattern. No significant correlation was found between the intensity of land use in a cropping pattern and low nutrient production input costs. However, of seventeen cropping patterns ranked, the five with the lowest

input costs were those with vegetable intensity indices (on a scale of 0.91 to 1.80) between 1.01 and 1.20.

A total of 29 kinds of vegetables were planted in the AVRDC home, school, and market gardens during the period June, 1981 to May, 1982. Table 2 shows that water convolvulus, amaranth, garland chrysanthemum, spinach, rape greens, kale, broccoli, lettuce, mustard, and cabbage were the cheapest ten vegetables for the five nutrients ranked by their input costs.

Radish, eggplant, tomato, common cabbage, spinach, cucumber, Chinese leek, broccoli, yard-long bean, and garland chrysanthemum were the ten most profitable vegetables. Their suggested growing periods, when the yield and price offer high potential to reach the break-even marketable yield and market price, are shown in Table 3.

Table 2. The cheapest ten vegetables for five nutrients from AVRDC home, market, and school gardens ranked by their input costs, June 1981 - May 1982.

	Protein	Calcium	Iron	Vitamin A	Vitamin C	Combination of the five nutrients
1	Water convolvulus	Amaranth	Kale	Carrot	Broccoli	Water convolvulus
2	Amaranth	Water convolvulus	Amaranth	Garland chrysanthemum	Mustard	Amaranth
3	Broccoli	Kale	Garland chrysanthemum	Spinach	Water convolvulus	Garland chrysanthemum
4	Garland chrysanthemum	Rape greens	Lettuce	Rape greens	Spinach	Spinach
5	Lettuce	Mustard	Water convolvulus	Water convolvulus	Kale	Rape greens
6	Cabbage	Garland chrysanthemum	Sweet potato tips	Head lettuce	Cabbage	Kale
7	Winged bean	Broccoli	Spinach	Lettuce	Cauliflower	Broccoli
8	Spinach	Pai-tsai	Rape greens	Ching-chiang pai-tsai	Ching-chiang pai-tsai	Lettuce
9	Rape greens	Spinach	Chinese leek	Cabbage	Pai-tsai	Mustard
10	Pai-tsai	Cabbage	Pai-tsai	Amaranth	Amaranth	Cabbage

Table 3. The ten most profitable vegetables[z] in the AVRDC market garden and their suggested growing periods during the year.

Vegetable type	No. of observations	Ranked income[z] (NT$/hr)	Suggested growing periods[y] Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 Radish	1	73.6							7———	———	1			
2 Eggplant	1	61.9						17..	7———	———	———	13		
3 Tomato	1	53.0						17..	7———	———	———	5		
4 Common cabbage	4	50.9									8...	5———	———	31
									7....	7———	———	18		
5 Spinach	3	46.7		25———	———	6							17———	31
6 Cucumber	2	44.8							7———	———	14			
7 Chinese leek	1	29.7	———	———	———	———	———	———	1					
								17..	7———	———	———	———	———	———
8 Broccoli	7	29.6	———	16									2.....	15
9 Yard-long bean	2	21.1									14———	———	19	
10 Garland chrysanthemum	2	18.8	———	16										3——

[z] Ranked by net cash income per family labor hour.
[y] ... = seedling stage, —— = field stage; data compiled from all AVRDC gardens, June 1981 to May 1982.

Table 4 shows that the relative nutrient costs of calcium, iron, and vitamin A in Taiwan are much higher than the input costs of the AVRDC home gardens, while that of protein is lower because the protein content of the garden vegetables is low.

Evaluation of farming/family living systems: The Chiu farm's total assets were valued at NT $1,821,940. Total debts were substracted from total assets, giving a net worth of NT $1,799,940, a positive increase of NT $33,700 over the previous year.

The total farm labor needed was 9,520 hours for the year, of which 80% were applied to crop production. The total family labor available was 10,560 hours including children or exchange labor during the peaks in labor use, so there was no need to hire labor.

Table 4. Relative nutrient costs in Taiwan for five select nutrients and input cost of four AVRDC home gardens by nutrient, June 1981 - May 1982.

	Unit	Relative nutrient cost in Taiwan[z]	Input cost Indonesia	Thailand	Philippines	Vitamin A
Protein	NT$/100g	76.21	47.86	52.46	61.76	65.47
Calcium	NT$/100mg	12.46	0.76	0.83	1.47	0.89
Iron	NT$/100mg	437.22	28.80	25.87	54.40	39.83
Vitamin A	NT$/100μgRE	9.39	0.34	0.52	0.47	0.28
Vitamin C	NT$/100mg	N.A.	2.58	2.27	2.88	3.25

[z] Based on Taiwan Food Balance Sheet 1980. The price of each commodity is from Monthly Statistics of Commercial Commodities, December, 1980.

To determine the profitability of adding alternative garden enterprises to Chiu's farm, data for AVRDC's garden cropping patterns were substituted in Chiu's farming system for comparative analysis. As shown in Table 5, the Thailand garden (alternative No. 2) could provide the highest value of farm-produced family food, while the market garden could give the highest total farm profit.

Worksheets: Worksheets for making essential calculations to evaluate gardens and farming/family living systems are compiled as follows:

A. On-farm data collection worksheets

Worksheet 1	Farm map
Worksheet 2	Family members and available labor
Worksheet 3A	Inventory of resources
Worksheet 3B	Farm financial statement
Worksheet 3C	Savings and credit
Worksheet 4	Recordkeeping of each cultural practice, product sale, and expense from the farming/family living system.
Worksheet 5	Summary of farm investment capital

B. Office coding worksheets

Worksheet 1-A-1	Continual coding sheet for each cultural practice from crop system
Worksheet 1-A-2	Production cost form
Worksheet 1-B	Continual coding sheet for each farm operation from livestock system
Worksheet 1-C	Continual coding sheet for each expense from family living system
Worksheet 2	Yearly cropping patterns of each plot from farming system
Worksheet 3	Agricultural commodities price list

C. Summary worksheets for analysis

Worksheet 1	Summary of annual value of production and variable costs from farming system by crop
Worksheet 2	Monthly labor used and nutrition acquired by crop
Worksheet 3	Agronomic, economic, and nutritional evaluation of crop type

D. Analysis worksheets

Worksheet 1	Summary of annual value of production from garden unit
Worksheet 2	Economic evaluation of garden enterprise
Worksheet 3	Labor distribution analysis - garden project
Worksheet 4	Summary: cropping system
Worksheet 5A	Summary: livestock system
Worksheet 5B	Value of farm-produced family food (VFP)
Worksheet 5C-1	Labor summary
Worksheet 5C-2	Labor distribution analysis - complete farming system labor
Worksheet 6	Summary: capital, labor, income, and summary
Worksheet 7	Summary: debt repayment and available cash (optional)
Worksheet 8	Estimating annual principal and interest payments (optional)
Worksheet 9	Comparing the profitability of adding an alternative enterprise to farmer's present farm

Table 5. Comparison of the profitability of adding alternative garden enterprises to Chiu's farm.

	Farmer's present system	Alternative No. 1 Indonesia garden	Alternative No. 2 Thailand garden	Alternative No. 3 Philippines garden	Alternative No. 4 Vitamin A garden	Alternative No. 5 Market garden
1. Investment capital (NT$)[z]	1,469,660	1,469,660	1,469,660	1,469,660	1,469,660	1,469,660
2. Labor requirement (man-days)	1,188	1,197	1,197	1,196	1,198	1,253
3. Income over variable cost	162,876	162,876	162,876	162,876	162,876	175,295
4. Unallocated variable cost	17,955	18,307	18,385	18,343	18,313	24,230
5. Net cash income	144,921	144,569	144,491	144,533	144,563	151,065
6. Farm business profit	136,205	135,853	135,775	135,817	135,847	142,349
7. Value of farm produced family food	7,348	10,367	10,607	9,224	10,115	7,348
8. Total farm profit	143,553	146,220	146,382	145,041	145,962	149,697
9. Return to capital	-126,962	-124,295	-124,133	-125,474	-124,553	-121,315
10. Percent return to capital (%)	-8.64	-8.46	-8.45	-8.54	-8.47	-8.25
11. Return to labor and management	-32,806	-30,139	-20,977	-31,318	-30,397	-26,662
12. Return to labor/month	-3,277	-3,055	-3,041	-3,153	-3,076	-2,806
13. Return to management	6,515	6,515	6,515	6,515	6,515	7,012
14. Net cash available	43,421	43,069	42,991	43,033	43,063	49,565

[z] Units are all NT$ unless specified otherwise.

Conclusions

The methodology of the feasibility study is technically and economically sound for evaluation of comparative advantages among AVRDC gardens.

The four types of home gardens demonstrated at AVRDC use more labor (which can be afforded by the poor) than capital inputs, and the input

costs for nutrient specific gardens are far lower than the relative nutrient costs in Taiwan. The gardens are therefore economically extendable to the rural poor in Taiwan. The AVRDC home garden type is most economically applicable to countries like Thailand, where the wage rate is lower than in Taiwan and there are many subsistence-type farms employing female family labor.

For the transfer of home gardens into practice by the rural poor of Taiwan and Thailand, certain recommendations can be made. The ten kinds of vegetables from the home gardens that are low in nutrient production input costs (Table 3) should be introduced. Lima bean and soybean are also nutritious crops (rich in vegetable protein) and technology on planting these crops should be carefully developed and extended to small farmers. No optimum economical cropping pattern has been identified, but the tendency of low land use intensity and low input costs suggests that heavy intercropping may not be the most efficient strategy. However, intercropping of garlic and shallot is suggested for biological control of insects. Vegetables should be harvested daily, both for efficient family labor use and to maintain a daily supply of vegetables.

Vegetables from the AVRDC school garden can significantly contribute to the daily intake of protein, vitamins A and C, and minerals for 100 to 200 children aged 10 to 12 years. The school garden is therefore suitable for transfer from AVRDC to Asian countries.

Market gardens can also be economically extended to Asia. Since vegetables are perishable, however, proximity to transportation facilities and appropriate markets is essential. During the typhoon or rainy season, short duration leafy vegetables (such as ching-chiang pai-tsai and rape greens) have potential to earn a good price, and are worth planting in the market gardens. Unmarketable yield can be consumed by farmers and their families. Market gardens can thus have a combined function of home garden and income-generation garden.

The return for capital and labor was negative for Chiu's farm and AVRDC's gardens. This implies that it is very difficult for the Taiwan farm sector to compete with the non-farm sector. (Taiwan has an expanding industrial sector, and hourly wage rates are relatively high.) In the long run, Taiwan's farm sector could not survive if appropriate government policy were not undertaken for the purpose of agricultural protection.

Taiwan's present level of development, government price-support programs may have to be instituted to keep farmers on the farms.

Socioeconomic Survey on Summer Soybean at Nei-men, Kaohsiung County, Taiwan

Introduction

The Kaohsiung District Agriculture Improvement Station (DAIS) cooperated with the Nei-men Township Office to improve the cropping system of rain-fed fields. In summer, 1982, a project was initiated to subsidize farmers who planted summer soybean-sorghum-ratoon sorghum instead of rice-sweet potato. AVRDC's AGS 12, released as Kaohsiung Selection No. 9, was extended to farmers in the project. The AVRDC economics staff collected summer soybean production data from 31 of these farmers to evaluate AGS 12 against the competitive variety, Kaohsiung No. 8, and against the competitive crop, rice.

Materials and Methods

The survey was conducted in November, 1982, with 31 soybean producers at Nei-men. Nineteen of these farmers were also interviewed about their rice production. Farmers were chosen randomly from each village in numbers proportionate to the village's area under summer soybean cultivation.

Before implementing the project the farmers were instructed that 1) the germination rate of soybean seeds is 90%; 2) sowing in clay soil must be done one week after rain; 3) beds should be 90 cm wide and 30 cm high. The width of the drainage ditch between beds should be 20 cm. Two rows should be sown per bed, and the distance between rows and plants should be 45 and 10 cm, respectively, with two seeds per hole; and 4) the subsidy to summer soybean producers would be US $510/ha, including a subsidy for quick lime (2400 kg/ha), seeds (60 kg/ha) and cash (US $375/ha).

Results

Fruits (such as longan, mango, banana, and pineapple) and miscellaneous crops (such as sweet potato, sugarcane, sorghum, cassava, sweet corn, and peanut) are of main importance in the commercial cropping systems of the four villages surveyed, while rice is less important and

is produced mostly for home consumption (Table 6). The average yield of rice at Nei-men is usually only 2.7 tons/ha, which is unprofitable.

The survey data revealed that the average germination rates of Kaohsiung Selection No. 9 and Kaohsiung No. 8 were 88% and 77%, respectively. About 60% of the farmers surveyed planted summer soybean more loosely than recommended and the distance between plants ranged from 12 to 25 cm.

The cultural practices suggested by extension workers were not always fully followed by farmers. Of the 31 farmers surveyed, 94% weeded their soybean field at least one time while only 29% sprayed pesticides and 23% sprayed herbicides (Table 7). Intensive cultural practices can be reflected in the total production cost but no significant correlation coefficient was found between yield and total production cost (Table 8). Farmers who planted Kaohsiung Selection No. 9 were more satisfied with their soybean yield than those who planted Kaohsiung No. 8 (Table 9).

Table 6. The extent of land use and the types of crops involved in soybean survey at Nei-men, Kaohsiung County, Taiwan, 1982.

Village	N	1982 crop type intensity index[z]					Total soybean area (ha)
		CII	RII	FII	SII	MII	
1. Nei-hsing	9	93	7	53	6	19	3.08
2. Mu-cha	14	100	11	50	8	29	4.90
3. Nei-feng	1	102	11	19	10	38	0.19
4. Kuanghsing	7	78	11	5	12	21	3.73
Total summer soybean area of surveyed farmers							11.91
Total area of summer soybean harvested at Nei-men							34.70
Total summer soybean extended area at Nei-men							42.70

[z] Percent of ha-months cropped to total crops (CII), rice (RII), fruit (FII), summer soybean (SII), and other miscellaneous crops (MII) within the study year.

Table 7. The frequency of surveyed farmers adopting recommended cultural practices for summer soybean at Nei-men, Koahsiung County, 1982.[z]

Cultural practice	N	%	Range of times
Weeding	29	94	1-6
Basal fertilization	25	81	1
Top dressing	14	45	1-2
Pesticide spraying	9	29	1-4
Herbicide spraying	7	23	1-2
Replanting	3	10	1
Thinning	1	3	1
Total surveyed farmers	31	100	

[z] Survey data.

Table 8. Linear production functions of 1982 summer soybean yields (Y) to total production costs (X) at Nei-men by extended variety and cultural method.[z]

Extended variety	Cultural method	N	Intercept (b)	Regression coefficient (m)	Correlation coefficient (r)
Kaohsiung Selection No. 9	monocropping	10[y]	654.68	-0.160	-0.276
	intercropping	12	409.49	-0.086	-0.295
Kaohsiung No. 8	monocropping	8	229.97	-0.082	-0.545

[z] Formula Y = mX + b.
[y] One farmer was omitted because of no yield data.

Table 9. Nei-men farmers' satisfaction with their 1982 summer soybean yield by variety and cultural method.

Farmer's response	Number of cultural practices[z]	Kaohsiung Selection No. 9				Kaohsiung No. 8		Total	
		Monocropping		Intercropping		Monocropping			
		N	Average yield (kg/ha)	N	Average yield (kg/ha)	N	Average yield (kg/ha)	N	Average yield (kg/ha)
Satisfied	1	1	790	1	430	1	258	3	493
	3	1	124	3	201	0	-	4	181
	4	1	619	0	-	0	-	1	619
	6	0	-	2	443	0	-	2	443
	9	1	742	0	-	0	-	1	742
Subtotal		4	569	6	320	1	258	11	405
Unsatisfied	1	0	-	0	-	1	124	1	124
	2	1	93	0	-	1	62	2	77
	3	1	64	2	141	1	49	4	101
	4	2	179	1	103	0	-	3	154
	6	0	-	0	-	2	87	2	87
	7	1	543	0	-	1	155	2	349
Subtotal		5	211	3	131	5	94	14	144
Passable	2	1	722	1	309	0	-	2	516
	3	0	-	1	309	0	-	1	309
	4	0	-	1	464	0	-	1	464
	6	0	-	0	-	1	247	1	247
Subtotal		1	722	3	361	1	247	5	410
Total		10	405	12	283	8	134	30	284

[z] Cultural practices comprised management after sowing, such as spraying herbicide, applying basal fertilizer, top dressing, spraying pesticides, weeding, replanting, and thinning.

The highest yield obtained by those surveyed was 790 kg/ha of Kaohsiung Selection No. 9. Table 10 shows that the average yield of monocropped Kaohsiung Selection No. 9 is better than that of Kaohsiung No. 8. The total subsidy to summer soybean producers can cover the negative farm income of soybean but the farm income of rice is still superior.

When farmers were asked whether they would plant summer soybean in the future, 68% said they wanted to try again but half of these farmers

asked for another subsidy. The other half recognized that soybean needs less pesticide and labor input than rice (Table 11).

Table 10. Comparison between production factors of second rice and summer soybean at Nei-men, Kaohsiung County, Taiwan, 1982.[z]

	Summer soybean[y]								Second rice (N=19)	
	Kaohsiung Selection No. 9				Kaohsiung No. 8		Total (N=30)[x]			
	Monocropping (N=10)		Intercropping (N=12)[x]		Monocropping (N=8)					
Yield (kg/ha)	405		283		134		284		4062	
Price (US$/ton)	625		632		625		625		336	
Revenue (US$)	253		179		83		178		1366	
	(US$)	(%)	(US$)	(%)	(US$)	(%)	(US$)	(%)	(US$)	(%)
Expenses:	1560	100	1464	100	1180	100	1420	100	1615	100
A. Materials	406	26	235	16	373	32	329	23	475	30
Seed	42	3	54	4	55	5	51	3	42	3
Chemicals	7	0	6	1	16	1	9	1	83	5
Machine	222	14	95	6	196	17	164	12	245	15
Other	135	9	80	5	106	9	105	7	106	7
B. Labor	993	64	1088	74	661	56	942	66	973	60
Seedlings	-	-	-	-	-	-	-	-	15	1
Fertilization	127	8	53	4	39	3	74	5	40	2
Spraying	9	1	10	1	12	1	10	1	79	5
Weeding	337	22	323	22	118	10	273	19	107	6
Irrigation	13	1	60	4	70	6	47	3	189	12
Harvest	173	11	144	10	81	7	137	10	109	7
Post-harvest	128	8	143	10	99	8	132	9	180	11
Other	206	13	340	23	242	21	269	19	254	16
C. Fixed costs	161	10	141	10	146	12	149	11	167	10
Net return (US$/ha)	-1307		-1285		-1097		-1242		-250	
Farm income (US$/ha)	-268		-74		-155		-160		+748	

[z] Survey data.
[y] Subsidy to summer soybean producers was US $510/ha.
[x] One farmer was omitted because of missing yield data.

Table 11. The relation between satisfaction with summer soybean yield in 1982 and the intention to plant summer soybean in 1983 among 31 farmers surveyed at Nei-men.

Intention to plant in 1983	Satisfied		Unsatisfied		Passable		Total	
	N	%	N	%	N	%	N	%
Yes	9	75	9	64	3	60	21	68
Undecided	3	25	5	36	2	40	10	32
Total	12	100	14	100	5	100	31	100

Conclusions

Kaohsiung Selection No. 9 (AVRDC AGS 12) produced a better yield than Kaohsiung No. 8 because of better germination rate and response to inputs. For future soybean planting, farmers asked for Kaohsiung Selection No. 9.

The yield and income of summer soybean were perhaps low compared to those of rice because 1) the plant density was low, which resulted in weed competition entailing extensive labor for weeding; 2) seeds were provided so late that farmers missed the best sowing period and yield was reduced by rain during the germination stage; 3) the rhythmic rainfall in the summer of 1982, which differed from the pattern of the previous 10 years, was extremely beneficial for rice but not for soybean; and 4) soybean was already almost at the harvest stage before farmers began to accept that soybean would indeed respond to varying levels of management inputs. In the future, farmers will be more fully convinced if they observe AVRDC soybean breeding experiments before they plant again.

Economic Analysis of Soybean Breeding Experiment

Introduction

The various soybean management inputs investigated in the soybean breeding report, "Optimum Management Input for Maximum Economic Yield in Soybean," were assessed from an economic standpoint to identify possible improvements in input use for soybean management studies. The experiment used a factorial design to test the response of varieties AGS 62 and AGS 144 to five input factors: Weed control, fertilizer, irrigation, and pest and disease control (Table 12).

Materials and Methods

Experiment inputs were accurately recorded by treatment, and the cost of each was calculated. Both a simple linear regression analysis and a Cobb-Douglas production function of the yield and total variable treatment cost were applied for both genotypes according to $Y = a + bX$ and $Y = aX^b$, where Y = soybean yield (kg/ha) and X = total variable treatment cost (NT$/ha). The marginal productivity (MP) was defined as the cost of additional inputs used to get an additional one unit of ouput. MPs were compared by treatment and genotype to show the economic feasibility of varying levels of management.

Results

The average treatment cost was highest in the spring because more irrigation and spraying were necessary in that season. The average yield of AGS 144 was much higher than that of AGS 62 in both spring and

autumn. The yield response to total variable costs of AGS 62 was significant in all three seasons from simple linear regression analyses, while AGS 144 gave higher correlation coefficients from the Cobb-Douglas production functions (Figure 1 and Table 13).

Table 12. Different levels of five input factors used in the orthogonal factorial experiment.

Factors	Details of levels
I. Irrigation	1. Normal (as needed) 2. One irrigation, 30 days after planting (DAP) 3. Twice, 30 and 60 DAP 4. No irrigation (control)
II. Fertilizer	1. 60:80:80 = $N:P_2O_5:K_2O$ 2. No fertilizer (control)
III. Weed control	1. Herbicide (Lasso, standard application) + one hand weeding at 60 DAP 2. Herbicide only 3. Hand weeding at 60 DAP 4. No weeding (control)
IV. Pest control	1. AVRDC standard insecticide application 2. No insecticide (control)
V. Disease control	1. Fungicide: Dithan M-45, standard application 2. No fungicide (control)

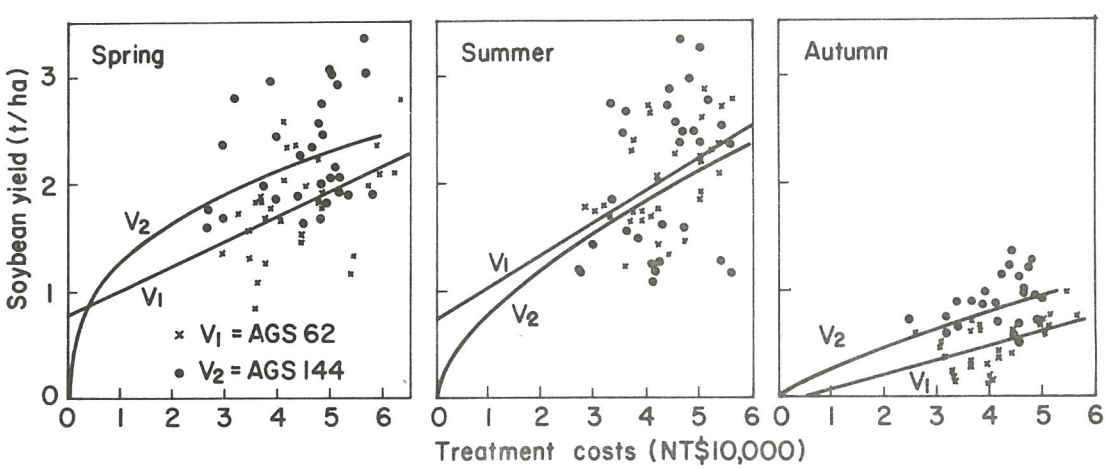


Figure 1. The relationship between yields and total variable treatment costs of grain soybean by genotype (V_1: the linear model; V_2: the Cobb-Douglas model) and season (spring, summer, and autumn, 1982), AVRDC.

If the MP was less than NT $25/kg, which was the ROC government's guaranteed soybean price in spring, 1982, then the level of management inputs was judged profitable. Fungicide spraying, at least one irrigation, and herbicide spraying were the three management practices that showed the highest frequency in contributing to high income over variable costs (Tables 14 and 15).

Conclusions

The reasons for low yields during the autumn experiment are still unknown. The linear model was better for analysis of AGS 62 and the Cobb-Douglas model was better for analysis of AGS 144 in all three seasons' experiments. It can be concluded that yield response is positively related to input costs, but the factors that significantly contribute to yield and income over variable costs need further investigation by factorial analysis.

Table 13. Simple linear regression functions (A) and Cobb-Douglas production functions (B) of the yield (Y) to total variable treatment cost (X) by genotype and season, AVRDC, 1982.[z]

Genotype	Season	Average cost ($\bar{X}$) (NT$/ha)	Average yield ($\bar{Y}$) (NT$/ha)	Function type	Intercept (a)	Regression coefficient (b)	Correlation[y] coefficient (r)
AGS 62	Spring	44,511	1,800	A	782.43	0.023	0.482**
				B	3.43	0.583	0.456**
	Summer	43,471	2,035	A	737.44	0.030	0.505**
				B	3.84	0.586	0.472**
	Autumn	40,351	473	A	-57.90	0.013	0.478**
				B	0.03	0.892	0.323
AGS 144	Spring	44,618	2,245	A	1,359.87	0.020	0.361*
				B	44.98	0.364	0.387*
	Summer	43,479	2,034	A	800.90	0.028	0.315
				B	2.58	0.620	0.328
	Autumn	40,705	823	A	216.36	0.015	0.481**
				B	0.14	0.817	0.554**

[z] Formula A: $Y = a + bX$. Formula B: $Y = aX^b$.
[y] Correlation coefficient at the 1% (**) or 5% (*) level of significance, d.f. = n-2 = 30.

Table 14. The five most profitable levels of management inputs compared by genotype with the minimum inputs check, spring, 1982, AVRDC.

Genotype	Treatment No.	Management added beyond indispensables[z]						Total variable costs (NT$/ha)	Yield (kg/ha)	Marginal productivity (MP) (NT$/kg)	Income over variable costs (NT$/ha)
		Spraying herbicides 1 DAP	Irrigation 32, 54 & 61 DAP	Hand weeding 60 DAP	Spraying fungicides 42, 55 & 81 DAP	Spraying insecticides 12,26,29,42, 55 & 81 DAP	Fertilizing 1 & 60 DAP				
AGS 62	6	x	x[y]		x			41,011	2,590	9.45	23,746
	21	x	x[y]	x	x			41,661	2,342	12.48	16,879
	8		x		x	x		43,411	2,365	13.93	15,709
	19		x[y]	x			x	36,744	1,897	12.65	10,679
	22	x	x[y]					32,244	1,713	8.15	10,570
Check	54	x						29,306	1,352		4,491
AGS 144	32		x[y]		x			31,500	2,807	4.62	38,678
	15		x	x	x			38,700	2,970	9.90	35,542
	64				x			29,306	2,366	4.35	29,844
	27		x[y]	x	x	x	x	56,217	3,355	18.45	27,652
	30	x	x[y]		x	x		49,694	3,088	17.25	27,505
Check	63			x				26,628	1,751		17,143

[z] Indispensable management in spring, 1982, included land preparation, furrowing, sowing, drainage ditch construction, thinning (12 DAP), harvesting, and threshing.
[y] Only 32 DAP.

Table 15. The five most profitable levels of management inputs compared by genotype with the minimum inputs check, summer, 1982, AVRDC.

Genotype	Treatment No.	Management added beyond indispensables[z]						Total variable costs (NT$/ha)	Yield (kg/ha)	Marginal productivity (MP) (NT$/kg)	Income over variable costs (NT$/ha)
		Spraying herbicides 2 DAP	Irrigation 33 DAP	Hand weeding 66 DAP	Spraying fungicides 47, 67 & 72 DAP	Spraying insecticides 10,17,33, 47 & 67 DAP	Fertilizing 1 & 66 DAP				
AGS 62	21	x	x	x	x			40,428	2,739	12.39	28,053
	53	x		x	x			40,933	2,654	14.19	25,412
	38	x	x		x			37,756	2,401	14.87	22,259
	50	x			x	x		51,144	2,879	20.61	20,819
	6	x	x		x			37,283	2,304	16.71	20,326
Check	54	x						28,594	1,784		16,018
AGS 144	10	x	x		x		x	46,611	3,338	8.81	36,831
	64				x			33,161	2,743	3.52	35,425
	25	x	x	x	x		x	50,572	3,262	11.04	30,989
	47		x	x	x			36,344	2,670	5.84	30,397
	29	x		x		x		44,689	2,862	10.16	26,869
Check	16		x					27,694	1,190		2,057

[z] Indispensable management in summer, 1982 included land preparation, furrowing, sowing, drainage ditch construction, thinning (15 DAP), draining (3 DAP), resowing (8 DAP), harvesting, and threshing.

Social Anthropology

Research on Group Vegetable Farming

Introduction

A study was conducted to assess how group vegetable farming in Taiwan might help solve some of the problems associated with agricultural development, such as poor technology transfer, inequity of benefits from development programs, rural labor shortages, and small, fragmented landholdings. It was hoped that the conclusions could then be applied to other areas of Asia as well.

Methods

In order to explore the problems and potentials of group approaches to vegetable production and marketing, intensive field research was carried out at two locations in Taiwan (Figure 1). In mid-1981 a six-month research effort was initiated in northwestern Chiayi County in the general area of Hsingang Township. There were two vegetable marketing cooperatives in this area, one specialized vegetable production area using cooperative marketing through the Township Farmers Association and, in 1980-81, one joint farm which specialized in vegetable production. The second research site was in the Puli region of Nantou County. Field research at that location took place mainly over two months in the summer of 1982. In this area there were at least eight vegetable production and marketing cooperatives as well as several cooperatives which did only joint vegetable marketing.

The first research site is typical of the plains, where paddy rice and other field crops predominate, whereas the Puli area site contains mostly non-irrigated slopeland where tree crops and a variety of miscellaneous crops are typically grown. In the former location cooperative vegetable production had not yet been successfully adopted, whereas in the latter location cooperative vegetable production was already important and expanding. In both sites joint marketing of vegetables has been extremely successful and widespread.

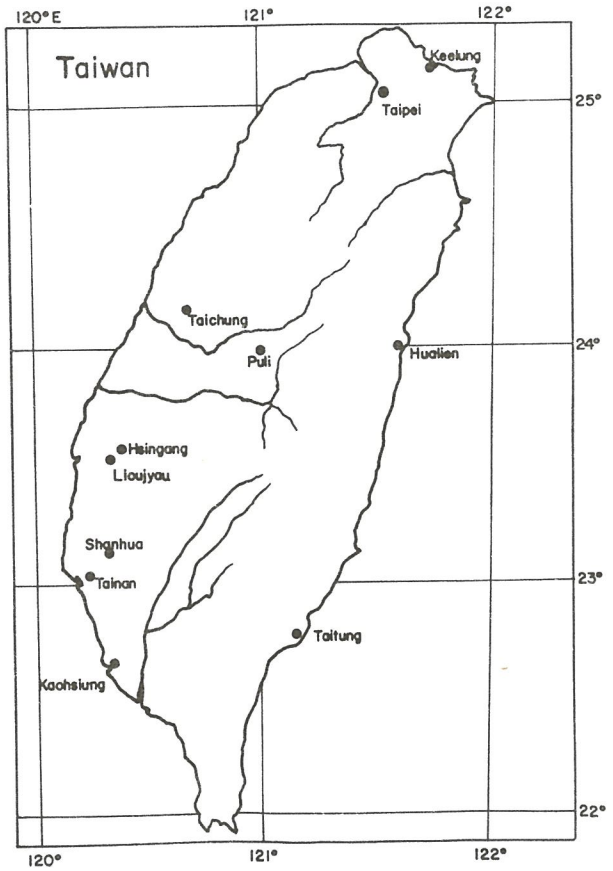


Figure 1. Field research sites in Taiwan.

Research methodology included participant observation, household surveys, in-depth interviews with key persons, mapping, collection of demographic and socioeconomic data, and a literature review. The objective of this methodology is to provide a comprehensive picture of the historical and contemporary context in which group vegetable farming has developed and is now functioning. From an understanding of this empirical data, some conclusions and a few limited recommendations can be made.

Results

The Hsingang area contains a number of villages with relatively high concentrations of vegetable farmers who have traditionally grown vegetables for Beigang Town, Chiayi City, and parts of Chiayi County. More recently they have been selling vegetables in Taipei and other major urban centers in Taiwan. In the summer they specialize in a variety of hot season vegetables, especially leafy ones, while in the

fall and winter they expand production to include cool season brassicas, crucifers, and fruit vegetables such as tomatoes. Thus at least some of the farmers in this area grow vegetables year-round.

The climate in the Hsingang region is characterized by relatively cool, dry weather from October through March or April and hot, rainy weather, including periodic typhoons, from May through September (Figure 2). The greatest climatic risks for vegetable production occur during the hot typhoon season, while the major cooler season problem is low market prices due to a much larger supply of vegetables in Taiwan at that time.

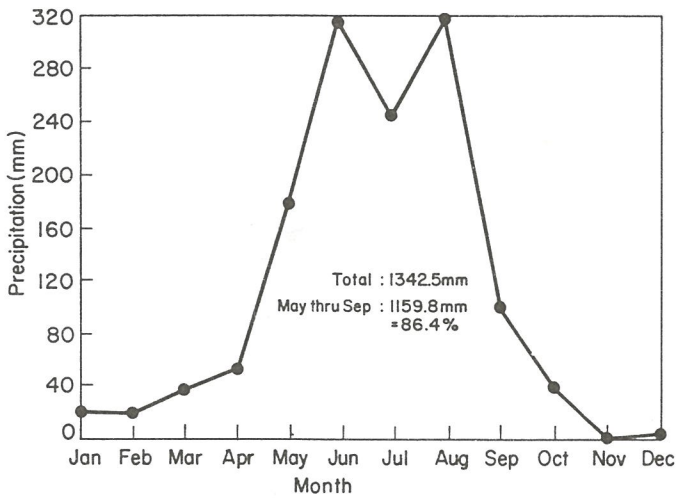


Figure 2. Annual precipitation, Hsingang area.

The Hsingang area has both double-rice and rotation irrigation land and most vegetable farmers have their own supplemental water sources from wells, rivers, ditches, etc. Many farmers in this region only grow vegetables on a small proportion of their land, while rice and other field crops are more important in the cropping system.

Good quality seeds, chemical fertilizers, and chemical pesticides are all easily available to vegetable farmers. Mechanization of vegetable production in this area is limited, so cultural practices are labor-intensive.

The development of cooperative vegetable marketing in Hsingang and neighboring townships has to some extent been a result of government planning, via the Farmers' Association (FA) and government extension

agents. In order to increase marketing efficiency and the percentage of profits reaching the actual vegetable producers, cooperative marketing has been promoted by the government through the FA and the Cooperative Union. These two groups in effect compete with each other for the farmers' business (Table 1). If the FA marketing service has not been satisfying farmers' needs, farmers can form a cooperative farm and market their vegetables through the Cooperative Union marketing channel.

A group of 20 farmers in one village of Hsingang Township decided to try joint production of vegetables on 5.12 hectares of their rotation irrigation land (Figure 3), with the strong encouragement and support of one FA extension agent. After only about one year of group production this joint farm disbanded, and the land reverted to individual farmer cultivation.

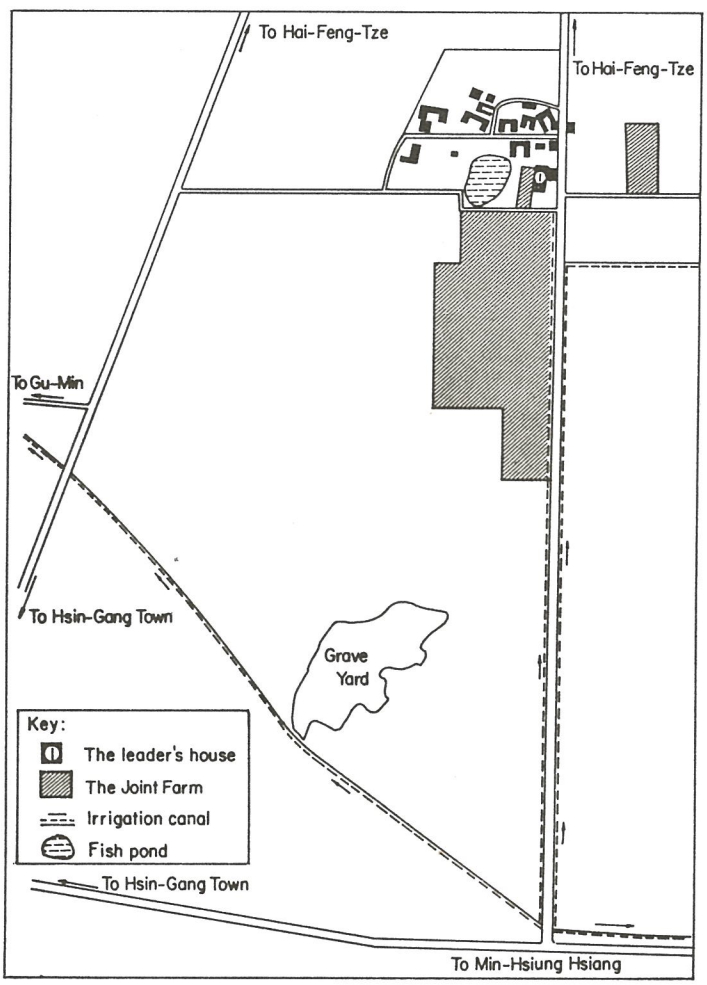


Figure 3: Joint farm, Hsingang township.

Table 1. Volume of vegetable supplied through cooperative vegetable marketing, 1974-1981 (kg).

Year	Hsingang Township		Liou Jyau Township		Puli Township			Yu Chih township	
	Hsingang FA	Hsingang coop.	Liou Jyau FA	Lunyang Coop	Puli FA	Tai Ping Coop.	Guang Cheng Coop.	Yu Chih FA	Yu Chih Coop.
1974	-	-	438,210 (100.0%)	-	-	-	-	252,424 (100.0%)	-
1975	1,576,994 (100.0%)	-	4,571,618 (100.0%)	-	81,565 (100.0%)	-	-	198,625 (100.0%)	-
1976	3,742,317 (100.0%)	-	5,446,017 (100.0%)	-	2,085,975 (100.0%)	-	-	174,651 (100.0%)	-
1977	5,275,205 (100.0%)	-	6,286,127 (100.0%)	-	1,998,255 (56.8%)	1,519,979 (43.2%)	-	-	-
1978	6,288,389 (100.0%)	-	4,939,226 (100.0%)	-	2,545,249 (51.0%)	1,870,237 (37.5%)	572,880 (11.5%)	10,780 (100.0%)	-
1979	5,500,375 (93.9%)	355,523[z] (6.1%)	2,686,063 (44.0%)	3,419,371 (56.0%)	2,957,094 (46.1%)	2,212,392 (34.5%)	1,245,356 (19.4%)	-	-
1980	6,636,503 (62.9%)	3,909,170 (37.1%)	2,382,280 (38.0%)	3,882,063 (62.0%)	2,758,541 (47.6%)	2,170,176 (37.4%)	866,600 (15.0%)	42,705 (100.0%)	-
1981	8,392,835 (61.9%)	5,161,941 (38.1%)	1,890,706 (37.7%)	3,120,891 (62.3%)	2,124,535 (47.0%)	1,629,668 (36.1%)	761,382 (16.9%)	53,036 (9.8%)	487,251 (90.2%)

[z] Questionable.

A number of factors contributed to the failure of this effort at group farming. Perhaps most crucial was the absence of an experienced, fully committed leader for the joint farm. No member farmer wanted to take on the responsibility and make the time commitment needed to run the farm properly.

A second major problem was a labor shortage. Only six member families made a regular contribution to the farm's operation. Most members, those with the most vegetable growing expertise, chose to spend their time working either on their individual farms or in non-agricultural, off-farm employment. Joint vegetable production was a low priority job for these member families.

A third negative factor was unfavorable weather conditions in 1980-81. Due to drought, the farm did not have an adequate supply of water for irrigation. Thus productivity and profits were well below normal, while production costs remained high. The joint farm lost money.

The farm's location was another problem. Half of the member families did not live in the village where the farm's land was located, and two members even lived in another township (Figure 4). Thus it was inconvenient or difficult for these more distant farmers to contribute labor to the farm, especially at the crucial times for vegetable cultivation, e.g. early morning, late afternoon, and even at night. In addition, there was no mechanization available to substitute for labor inputs.

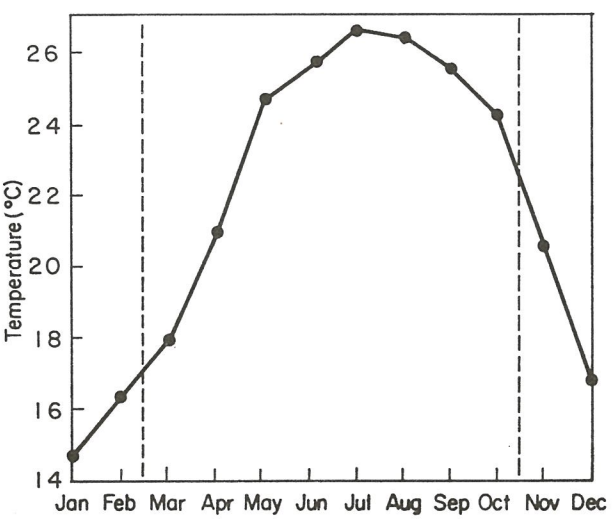


Figure 4. Annual temperature, Puli area.

In the Puli area, vegetable production occurs almost exclusively in the warmer and wetter months, March through October (Figures 4 and 5). The Puli vegetable growing areas are all located at cooler altitudes (over 500 m above sea level), and can produce types of vegetables which cannot be grown easily in the plains during most of this period. Damage from typhoons is not a major problem. The mountain ecology prevents both excessive wind and flooding damage. Because most of the slopeland areas do not have irrigation and there is very little rain in the winter, and in part because of the already excessive production by the plains farmers, large-scale vegetable production does not take place from November through February. Thus vegetable cooperatives only function for about eight to nine months of the year. Long-term tree crops (e.g. fruit, bamboo, tea) are grown on much of the land not devoted to summer vegetable production, and the vegetable land is left fallow from November to about February. However, in contrast to the situation in the Hsingang area, vegetables are the most important cash crop for most of the production cooperatives' members. In one area well over 90% of the group production effort is devoted to producing white radish, while in another much smaller location common cabbage and snap bean are the main jointly cultivated crops.

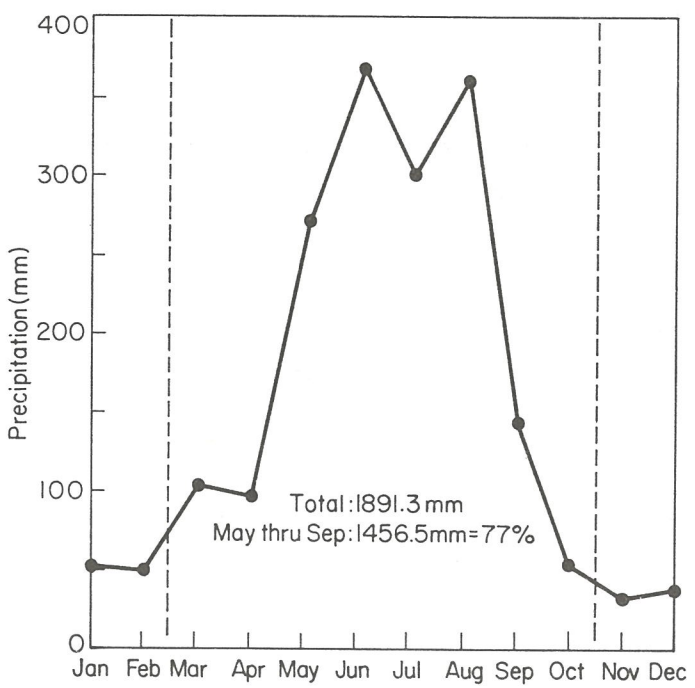


Figure 5. Annual precipitation, Puli area.

The radish farmers must rely completely on rainfall to water their fields, while the cabbage/bean farmers have a limited and very costly supply of irrigation water which they use sparingly. Thus both sites have specialized in only one or two vegetables grown on land which has a relatively simple cropping pattern.

Cooperative production first began in Da Ping Ding Village when small groups of radish growers joined forces to improve both the production and marketing of their produce. In an area where rainfall is uncertain, group production helped reduce risks and even out the daily supply of marketable radish by using production planning. Originally, joint marketing developed in large part because of the lack of adequate marketing channels. To date the Da Ping Ding area has been supplying roughly 95% of the radish marketed in Taipei and elsewhere on Taiwan between June and October. Thus production planning and organized marketing can have an important impact on the profits of these radish farmers.

In Da Ping Ding there are presently seven cooperative radish production groups. Two are officially registered cooperatives, one is a community cooperative, and four are registered with the Puli FA as joint farms, even though locally they are called "companies". Each cooperative has a different size and somewhat different style of leadership and management. The two most successful groups so far have been one of the cooperatives and one of the joint farm companies. These two groups represent the two basic approaches to cooperative production applied in Da Ping Ding and can be usefully compared.

The cooperative, because of its official status, gets more government support than the other groups, mainly in the form of subsidies for special projects and reduced interest on loans. The cooperative leadership consists of a small (five to six person) group of farmers that makes all decisions about the cooperative's operation, with little or no opportunity for suggestions or criticism from the members. The shares within the cooperative are thought by most farmers to be distributed unfairly, with the leadership holding a disproportionate percentage. Many members have little or no interest in active participation in the regular farming operations, preferring to spend their time in other income-generating activities. As a result the cooperative hires a high percentage of its labor from non-member

households (Table 2), and in fact prefers this arrangement. The cooperative now jointly owns 13 hectares of land, and hopes to increase this amount over time, thereby reducing its reliance on land that is rented from its members. In sum, this cooperative farm has a highly centralized decision-making structure with unequal benefits accruing to its members and a strongly businesslike approach to agricultural production. It might be called corporate farming.

The other approach to cooperative farming found in Da Ping Ding is exemplified by one of the joint farm companies. This farm's size is only somewhat larger than the cooperative described above (Table 3), but its membership is distinctly larger. Moreover, all of the members are full-time farmers, and they all have relatively equal farm sizes. The joint farm expects that all of its members will contribute both land and regular labor to the farm's operation. The leadership of this cooperative is considered to be receptive to members' suggestions and criticisms, and their accounts and profit distribution system are thought to be open, honest, and fair. This group emphasizes active and equal participation by all of its members and a leadership which is experienced and respected but not authoritarian. It requires a high degree of member commitment and motivation in order to function properly, and the non-farmer or part-time farmer would not be a suitable member.

Table 2. Comparison of member and non-member labor contribution to four radish cooperatives in Da Ping Ding. July 1-August 15, 1982.

	Tai Ping	Lian Fu	Yung Chang	Hsieh Cheng	Total
Man-days of non-member labor	3,297.5	1,270.0	1,297.0	613.0	6,477.5
Man-days of member labor	633.0	2,529.0	1,231.0	1,098.0	5,491.5
Total man-days	3,930.5	3,799.0	2,528.0	1,711.0	11,969.0
Non-member percentage	83.90%	33.43%	51.31%	35.83%	54.12%

Table 3. Comparison of characteristics of six radish cooperatives in Da Ping Ding, 1982.

	Tai Ping Coop.	Guang Cheng	Lian Fu Joint Farm	Yung Chang	Hsieh Cheng	Ho Cheng
No. of members	30	10	42	38	37	57
Farm size (ha)	78.29	38.16	92.03	66.33	42.05	68.62
Total shares	40.91	≅10.00	35.60	28.95	28.15	47.00

Since both the cooperative and the joint farm have been financially successful, it is clear that both approaches to group farming can work in the same ecological and sociocultural context. Since farmer households are relatively free to join the group production team which best suits their own individual needs, there is, to some extent, a self-selection process at work. The other two cooperatives and the other joint farms have characteristics somewhere between the two groups described above. The snap bean/common cabbage cooperative has tried to model itself after the successful radish cooperative described above and will not be discussed here.

Conclusions

Conditions favoring group production: This research suggests certain conditions that seem to favor cooperative vegetable production in Taiwan. Ecological conditions which favor sucessful cooperation include lack of irrigation facilities and low risk of crop failure due to climate, soil, or pests. Technological variables facilitating cooperative production include the availability of ecologically suited vegetable varieties, widespread knowledge among farmers of appropriate cultural practices, the ability to mechanize at least part of the production process for large-scale farming, and a research and development system that can provide technical support when needed.

Socioeconomic conditions that make group farming more likely to succeed are mainly those that entail high, stable profits. If there is a rural labor shortage and large-scale farm mechanization can substitute for some or even most of the labor, or if labor is adequate but recruitment and use of labor can be more easily managed through group efforts than through the individual, then group production becomes more attractive. Farmers can pool their capital and other resources to make large purchases and take advantage of economies of scale. Group farming is clearly advantageous if many part-time farmers or non-farming landholders want to have their land profitably farmed while they engage in other work. If the vegetable crops chosen are suitable for large-scale, planned production and marketing and the economic benefits are substantial, farmers will prefer cooperative production. The crops chosen should be of major importance to farmers' incomes. There must be good marketing information and infrastructure, and a cooperative's accounts must be well-kept and accessible to all members. Small- and

medium-scale farmers with similarly sized farms are more successful cooperators. Leadership must be trustworthy, respected, and experienced.

Other factors which make cooperative approaches more desirable can be classified as sociopolitical. Some form of financial support and incentives from governmental or external institutions to farmers who form cooperatives is clearly a positive factor, but in order to develop self-sustaining, well-organized cooperatives, actual monetary aid should be held to a minimum and used selectively. Indirect incentives, e.g. tax benefits and technical and training support, are very helpful. Moreover, regulations pertaining to cooperatives should not be too rigid or complex, and land tenure laws must make joint production legally feasible. Previous experience among farmers in any type of cooperative organization or project (agricultural or not) should make group farming easier to organize and operate, and a community with a history of peaceful and integrated social relationships, through kinship or other ties, would be more likely to adapt to cooperative farming. All members must agree on the rules of a cooperative's organization and operations.

Characteristics of different farming groups: Comparing marketing cooperatives and production/marketing cooperatives, certain characteristics stand out. In marketing cooperatives, where all production is carried out by individual farmer households, production planning on a meaningful scale is impossible, since all farmers compete with each other for higher profits. Secondly, marketing cooperatives can have many more members than production cooperatives, and farmers can grow a large variety of vegetables rather than being limited to a designated few. Thirdly, marketing cooperatives are generally easier to form and maintain than production cooperatives because the individual members need to make only a small investment and commitment to the group, and areas of potential disagreement are fewer. Yet by the same token, the farmers stand to gain less from the cooperative.

A major advantage of the production cooperative is the capacity to utilize production planning to supply the market with a specified quantity of vegetables at the appropriate time. Membership tends to reach an optimal size for the most efficient and profitable production, varying with the type of crop and the technology needed to farm it.

These cooperatives seem to function best when producing only one or two crops, thus allowing for specialization and an efficient division of labor. A very important criterion is that group vegetable production is the main income source for the farmer members, otherwise commitment and motivation to cooperate will be insufficient. Other characteristics of cooperatives tend to vary depending on the situation, but in all cases a steady and respectable annual income must be attained by all members, especially in the initial few years of operation. Cooperative farmer groups cannot readily tolerate financial loss. Production cooperatives, in general, demand a high level of financial commitment and participation, but the benefits of cooperation can be significantly higher than in simple marketing cooperatives and thus the extra effort may be worthwhile.

Advantages of cooperatives: The main advantages of vegetable cooperatives include 1) economies of scale (lower production costs); 2) larger base of capital and other resources for better investment potential and scale of operations; 3) potential for higher and/or steadier profits than individual farming (under certain circumstances); 4) more equitable distribution of benefits from development and new technologies; 5) more efficient and effective transfer of technologies; 6) the ability to overcome labor and land constraints; and 7) the potential for effective integrated pest management.

Disadvantages of cooperatives: Significant disadvantages include 1) the individual farmer's loss of freedom and flexibility; 2) the potential for exploitation of member farmers by a corrupt leadership; 3) some loss of labor efficiency and motivation due to a lack of solely personal returns from one's labor; 4) an inability to engage in long-term planning if land and other major resources remain privately owned; and 5) a restriction in the number of situations in which cooperative farming is clearly superior to private farming.

Recommendations: Vegetable farmer cooperatives might be fostered under current Taiwanese conditions by 1) revising land tenure laws to allow joint ownership of farm land by farmer cooperatives; 2) improving and expanding marketing facilities and establishing a guaranteed pricing system to be more responsive to farmers' needs; 3) offering subsidies and loans much more selectively to prevent farmers from forming superficial cooperatives that are not really cooperatives in practice,

merely to qualify for these benefits; 4) revising the tax structure so that cooperative farming is not taxed in the same way as non-farming businesses; 5) providing training in cooperative management and correct accounting procedures for cooperative leaders; 6) offering better research and development support for vegetable farmers; 7) revising cooperative regulations to allow flexibility where appropriate and to reduce paper work, yet protecting small farmers from exploitation by larger farmers and businessmen through frequent supervision and enforcement of rules; 8) encouraging crop specialization because cooperatives work better when cultivating only a small number of crops; 9) making fertilizers available to cooperatives as well as individual farmers; and 10) providing technical training for each cooperative's pesticide specialists on the use of agricultural pesticides.