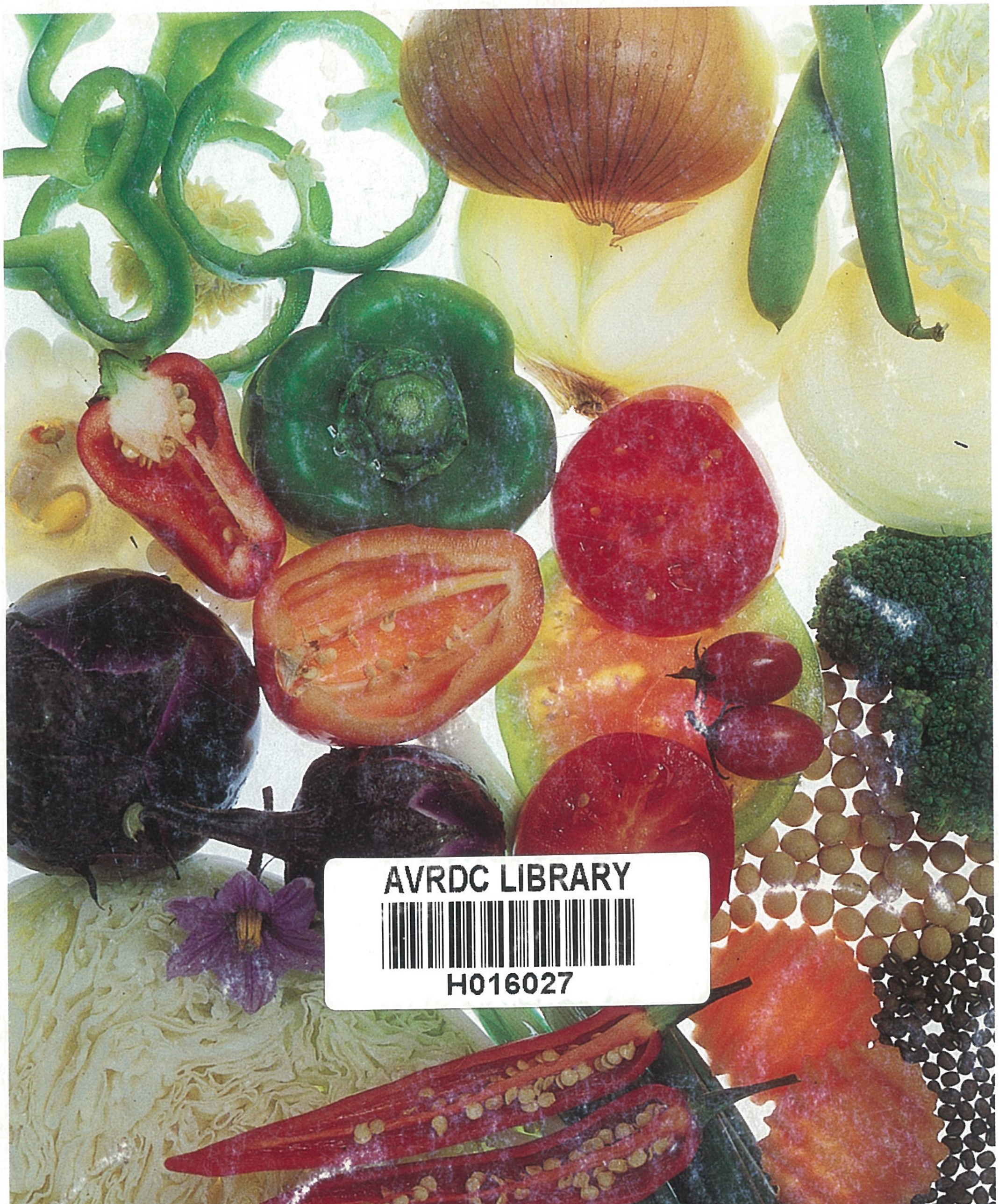
AVRDC Report 1997



Asian Vegetable Research and Development Center

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AVRREP

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Abbreviations and Acronyms

acc. — accession
ADB — Asian Development Bank
AFLP — amplified fragment length polymorphism
AGS — AVRDC *Glycine max* selection
ANOVA — analysis of variance
ARC — AVRDC Asian Regional Center
ARP — AVRDC Africa Regional Program
ASET — AVRDC Soybean Evaluation Trials
AUDPC — Area under disease progress curve
avg. — average
AVNET — Collaborative Vegetable Research Program for Southeast Asia
AVSET — AVRDC Vegetable Soybean Evaluation Trials
AYT — advanced yield trial
BePMV — bell pepper mottle virus
BLM — black leaf mold
BP — bacterial pustule
BS — bacterial spot
Bt — *Bacillus thuringiensis*
BW — bacterial wilt
BWR — bacterial wilt resistance
CF — cylindrical fruit type
cfu — colony-forming units
ck — check
CHC — cabbage head caterpillar
CLS — cercospora leaf spot
CLVNET — Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam
cM — centimorgan
CMS — cytoplasmic male sterility
— cell membrane stability
CMV — cucumber mosaic virus
CONVERDS — Collaborative Network for Vegetable Research and Development in Southern Africa
CT — cherry tomato
cv. — cultivar
CV — coefficient of variation
CVMV — chilli veinal mottle virus
CWW — cabbage webworm
DAE — days after emergence
DAI — days after inoculation
DAS — days after sowing
DAT — days after transplanting
DBM — diamondback moth
diam. — diameter
DM — downy mildew
DMRT — Duncan's multiple range test
DNA — deoxyribonucleic acid
DSR — disease severity rating
DTM — days to maturity
EDTA — ethylenediaminetetraacetic acid
ELISA — enzyme-linked immunosorbent assay
ER — enhancing ratio
EVT — elite variety trial
FM — fresh market
FMTT — fresh market tropical tomato
FMV — feathery mottle virus
FW — fusarium wilt
GA — gibberellin
GCA — general combining ability
GCLV — garlic common latent virus
GRSU — Genetic Resources and Seed Unit
GYT — general yield trial
gv — geminivirus
HS — heat-sensitive
HSP — heat shock protein
HT — heat-tolerant
ICMV — Indian cassava mosaic virus
ICPN — International Chili Pepper Network (AVRDC)
ICW — imported cabbageworm
IMN — International Mungbean Nursery (AVRDC)
IPM — integrated pest management
IYT — intermediate yield trial
LSD — least significant difference
LSF — long-styled flower
LYSV — leek yellow stripe virus
MAb — monoclonal antibody
m asl — meters above sea level
MbFV — mite-borne filamentous virus
MC — moisture content
MDS — multidimensional scaling
mkt. — marketable
MPC — membrane protein complex
MR — moderately resistant
MY — marketable yield
— mean yield
MYMV — mungbean yellow mosaic virus
NARS — national agricultural research systems
NC — nitrocellulose
NGO — nongovernmental organization
NIRS — near-infrared reflectance spectroscopy

NPV	— nuclear polyhedrosis virus
OP	— open-pollinated
OPC	— Office of Publications and Communication
OT	— observation trial
OYDV	— onion yellow dwarf virus
OYT	— observational yield trial
PB	— phytophthora blight
PBNV	— peanut bud necrosis virus
PCR	— polymerase chain reaction
PDA	— potato dextrose agar
PeMV	— pepper mottle virus
PMMV	— pepper mild mottle virus
Ps	— *Pseudomonas solanacearum*
PVMV	— pepper veinal mottle virus
PT	— processing tomato
PVX	— potato virus X
PVY	— potato virus y
PYT	— preliminary yield trial
R	— resistant
RAPD	— random amplified polymorphic DNA
RCBD	— randomized complete block design
REDCAHOR	— Collaborative Network for Vegetable Research and Development in Central America
RF	— round fruit type
RFLP	— restriction fragment length polymorphism
RH	— relative humidity
RIL	— recombinant inbred line
RYT	— regional yield trial
S	— susceptible
SA	— soil amendment
SAVERNET	— South Asian Vegetable Research Network
SCAR	— sequence characterized amplified region
SD	— standard deviation
SD	— Swiss Development Cooperation
SDI	— selective dissemination of information
SDS-PAGE	— sodium dodecyl sulfate-polyacrylamide gel electrophoresis
SLB	— stemphylium leaf blight
SLV	— shallot latent virus
SSF	— short-styled flower
SST	— summer stress tolerance
SSD	— single-seed-descent
SYT	— standard yield trial
SYSV	— shallot yellow stripe virus
TBSV	— tomato bushy stunt virus
TEV	— tobacco etch virus
TLCV	— tobacco leaf curl virus
TLCV Tai or TTLCV	— Taiwan tomato leaf curl virus
TMV	— tobacco mosaic virus
ToMV	— tomato mosaic virus
TSS	— total soluble solids
TSWV	— tomato spotted wilt virus
TTC	— triphenyl tetrazolium chloride
TuMV	— turnip mosaic virus
TVMV	— tobacco vein mosaic virus
TYLCV	— tomato yellow leaf curl virus
TYTV	— tomato yellow top virus
var.	— variety
VSB	— vegetable soybean
YVMV	— yellow vein mosaic virus
WAS	— weeks after sowing
WAT	— weeks after transplanting
WSMV	— watermelon silver mottle virus

Allium Improvement

The bulb alliums project conducts research on onion (*Allium cepa*), garlic (*Allium sativum*) and shallot (*A. cep.* var *aggregatum*). The primary target of the project is to improve the productivity of the above crops in the tropics by developing lines with (l) resistance to major diseases (stemphylium leaf blight (SLB), purple blotch, and anthracnose) and insect pests (thrips and beet armyworm), (2) tolerance to summer stress, and (3) improved storage quality of bulbs. Additional targets include (4) virus elimination and indexing in garlic and shallot, (5) generating basic knowledge on the effects of photoperiod, temperature, and flooding on growth and development, and (6) use of biotechnolgy to improve efficiency.

One onion line, AC740, with only 25% storage loss, 63 t/ha yield, and firm bulb, was identified. Selection for bulb firmness might be an effective means of selecting for storage quality. Four garlic lines with good storage quality have been identified.

Onions yielding more than 60 t/ha have been identified through progeny selection. Progenies that mature within 100 days after transplanting have been identified. Marketable yield of 70 to 96 t/ha has been obtained in five newly introduced onion germplasm lines.

One *A. cepa* x *A. fistulosum* backcrossed to recurrent parent *A. cepa* has improved pollen fertility, seed set, moderate bulb development, and resistance to SLB.

Four promising garlic lines were identified through clonal selection. Through ELISA reaction, resistance to four viruses was confirmed in four virus-resistant garlic clones. They also combine large bulbs and good bulb quality. Yields of meristem-derived virus-free clones were 78% higher than those from continuously field propagated cloves. However, incidence of two potyviruses was high. Although caging reduced virus incidence, it also reduced yield.

Six onion accessions and 14 garlic entries were found to be resistant to SLB. One *A. cepa* accession appears to have some level of resistance to beet army worm. Screening for resistance to thrips has identified a few promising onion entries.

Genetic resources enhancement and varietal development

Genetic resources activities

AVRDC maintains an *Allium* germplasm collection for conservation and utilization by Center scientists and other researchers. The collection now totals 1040 accessions, 53 of which were acquired in 1997 (Table 1). A total of 418 seed packets were sent to 29 countries, 90 to the Center's regional programs and 66 given to Center scientists at headquarters (Table 2).

A total of 106 accessions of onions were regenerated from bulbs (61) or seeds (45), while 103 accessions of garlic and 15 of shallot were maintained in the field genebank. Regeneration of onion was done through the production of storage bulbs followed by seed production from storage bulbs. Bees and/or flies were used as pollinators. Seeds are dried to low moisture content and stored in cold cabinets. Garlic and shallots, vegetatively reproducing crops, are maintained in a field genebank. Morphological characterization, based on a standard set of descriptors, was done during regeneration. In addition, preliminary studies on leaf epidermal patterns were carried out using safranin-stained leaf peels.

Some 38 accessions of onion, seven of garlic, and eight of shallot were acquired in 1997. Registration, passport, distribution and seed inventory databases were updated.

The following characterization data were based on 35 accessions of onions planted from bulbs in 1996-97. Leaf length varied from 37 to 78 cm, leaf wax from none to few to intermediate, and leaf erectness ratings varied from 3 to 7. Leaf color did not vary. Only 22 accessions flowered. Number of flowers per umbel ranged from less than 30 to more than 120. Anther color ranged from yellow to green, and scape length from 50 to 87 cm. Preliminary studies on epidermal leaf patterns in 12 accessions of garlic (10 from the Philippines and 2 from Indonesia) showed no significant differences in stomatal cell size, stomatal density in the mid-region of the leaf, and length, width, and length:width ratio in cells near the apical region, and cell width in the basal region. Significant differences were noted in stomatal density in the apical and basal region, length, width, and length:width ratio in cells in the mid-region, and length and length:width ratio in cells in the basal region. The presence of variation in some cell traits needs to be confirmed.

Table 1. The *Allium* germplasm collection at AVRDC, 1997

Species	No. of accessions	
	acquired in 1997	total
A. ampeloprasum		2
A. cepa	38	413
A. cepa ssp aggregatum	8	30
A. cepa fistulosum		13
A. longicuspis		3
A. porrum		12
A. sativum	7	477
A. schoenoprasum		2
A. tuberosum		4
A. sp.		84
Total	53	1040

Table 2. Recipients of *Allium* germplasm from AVRDC, 1997

Recipient	No. of samples	
External		418
Bangladesh	43	
Ghana	40	
Lao PDR	36	
India	35	
Vietnam	34	
Philippines	28	
USA	22	
Cambodia	16	
Sri Lanka	15	
Zaire	15	
Others [1]	134	
ARC		45
ARP		45
Headquarters		66
Breeding	66	
Total		574

[1] "Belize, Bhutan, China, Congo, Costa Rica, Ethiopia, Gabon, Guinea-Bissau, Indonesia, Korea, Liberia, Namibia; Nigeria, Poland, Senegal, Sudan, Thailand, Togo, and Tonga.

Developing onion and garlic varieties/breeding lines for long storage life of bulbs

Short-day onions and garlic cultivars in the tropics lack storability. Rotting and sprouting of bulbs cause major losses. Therefore, genetic sources for long storage life, identified in earlier work at AVRDC, are being used in a breeding program which combines useful traits. Major activities in 1997 included evaluation of germplasm lines, F_1 and F_2 progenies for storage quality in onion, and evaluation of clonally selected garlic lines for storage quality.

Onion (50 lines) and garlic (100 lines) germplasm and breeding progenies were evaluated for bulb storage quality under ambient conditions. Onion bulbs were kept in plastic crates and garlic bulbs kept in nylon bags. The bulbs were stored in a ventilated room for 4-5 months and assessed monthly for sprouting, rotting, and weight loss. Crosses were made between long-bulb-storage lines and high-yielding lines, SLB-tolerant lines, and summer-stress-tolerant lines in onion in an effort to combine these traits in long-storage lines.

Onion storage quality improvement

Of the 50 new germplasm lines evaluated for storage quality, four lines (AC544, AC576, AC578, and AC740) were found to be promising, with less than 50% storage loss in four months. Check varieties recorded more than 75% loss, and their non-rotted bulbs were soft (Table 3). Storage losses were high during the year because of continuous rain at harvest time. Line AC740 was best with only 25% storage loss, high bulb yield (63 t/ha), and very firm bulbs. The identified lines will be evaluated further and used in the breeding program.

Table 3. Performance of promising onion germplasm lines for storage losses * and yield

Entry no.	Variety	Source	Bulb yield (t/ha)	Firmness of bulb [a]	Storage losses (%)
AC740	Explorer	Netherlands	63.0[a]	VF	25.0[e]
AC576	Red Creole	Denmark	45.0[b]	F	42.4[cd]
AC578	Texano	Denmark	50.2[b]	F	46.5[cd]
AC544	Sweet success	USA	62.0[a]	MF	48.1[cd]
	Granex 429 (CK)	USA	61.1[a]	S	76.7[b]
	TEG502 (CK)	USA	45.5[b]	S	93.3[a]

[a] VF = very firm; F = firm; MF = moderately firm; S = soft.
[b] Means in the same column followed by the same letter are not significantly different at the 5% level (DMRT).
* After stored for four months in ambient conditions.

Genetic sources for long-storage quality (AC50, AC319, TA377), identified in previous work, were used in a crossing program designed to combine useful traits. The F_1 progenies were evaluated in 1997. Out of 35 F_1 hybrids evaluated, five were found to be promising, although the storage losses were very high due to unfavorable weather at harvest time. The best hybrid, AC319 × AC169, had 49.7% loss in 4 months of storage, compared to check TEG502 which had 77.1% loss (Table 4). Of the parents, AC319 had lowest storage loss (45.1%). These crosses will be used to produce F_2 seeds for further selection for improved storage quality, combining other desirable traits such as earliness and high bulb yield. Among the F_2 progenies developed from the crosses involving long-storage lines, promising selections were obtained in the crosses AC431 × AC50, AC384-2 × TA188, AC429 × AC50, and AC50 × TA69. Bulbs (120 from four crosses) with improved traits, such as earliness, firmness, large bulbs,

Table 4. Evaluation of onion hybrids (F_1) and parents for storage quality and bulb yield

Entry	Bulb yield (t/ha)	Total storage loss* (%)	Firmness of bulb
AC319 x AC169	42.4 b[c]	49.7 [d-e]	VF
AC319 x TA188	30.0 [e]	59.0 [b-d]	F
AC50 x TA377	35.6 [c-e]	60.7 [bc]	VF
AC319 x TA377	39.8 [c-e]	62.0 [bc]	F
TG502 x TA377	71.7 [a]	67.0 [bc]	F
AC319 x TG502	48.9 [bc]	69.0 [bc]	MF
AC50 x AC319	34.8 [c-e]	69.3 [bc]	VF
AC319-1	36.4 [c-e]	45.1 [e]	VF
TA377-1	59.4 [ab]	55.5 [b-d]	F
TA188-1	49.2 [bc]	92.2 [a]	S
AC169-1	36.5 [c-e]	92.6 [a]	S
TG502-1	76.2 [a]	77.1 [b-c]	S

[a] VF = very firm; F = firm; MF = moderately firm; S = soft.
[b] Means in the same column followed by the same letter are not significantly different at the 5% level (DMRT).
* After stored for four months in ambient conditions.

and including long-storage quality (up to five months), were selected for further evaluation. It was observed that bulbs having good firmness tend to have better storage quality compared to soft bulbs (Table 4). Thus, selecting for bulb firmness is an effective means of selecting for storage quality.

Garlic storage quality improvement

Storage quality of more than 100 clonally selected garlic lines was studied. Seven lines displayed long storage quality and high bulb yield. Four lines (GL42-5, GL80-8, GL50-1, and GL28-7) had less than 25% loss in five months of storage in ambient conditions (Table 5). Among these lines, bulb yield was more than 8 t/ha, 2 to 47.5% higher than the check variety, Hsilo. Line GL50-1 had very low storage losses (24.9%) and high bulb yield (11.8 t/ha), 47.5% higher yield than Hsilo.

Development of high-yielding, better quality onion breeding lines/varieties

The problems related to onion production in the tropics are many and varied, and result in low productivity. AVRDC has so far identified genetic sources of useful traits, such as good bulb quality, firmness, earliness, and high yield. These are used in a breeding program designed to develop high-yielding lines with early maturity and good quality, firm bulbs, suitable for production in short-day, tropical environments.

Germplasm lines (70) and previously selected progeny lines (47) were evaluated for bulb yield and quality traits. Yield, bulb color, firmness, and days to maturity were assessed and selections made. F_2 progenies (106) were evaluated and selections were made for combined targeted traits, such as bulb yield, bulb size, firmness, and earliness.

Improvement of onion lines through progeny selection

Progeny selections were made to improve populations for yield and bulb quality characters. During the year, 47 previously selected lines were further evaluated for various traits. Fourteen lines produced bulb yields above 40 t/ha with very low incidence of split bulbs (0-12%) (Table 6). Eight lines had marketable bulb yield (47.5-61.5 t/ha) higher than the OP check variety, Texas Grano 502 (38.3 t/ha). Line AC132-1C had the highest average bulb weight (316 g) and the highest marketable bulb yield (61.5 t/ha). Selections were also made for lower bulb splitting and lower premature bolting. Some of these lines will be used for

Table 5. Performance of promising garlic lines for storage losses * and yield at ambient conditions

Garlic line	Bulb yield (t/ha)	Total losses* (%)
GL42-5	8.4 c	18.9 e
GL80-8	10.4 ab	24.0 de
GL28-7	8.9 c	24.3 cd
GL50-1	11.8 a	24.9 de
GL80-5	10.4 ab	25.1 de
GL26-2	8.1 c	25.2 de
GL84-7	11.5 a	32.6 c
Hsilo (ck)	8.0 c	68.7 a
Ho-mei (ck)	8.7 bc	47.8 b
Significant	**	***
Mean	9.3	33.2
CV %	7.2	8.7

* See Table 4.

Table 6. Promising progenies among selected onion lines

Entry	Bulb yield (t/ha)	Av. bulb wt. (g)	Split bulbs (%)	Bulb color
AC132-1-C	61.5 a	307.6 a-e	0.0	Yellow
TA247-ST-N-(1)	50.2 ab	243.3 d-i	0.0	Yellow
TA239ST-1N	49.8 abc	248.2 c-i	0.0	Yellow
TA364-1N-2	49.5 abc	216.9 g-k	12.9	Red
TA377-1-C	47.5 a-d	302.9 a-e	2.3	Yellow
AC145-1N-2	47.5 a-d	229.6 e-j	0.0	Red
TA377-1C-8	47.0 a-d	316.1 a-d	0.0	Yellow
AC499-1C	47.0 a-d	269.4 a-h	3.7	Yellow
TA369-1N	43.5 a-d	325.9 abc	0.0	Yellow
Granex 429 (Hybrid ck)	45.6 a-d	331.3 ab	10.0	Yellow
Texas Grano 502 (OP ck)	38.3 b-c	283.1 a-g	0.0	Yellow
Mean	28.9	219.3		
CV %	64.9	36.7		

large-scale and mutilocation testing in 1998 for yield and bulb quality.

Evaluation of F_2 progenies

Fifty F_2 progenies originating from 25 cross combinations were evaluated during the year. The main focus was on identifying recombinants combining desirable traits. The traits given major emphasis were earliness to bulb maturity, bulb size, and firmness.

Twenty progenies were found very promising and individual plant selections were carried out for combined useful traits. A total of 106 such plants were selected combining two or three useful traits. Selfed seed was produced from all of these plants for evaluation and selection in the next generation. Seventy-five plants were selected for earliness combined with large bulb size. Similarly, 31 plants were identified as having firm bulbs. The F_2 progeny of the cross between TA69 and TA57 produced plants with extra-early maturity (bulbs maturing around 100 days after transplanting), approximately 25 days earlier than the check variety. The cross produced plants which had bulb maturity better than both of the parental lines. Apart from earliness, the plants produced fairly large bulbs with average bulb weight, >180 g. From the crosses AC431 × AC50, AC49 × AC132, TA377 × AC49, selections were made for large bulbs (>300g) and high firmness (Table 7).

Table 7. Promising selections identified in F_2 progenies

Traits	No. of plants selected	F_2 progenies
Earliness and large bulb size	75	TA69 x TA57, AC380 x TA72 ACC8 x TA57, TA188 x TA72
Bulb firmness and large bulb size	31	AC49 x AC132, AC431 x AC50 TA377 x AC49, AC50 x TG502

Evaluation of germplasm accessions collected during the year

Out of 70 new germplasm lines collected from more than 10 countries, 13 lines were found to be promising, with bulb yield >60 t/ha. In five lines (AC540, AC541, AC571, AC589, and AC729), marketable bulb yield ranged from 69.5 to 96.2 t/ha, 20 to 57% over the check variety, Granex 429 (Table 8).

Out of 70 germplasm lines evaluated, 13 lines were identified for high marketable bulb yield, low incidence of splitting, and low incidence of premature bolting. All these lines had marketable bulb yield higher than the best check, Granex 429 (Table 8). Marketable bulb yield ranged from less than 10 t/ha to 96 t/ha. Tremendous variability was noted in bulb yield, bulb shape,

Table 8. Promising germplasm lines identified during the year

Entry	Variety	Source	Mkt. bulb yield (t/ha)	Av. bulb wt. (g)	Split %	Bolters %	Color
AC571	PS13489	USA	96.2 a	384.0 a-b	0	0	yellow
AC729	Red bone	USA	80.5 ab	419.7 a	7	3	red
AC540	Gladiator	Australia	74.0 a-d	307.1 d-i	0	0	yellow
AC541	Sunex 1502	USA	73.0 a-e	341.5 a-h	0	0	yellow
AC589	Liberty	Netherlands	69.5 a-f	338.2 a-h	0	7	yellow
AC525	Mercedes	USA	69.5 a-f	336.7 a-h	0	13	yellow
AC526	High Gold-1	Japan	68.5 a-g	400.0 abc	7	0	yellow
AC582	Gold Rush	South Africa	68.0 a-g	309.6 d-i	0	4	yellow
AC588	BGS85	Netherlands	65.5 a-h	405.1 ab	10	3	yellow
AC740	Explorer	Netherlands	63.0 b-i	373.1 a-e	4	0	yellow
Granex 429 (ck)			61.2 b-i	384.3 a-d	5	0	yellow
Texas Grano 502 (ck)			45.5 c-p	313.5 d-i	2	2	yellow
Superex (ck)			28.4 j-q	305.0 d-i	2	2	yellow
Mean			41.1	277.0			
CV %			65.9	38.7			

weight, splitting, and bolting. AC729 was red while all the others were yellow.

Breeding for resistance to stemphylium leaf blight, purple blotch, and anthracnose in onion

Resistance to SLB was confirmed in five *A. fistulosum* accessions (TA104, TA108, TA198, TA204, and AF468) in field and in laboratory experiments in past years. Interspecific barriers have, however, limited the use of genes from *A. fistulosum* to improve onion lines. These barriers act at several levels, such as 1) disturbance in meiotic cell division leading to highly sterile gametes, 2) stylar incongruity resulting in lack of pollination, and 3) nuclear-cytoplasmic incompatibility, and as a result, only selected gametic combinations had fertilization. There is no problem producing F_1 hybrids. These barriers start to operate, however, at the F_1 generation and onwards. Our strategy has involved crossing *A. fistulosum* with a large number of *A. cepa* (onion) accessions originating from various geographical regions. During the year, 13 F_1, 57 F_2, 81 F_3, 34 BC_1, and 5 BC_1F_2 progenies involving *A. cepa* and *A. fistulosum* crosses were evaluated for resistance to SLB, bulb traits, and fertility.

Table 9. Pollen fertility, seed set and SLB reaction of F_1 plants

Cross		Pollen fertility (%)	Seed set (%)	Disease reaction
CF16	AC15 x TA198	33.1	10.3 (750)	R
CF19	AC50 x TA198	40.2	8.2 (300)	R
CF52	AC49 x TA204	42.0	7.1(500)	R
CF54	AC319 x TA204	36.0	8.0 (1200)	R
CF57	AC444x TA204	25.0	1.0 (104)	R
CF67	AC425 x TA198	21.0	2.0 (61)	R
CF68	AC426 x AF468	32.0	4.0 (3200)	R
CF69	AC431 x AF468	15.0	0.5 (19	R
FC45	TA198 x AC50	35.7	7.0 (300)	R

Screening for disease resistance was carried out both in the field and in a growth room after artificial inoculation. Screening for resistance to anthracnose was carried out under controlled conditions. New backcrosses were made.

Development of SLB resistance in onion

All 14 F_1 hybrids showed resistance to SLB in field evaluations, indicating a possible dominant gene action controlling this disease (Table 9). In controlled-condition experiments, after artificial inoculation, most plants were found to be resistant. Some were classified as moderately resistant. The cross CF16 had moderate pollen fertility (33.1%) and low seed set (10.3%), but it had poor bulb development. CF19 and FC45 had good pollen fertility (40.2 and 35.7%, respectively), low seed set (8.2 and 7.0%, respectively) and medium bulb development. No reciprocal differences were noticed for the fertility level in CF19 and FC45 crosses (Table 9). The crosses CF52 and CF54 also had moderate pollen fertility (36 and 42%) and low seed set (7.1 and 8.0%). These five F_1s were identified for further study, as all other crosses had extremely poor pollen fertility and seed set.

Out of 57 F_2 progenies evaluated, six (CF16, CF19, FC45, CF52, CF54, and CF56) were found to be promising for pollen fertility, seed set, and resistance to SLB (Table 10). Progenies segregated for disease reaction to SLB, but the majority of the plants were either resis-

Table 10. Promising F_2 progenies of *A. fistulosum* and *A. cepa* crosses for SLB resistance, fertility, and bulb development

Cross	No. of plants	Bulb. development	Pollen fertility (%)	Seed set (%)	Disease reaction (% plants)		
					R	MR	S
CF16-0 (AC15 x TA198)	6	Poor	35-50	25-35	6	0	0
CF19-0 (AC50 x TA198)	17	Very good	40-65	5-30	10	7	10
FC45-0 (TA198 x AC50)	10	Very good	25-55	8-15	10	0	0
CF54-0 (AC319 x TA204	3	Medium	30-65	7-25	3	0	0
CF52-0 (AC49 x TA204)	3	Small bulb	35-71	10-20	3	0	0
CF56-0 (AC426 x TA209)	2	Medium	45-65	5-30	2	0	0

tant or moderately resistant. A dominant gene control of the disease is speculated. The best progenies identified were CF16-7, CF19-1, and FC45-1 (Table 11). In these lines, plants were selected for SLB resistance both in the field and in the laboratory, with high pollen fertility, good seed set, and good bulb development. Out of 83 F3 progenies evaluated, progeny CF16-7-1 had excellent seed set (60%) and resistance to SLB, but had poor bulbs. CF19-15-1 had good seed set (up to 50%), resistance to SLB, and good bulb development. Progeny FC45-15-1 had low seed set, but was resistant to SLB and had good bulbs (Table 11).

Among the 34 BC_1 progenies evaluated, only three (CF16 × TA377, CF19 × AC50, and FC45 × TA364) were found promising for fertility, apart from resistance to SLB (Table 12). Others had high levels of pollen sterility leading to very poor or no seed set. The best backcross progeny, CF16 × TA377, had 60% pollen fertility, 41% seed set, and moderate bulb development, apart from resistance to SLB.

Evaluation of A. cepa *and* A. fistulosum *crosses for resistance to anthracnose*

Screening under controlled conditions found resistance sources for anthracnose disease in several *A. fistulosum* accessions: TA198, TA204, AF468, AF556, AF557, AF558, AF559, AF560, AF561, AF562, and AF684. Four F_3 progenies involving *A. cepa* and *A. fistulosum* crosses developed for SLB resistance were also evaluated for anthracnose disease under controlled conditions. Resistant plants were obtained in all the four progenies, ranging from 19 to 55.5%. Most plants were resistant or moderately resistant to anthracnose. The selected resistant plants will be used to develop onion lines with combined resistance to SLB and anthracnose.

Improvement of garlic through clonal selection and mutation breeding

Clonal selection (garlic does not set seed) was carried out to utilize existing variability. Garlic planting materials were irradiated to generate mutations for desirable traits including disease resistance. The major objective of the program was to select garlic clones superior in yield and quality, having large size bulbs, larger cloves, besides having resistance to SLB and viral diseases. Several clonally selected and mutation derived lines have been developed and are now being further evaluated for yield and bulb traits, besides resistance to viral and fungal (SLB) diseases.

Evaluation of clonally selected Vg_4 (57 lines) and Vg_3 (30 lines) generation lines was carried out to identify superior genotypes for yield and quality traits. Virus-resistant clones identified in five lines were evaluated for bulb yield and resistance to viral diseases

Table 11. Promising F_3 progenies of *A. cepa* and *A. fistulosum* crosses

Cross	No. of plants	Bulb development	Pollen fertility (%)	Seed set (%)	SLB reaction (no. of plants) R	MR
CF16-7-0-1 (AC15 x TA198)	8	Poor	50-60	60	8	0
CF19-15-0-1 (AC50 x TA198)	11	Good	40-55	20-50	8	3
FC45-15-1-P (TA198 x AC50)	2	Good	31-35	5-8	2	0

Table 12. Evaluation of backcross progenies

	Characters	% of progenies
1.	Good or med. bulb development, R or MR to SLB Poor pollen fertility (<25%), Very low seed set (<1%)	22
2.	Good bulb dev., resistance to SLB, No. flowering	7
3.	Good or med. bulb dev., resistance to SLB, good pollen fertility (>40%), low seed set (<5%)	2
4.	Good bulb development R to SLB, good pollen fertility (>50%), good seed set (>40%)	3

through ELISA testing. Virus-free lines generated through meristem culture were evaluated in the field under a net cage. Promising mutations/variants identified among mutation breeding populations presently at the VgM_4 generation were evaluated.

Since 1993, four groups of clonal selections (IBS1, IBS2, IBS3, and IBS4) have been generated. These clonal selection groups are presently in Vg_5, Vg_4, Vg_3, Vg_2, and Vg_1 generations. The clonal selection made in 1993, i.e., IBS1, is presently in Vg_4 generation, IBS1Vg_4. Similarly other groups are denoted as IBS2Vg_3, IBS3Vg_2, and IBS4Vg_1. Results obtained in IBS1Vg_4 and IBS2Vg_3 generations are reported here. In the first group (IBS1Vg_4), 22 lines were evaluated in a replicated trial. Significant yield differences were observed (Table 13). Four promising selections (Gl68-1, Gl68-3, Gl71-5, and Gl77-6) with >11 t/ha bulb yield were identified showing more than 45% increase in yield over the best check variety, Hsi-lo. The best selection, Gl68-1, yielded 61% higher than the check variety.

Sixty-eight lines of IBS2Vg_3 were evaluated. Bulb yield ranged from 7.1 to 13.5 t/ha. Eight lines were identified for high bulb yield, from 10.3 to 13.5 t/ha (Table 14). These lines yielded as much as 34% higher than Hsi-lo. The lines GL46-3 and GL97-1 had fewer but larger cloves.

Table 13. Performance of promising garlic clonal selections (IBS1Vg_4 generation)

Selected clone	Bulb yield (t/ha)	Av. bulb wt. (g)	Bulb diameter (mm)	Clove no.
GL68-2	12.9 ab	57.3	58.2 ab	15.3 b-d
GL77-6	11.9 a-d	45.3	54.2 a-d	15.5 b-e
GL71-5	11.8 a-e	45.4	55.2 a-d	18.3 bc
GL68-3	11.8 a-e	50.5	55.3 a-d	18.8 b
GL73-8	10.9 b-j	27.2	54.6 a-d	14.5 b-e
GL79-3	10.8 b-k	45.2	53.9 a-d	14.2 b-e
GL77-4	10.0 d-m	24.0	52.7 a-d	10.9 d-f
Hsilo (ck)	8.0 p	39.5	54.4 ad-	13.1 b-e
Significance	***	ns	**	***
Mean	9.7	42.3	52.8	14.5
CV (%)	7.7	25.2	4.9	17.6

Hsi-lo was irradiated at 0.5, 0.75, and 1.0 K Rad gamma-rays and resulting mutants/variants were selected. Out of 40 lines (presently in VGM_4 generation) evaluated for bulb yield, 18 had higher bulb yield than the non-irradiated Hsi-lo (Table 15). Four lines, HS.75KR-M12, HS0.5KR-S1, HS0.5KR-L1, and HS.75KR-L14, had bulb yield of 9.5 to 13.3 t/ha, 18 to 66% higher than the check.

Resistance to virus diseases in garlic

Virus-resistant garlic clones of GL42, GL98, GL49, and GL50 were evaluated for virus resistance and bulb yield. Results confirmed previous findings, as the lines displayed negative ELISA reaction to onion yellow dwarf virus (OYDV), shallot latent virus (SLV), garlic common latent virus (GCLV), and leek yellow stripe virus (LYSV). Each line had negative ELISA reaction

Table 14. Performance of promising garlic clonal selections (IBS2Vg_3 generation)

Selected clone	Bulb yield (t/ha)	Av. bulb wt. (g)	Bulb diameter (mm)	Clove no.
GL50-3	14.3 a	51.5 a	57.9	26.0 b-h
GL97-4	13.0 a-d	45.2 a-c	53.5	26.2 b-g
GL97-1	13.5 ab	44.2 a-c	53.6	23.6 c-i
GL105-4	12.6 a-f	51.3 ab	58.2	29.9 a-e
GL101-2	12.6 a-f	42.1 a-c	53.1	24.0 b-i
GL50-2	11.9 a-g	46.4 a-c	57.1	31.2 a-d
GL98-10	10.4 b-h	48.3 ab	57.8	28.9 a-e
GL46-3	10.3 b-h	43.0 a-c	54.7	17.8 f-k
Hsilo	10.1 c-h	48.1 ab	55.6	33.2 a-c
Homei	9.6 d-i	43.1 a-c	55.8	30.3 a-d
Significance	***	***	ns	***
Mean of 39 entries	9.5	33.8	53.5	18.9
CV (%)	15.2	20.4	7.0	23.1

Table 15. Performance of promising lines developed through mutation breeding in variety Hsi-lo

Line	Bulb yield (t/ha)	Av. bulb wt. (g)	Bulb diameter (mm)	Clove no.
HS.75KRM12	13.3 a	52.0	55.9	16.9
HS.5KRS1	12.4ab	55.0	54.0	15.2
HS.5KRL1	12.0 ab	52.2	53.8	14.3
HS.75KRM3	9.5	43.6	53.3	16.1
Hsi-lo (ck)	8.0 cd	39.5	54.0	13.1
Significance	***	ns	ns	ns
Mean	7.9	42.3	52.4	16.8
CV (%)	17.1	19.0	7.7	10.3

to two or three viruses. In the line GL42-2E, four populations had negative reaction to OYDV, GCLV, and LYSV. The plants had no visible leaf symptoms. These lines had fairly good bulbs with an average bulb weight of 35 g. Six clonally selected lines of GL98 were evaluated for virus resistance. All six lines displayed negative reaction to OYDV, SLV, and GCLV. One of the lines, G98-6-2-3, displayed negative reaction to all the four major viruses, i.e., OYDV, LYSV, SLV, and GCLV. Extremely mild virus symptoms were observed in all the lines. These lines had good bulb quality and were fairly large and bulb weight averaged from 45 to 75 g. Thus, they have commercial potential. Negative virus reaction in these lines has been observed over the last three years.

Breeding for true-seed shallot varieties with improved yield and quality

Shallots are presently planted using vegetative planting materials. But there are drawbacks to using bulbs for commercial plantings. Apart from the expense, viral, fungal, and bacterial pathogens, and nematodes are easily transmitted in planting materials. To help remedy this, the Center set out to develop a true-seed propagation system for shallot. Forty-seven lines showing good flowering and seed set have been identified. Initial selection to improve bulb quality and yield have given good results.

Seed production in 25 lines selected for good bulb quality and yield was carried out during 1997 in net cages using controlled pollination. Some 111 selected self and sib progenies were planted as seed and were evaluated for their bulb yield, uniformity, maturity duration, and bulb quality traits. Further selections were made for bulb uniformity, maturity duration, and bulb quality.

Among the nine selfed progenies evaluated in observational trials, three progenies, S8-S, S24-S, and TA265-S, were the best with bulb yields of more than 25 t/ha, average bulb weight from 50 to 80 g, and 4 to 15 bulblets per plant.

Of the 102 sib progeny lines evaluated in observational trials, 20 lines had bulb yield above 20 t/ha. Six lines were found highly promising with estimated bulb yield ranging from 22.9 to 28.4 t/ha, which was 7 to 34% higher, respectively, than the check variety S-28 (21.3 t/ha) planted as bulbs (Table 16). Bulb quality was good with red to deep-red color. Number of bulblets ranged from 7 to 17 and average bulb weight of the selected lines ranged from 108 to 128 g. The check variety had very many bulblets (46) and low average bulb weight (96 g). Three lines, S25-C(2), S44-S-C, and S59-N, had high bulb yield (>25 t/ha) and good bulb quality. Bulb color and maturity duration in these lines were not uniform and need further improvement. The lines take about 15 days longer to mature compared to the bulb-planted crop.

Genetic studies on clonal selection of garlic

Clonal selection is a major breeding method for garlic, since plant sterility usually precludes crop improvement by means of cross hybridization. Since no segregating population is available, stability and inheritance of specific traits obtained through clonal selection is hard to monitor by normal genetic analysis. Amplified fragment length polymorphism (AFLP) is a technique for fingerprinting genomic DNA. It generates a visual image of DNA which can be used to detect DNA differences between plants, or DNA polymorphism. Thus, AFLP might help identify genetic

Table 16. Performance of promising shallot progenies for bulb yield and related traits

Line	Bulb yield (t/ha)	Av. bulb wt. (g)	No. of bulblets per plant	Bulb color
S25-C(2)	26.6	120	17.2	red
S44-S-C	28.4	128	14.4	red
S103-C	22.9	108	16.4	deep red
SVF96m1-S	23.9	108	8.2	red
S101VFm4-S	24.9	108	7.2	deep red
S59-N	28.0	128	15.2	red
S28 (ck)	21.3	96	46.0	light red

variability among selected garlic clones. The purpose of this experiment was to establish an AFLP analysis technique for garlic, and assess its usefulness for identifying clonal variation.

Leaves from GL42, and its clonally selected lines, GL42-2-E, GL42-3-E, GL42-4-E, and GL42-5-E, were harvested for genomic DNA extraction. The AFLP analysis system I kit, developed by Life Technologies (USA) , was used in this study.

Primer combinations able to generate polymorphism in garlic have been identified for AFLP analysis (Table 17). About 150 bands could be detected simultaneously by each polymorphic primer pair. The number of fragments amplified per sample per primer pair depends on the sequence context of the selective nucleotide, and the complexity of the genome and averages 50 with the AFLP analysis system I kit. The high number of bands amplified relative to most reports of other crops might be partially due to the large genome size of garlic.

Table 17. Informative primer combinations for the AFLP analysis in garlic

	E-AAC[z]	E-AAZ	E-ACA	E-ACT	E-ACC	E-ACG	E-AGC	E-AGG
M-CAA[y]		+	+	+	+	+	+	+
M-CAC	+[x]	+	+	+	+		+	+
M-CAG		+	+	+	+		+	
M-CAT	+	+	+		+		+	+
M-CTA	+				+		+	
M-CTC	+	+	+		+		+	+
M-CTG	+	+	+		+		+	
M-CTT	+		+		+			

[z] Primer with *Eco*RI restriction site and 3 selective nucleotides.
[y] Primer with *Mse*I restriction site and 3 selective nucleotides.
[x] "+" indicates positive amplification.

Due to limited data, the similarity matrix analysis of polymorphic loci between clonal selection lines cannot be evaluated at this point. However, the polymorphic profile of these materials indicated genetic variation exists between GL42 and its clonally selected lines as well as among selected lines (Fig. 1). As these lines were vegetatively propagated, genetic variation could result from mutation accumulated during the long-term cultivation. The data also suggested that the mutation frequency could be an important driving force of genetic variability in garlic. Some tested lines were also reported to show resistance to some virus diseases. Further study is required to verify the correlation of AFLP with these disease resistance traits.

Virus elimination and virus indexing

Because garlic and shallot are usually vegetatively propagated, virus infection is almost 100%. So far, seven viruses have been described and characterized, but there is strong indication that still other viruses and other serologically distinct strains are present. As an international center, we have to assure that all incoming and outgoing germplasm is free of virus. Our ob-

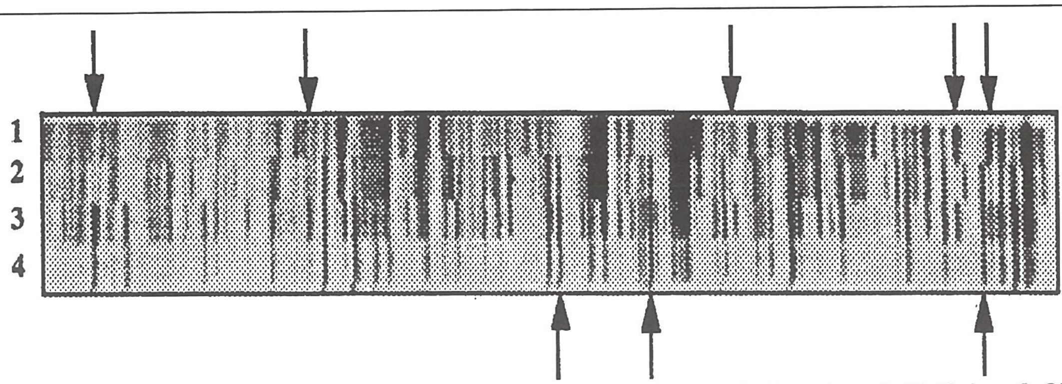


Fig. 1. Example of AFLP test using E-5 and M-3 primers in garlic. From top to bottom: lane 1, GL42; lane 2, GL42-2-E; lane 3, GL42-5-E; lane 4, (GL-3-E + GL-4-E). Arrows indicate polymorphism between tested lines.

jectives are, therefore, to set up an effective virus-elimination and virus-indexing system, to clean our germplasm of virus, and to determine the fate of virus-free plant material once planted in the field.

For routine virus-elimination, the scheme described in AVRDC's 1994 Annual Report is followed. It comprises virus elimination by meristeming followed by three ELISA tests for seven viruses, the first one before the young tissue-cultured plantlets are transferred to soil, the second and third at the end of the first and second growth cycles, respectively, in the greenhouse.

To improve the efficiency of virus elimination, heat treatment of bulbs before meristeming was tested (30°C – one week; 36°C– one week; 38°C– seven weeks). An electronmicroscopic examination of plantlets at the end of the second growth cycle was also introduced to detect any virus that could not be detected by ELISA.

The effect of virus reinfection of virus-free garlic was studied on two meristem-derived clones of the garlic cultivar 'Black Leaf' planted in an AVRDC field, both protected by an insect proof net cage and without protection. Before harvesting, all plants were tested by ELISA for six viruses.

- Routine virus elimination and virus indexing

The routine virus elimination/indexing of garlic and shallot continued, bringing the total to 231 virus-free garlic lines and 27 virus-free shallot lines. Initial virus infection was high. All but three of 169 lines subjected to virus indexing in 1997 were virus-infected. Mite-borne filamentous virus (MbFV) was the most frequently encountered virus (in 60% of the cloves tested) followed by GCLV (40%), OYDV (37%), SLV (27%), and LYSV (17%).

- Improvement of virus elimination/indexing

A heat treatment of five lines before meristeming was found to have a differential effect on the six viruses present in the original materials. The treatment considerably decreased incidence of LYSV and MbFV, but increased that of SLV. In the case of OYDV, results were inconclusive (Table 18); in three of the five lines tested, OYDV incidence had increased, in the other two it had decreased. An electronmicroscopic examination of tissue-cultured plants at the end of the second growth

Table 18. Presence of viruses in heat treated garlic cloves

Garlic line[1]	Treatment[2]	% meristem survival	% cloves infected with virus[3]					
			SLV	OYDV	MbFV	LYSV	GLCV	SYSV
G29	no heat	85	38	42	100	8	0	0
	heat	95	68	49	70	2	0	0
G 34	no heat	90	43	79	43	14	0	0
	heat	70	72	28	36	0	4	0
G 37	no heat	100	32	52	96	0	0	0
	heat	100	58	90	47	0	0	0
G 43	no heat	100	28	61	72	6	0	6
	heat	100	66	86	46	0	0	0
G 50	no heat	100	22	11	85	11	0	4
	heat	90	41	44	6	0	0	0

[1] The lines originated from Tainan DAIS.
[2] 30°C/1 wk, 36°C/1 wk, 38°C/7 wk (growthroom, dark). Six bulbs/line were subjected to the heat treatment before meristeming, after the dormancy had been broken. Of each bulb 2-3 meristems were excised to obtain a total of 20 meristems per line.
[3] Tested by ELISA before transplanting to soil.

cycle was quite effective in detecting viruses not detected by ELISA. Forty percent of the samples tested were found to harbor viruses.

- Effect of virus elimination on yield and virus reinfection of garlic

In the fourth season of field planting, the yields of meristem-derived clones were still on average 78% higher than those of continuously field-propagated clones (Table 19). This compared to an average of more than 200% yield increase observed in meristem-derived plants in the third field planting. A high incidence of two potyviruses, LYSV, and OYDV, was noted in the meristem-derived plants. SLV and MbFV were detected in a small percentage of the meristem-derived plants. From the results it is also obvious that caging of meristem-derived plants greatly reduces virus-reinfection, although it does reduce yield.

Host resistance to stemphylium leaf blight of bulbing alliums

Stemphylium leaf blight, caused by *Stemphylium vesicarium*, is one of the most serious foliar blights of onion and garlic in Asia, where it is often misidentified as purple blotch. Recent surveys have shown SLB to be more prevalent than purple blotch in many areas. Control of SLB is primarily by use of fungicides because no resistant varieties are available. The objectives of this study were (1) to develop a laboratory protocol for assessing SLB reactions of onion, (2) to screen onion breeding populations and accessions for their SLB reactions in the laboratory, (3) to evaluate onion and garlic entries planted in the fields at AVRDC for their reactions to SLB, and (4) to compare the effectiveness of azoxystrobin with the effectiveness of a currently recommended fungicide treatment for control of SLB in onion.

To determine the effect of leaf wetness duration on SLB development, inoculated plants were transferred at 6-hour intervals from the humidity chamber to the

Table 19. Yields and virus reinfection of meristem-derived virus-indexed plants of the cultivar 'Black Leaf' grown for the fourth season[1] in the field

Origin of line	Treatment[1]	Yield/ plant g (% increase)	% virus reinfection[2] SLV	LYSV	OYDV	MbFV	SYSV	GCLV	% virus-free plants
M1	cage	48.3a (123)	0	38	28	12	0	0	57
	no cage	66.9b (120)	7	62	68	0	0	0	12
M2 (cage)	cage	36.3cd (67)	0	0	0	0	0	0	100
	no cage	45.9bc (51)	8	67	93	0	0	0	3
M2 (no cage)	cage	34.8cd (60)	0	17	13	12	0	0	80
	no cage	45.6bc (47)	5	75	83	3	0	0	5
F	cage	21.7e	3	100	100	98	2	0	0
	no cage	30.4de	8	100	100	90	2	0	0
	CV	15.2							
	LSD	11.0							

[1] In the first season (Spring 94/Summer 95) (planting May 19, harvesting Sept. 2) the cloves were planted for multiplication in autoclaved soil under a net cage (400 mesh/m^2) to prevent virus reinfection (planting May 19, harvesting Sept. 2). In the second season (Fall 94/Spring 95) (planting Dec. 2, harvesting March 30) the cloves were planted both under the net cage and directly in the *Allium* breeding field. At the end of the second growing season no virus was detected. In the third season (Fall 95/Spring 96) (planting Oct. 23, harvesting April 11) planting was as for the second season. However the cloves of line M2 were chosen both from the second season caged as well as non caged plants. For the fourth season planting (Fall 96/Spring 97) (planting Nov. 8, harvesting April 18) planting materials were as described for the third season.

[2] Tested by ELISA before harvesting.

greenhouse where the foliage dried rapidly. Disease severity in each group of plants was compared at 7 days after inoculation. The protocol presently in use at AVRDC is as follows: Inoculate 30 to 60-day old plants with a 1x105 conidia per ml suspension from *S. vesicarium*; add 0.01% Tween 20 as a wetting agent; spray foliage to the point of runoff; hold plants at 22°C in the dark with a saturated environment to maintain leaf wetness for 36 h; thereafter allow the foliage to dry and keep the plants at 22°C and 60-95% RH with a 14-hour/day light period. Assess the disease reactions at 5 to 7 days after inoculation on a scale of 1-5 in which 1 = no symptoms and 5 = >50% of the leaf area affected.

Garlic and onion lines and accessions planted in the fields at AVRDC during winter/spring, 1996-1997, were rated for their reactions to SLB that developed from natural inoculum. Three rates of azoxystrobin were compared with a standard fungicide treatment, iprodione+mancozeb, in a field study for their effectiveness against SLB in onion. The field study was arranged in a RCBD with four replications and 176 onion plants per plot. Fungicides were applied at 2-week intervals for a total of eight applications. Border rows were inoculated with *S. vesicarium* to assure uniform heavy inoculum in the test plots.

Table 20. The effect of duration of the leaf wetness period following inoculation on development of stemphylium leaf blight on onion[a]

Duration of the leaf wetness after inoculation	Disease severity rating[b] at 7 DAI			
	AC 47	Granex 429	TA 108	AF 468
0 hr	1.22 d	1.29d	1.00 c	1.03 c
6 hrs	1.59 cd	1.31 d	1.08c	1.08 bc
12 hrs	2.41 bc	2.08 c	1.03 c	1.14 abc
18 hrs	2.81 b	2.64 bc	1.09 c	1.28 ab
24 hrs	3.17 b	3.17 ab	1.20 b	1.22 abc
30 hrs	3.33 b	3.25 ab	1.28 ab	1.25 abc
36 hrs	4.33 a	3.78 a	1.32 a	1.31 a

[a] Sown: 14 March 1997. Inoculated: 5 May 1997 (*Stemphylium vesicarium* isolate Sv-7, $1x10^5$ conidia/ml suspension).

[b] Mean of 12 plants in each of 3 rep; the disease reactions were rated on a scale of 1 to 5 in which 1 = no symptoms; 2 = <5% of leaf area affected; 3 = 6-25% of leaf area affected; 4 = 26-50% leaf area affected; and 5 = >51% leaf area affected.

Data followed by the same letter in the same column were not

Testing the effect of leaf wetness

An experiment was conducted to evaluate the effect of leaf wetness duration on SLB severity on known resistant and susceptible onion lines. Disease severity on the susceptible varieties at 7 days after inoculation increased steadily from a rating of about 1 with no leaf wetness period, up to about 4 when exposed to 36 hours of leaf wetness (Table 20). Severity ratings of resistant lines only increased from about 1 to 1.3 under the same conditions. Thus, the 36-hour leaf wetness period was deemed most appropriate for evaluating SLB reactions because of the greater disease severity differences between resistant and susceptible lines.

Laboratory evaluations for SLB-resistance

Five sets of plant materials were evaluated for their reactions to SLB in the laboratory. They were as follows: 16 elite garlic lines, 24 promising onion genotypes, 11 onion accessions, 41 *A. cepa* × *A. fistulosum* lines from seed, and 15 *A. cepa* × *A. fistulosum* lines

Table 21. Evaluation of Allium entries for their reactions to stemphylium leaf blight following inoculation in laboratory

Project	No. of entries in each category[a]					
	VR	R	MR	S	VS	Total entries
Elite garlic lines	0	0	0	0	16	26
Onion promising genotypes	0	0	0	0	24	24
A. cepa x *A. fistulosum* lines, seed	0	16[b]	12	7	6	41
A. cepa x *A. fistulosum* lines, topset	0	1[c]	13	1	0	15
Onion accessions	0	6[d]	0	0	5	11
Total	0	23	25	8	51	107

[a] Disease reaction categories are based on mean DSRs; mean DSR of 1 = Very resistant (VR); 1.1 -2.0 = Resistant (R); 2.1-3.0 = Moderately resistant (MR); 3.1-4.0 = Susceptible (S); and 4.1-5.0 = Very susceptible (VS).

[b] Resistant pedigrees: TA105S(3)-0; TA108S(1)-0; TA198S(2)-0;CF19-31-P; CF19-32-P;FC27-9-P; FC45-28-P; FC42-P; FC45-P; FC46-P;FC51-P; CF21xTA198-P; TA204(1)-0;AF468S(1)-0; TA198-S; TA204-S.

[c] CF52(1)

from top-set bulblets. All of the garlic lines were rated very susceptible to SLB (Table 21). Seventeen of the onion lines *A. cepa.* × *A. fistulosum* crosses (16 from the seed group and one from the top-set group) were rated resistant to SLB. Six of the 11 onion accessions were found to be resistant.

Field evaluations for SLB resistance

Garlic and onion entries were evaluated on 28 March and 7 April 1997, respectively, for their SLB reactions to natural inoculum in the field at AVRDC. A total of 453 garlic entries were evaluated. None of the entries was rated to be 'very resistant', but 14 were rated 'resistant' and 63 'moderately resistant'. The entries found to be resistant were: FG1CKL3, FG1CKL4, FG1CKS9, FG10.5L3, FG10.5M27, FG11M15, FG11S7, G37R2S2, G37R2S8, G37R2VS11, 95G120-4, TA149m3, TA158m5, and TA158m6. A total of 127 onion entries were evaluated. None of the entries were rated as very resistant or resistant, but 12 were rated moderately resistant, they included: AC512, 514, 515, 522, 523, 530, 531, 552, 553, 564, 574, and 726.

Table 22. Effect of fungicidal treatments on *stemphylium* leaf blight development and yield of onion[1] - AVRDC 1996-97

Treatment [2]	Concentration	Yield (t/ha)	Disease severity[3]
Iprodione 50% W.P.	1.0 g/liter	113.4 b[4]	127.8c[4]
+Mancozeb 80% W.P.	2.5 g/liter		
Iprodione 50% W.P.	1.0 g/liter	95.7 c	183.8 b
+Mancozeb 80% W.P.	2.5 g/liter		
+Citrole	15.0 ml/liter		
Azoxystrobin 25% E.C.	0.2 ml/liter	125.2 a	112.0 c
Azoxystrobin 25% E.C.	0.4 ml/liter	133.0 a	91.0 d
Azoxystrobin 25% E.C.	0.8 ml/liter	134.2 a	80.5 d
Nonsprayed check		76.6 d	266.0 a

[1] Cultivar Granex 33, transplanted 13 November 1996 and harvested on 16 April 1997.
[2] The first fungicidal application made on 18 December 1996 and thereafter at 2-week intervals. 0.1% Tween-20 added to each treatment.
[3] Area under disease progress curve.
[4] Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT.

Efficacy of azoxystrobin for control of SLB of onion

Azoxystrobin was evaluated in the field for control of SLB on Granex 33 onions. Three rates of azoxystrobin (50, 100, and 200 ppm) were compared with a standard fungicide treatment, with and without Citrole, and an untreated check to assess its efficacy against SLB. All fungicide treatments significantly ($P<0.05$) reduced the severity of SLB and led to increased bulb yields in comparison with the untreated check (Table 22). Control of SLB by azoxystrobin at the 100 and 200 ppm levels was significantly better than that by all other treatments. Azosystrobin at 50 ppm was as effective as the currently recommended treatment, iprodione plus mancozeb. Addition of Citrole reduced the effectiveness of the standard treatment. Onion yields in the three azoxystrobin treatments were significantly higher than those in all other treatments, but there were no differences in yields among the three rates of azoxystrobin. The addition of Citrole to the standard treatment resulted in a significant yield loss.

Studies on the control of beet armyworm in onions

Onion and shallots in Asia are attacked by *Spodoptera exigua* (Huebner), the beet armyworm (BAW) and *S. litura* (F.), the common armyworm (CAW). Larvae of these pests either feed on the leaf surface or, in most cases, bore inside the tubular leaves and feed while remaining concealed in the leaf. Pupation takes place in soil. This life cycle protects larvae and pupae from natural mortality factors, such as parasites and predators, rainfall, and insecticide foliar sprays. In a series of three field experiments, we studied the possibility of managing the pest by manipulating the behavior of its adults. In particular, we studied the utility of one component of a 4-5 component sex pheromone of BAW, (Z,E)-9, 12-tetradecadienyl acetate [(Z9, E12)-14:OAc], in disrupting mating, leading to reduction in pest damage. We also studied the height at which the adult insects fly so that certain barriers might be used to prevent their migration, the subject of our third field study.

Two parcels of land, each measuring 30 m × 20 m and located 30 m away from each other were transplanted with 6-week-old bulb onion seedlings. Immediately after transplanting, pheromone release stations (1-m tall plastic pole or bamboo stick) were erected at the junction of a 4-m grid laid throughout one parcel. A 10-cm long and 2-mm diameter special plastic tube containing 20 µg (Z9, E12)-14:OAc was tied at 30 cm above the plant canopy. A new tube containing 20 µg of the chemical was tied once every week. The BAW and CAW male adult populations were monitored once a week by placing full blend sex pheromone traps in both fields. We also observed all onion plants in 10 randomly selected 1-m long rows and recorded armyworm-damaged and healthy plants on a rating scale of 0 to 5 (0 = no damage, 5 = maximum damage).

In the second test, a 0.05-ha parcel of land was planted to bulb onion. Six 4.5-m high poles were erected, three to the south and three to the north edges of the planted area. At 1-, 2-, 3-, and 4-m above the ground, 21.5 cm × 21.5 cm white paper boards coated with Tangle Foot glue were posted with the sticky surface pointing away from the onion planting. The number of male and female BAW adults trapped on the sticky boards was recorded once a week for 11 consecutive weeks. During the observation, the boards were replaced when moth scales or dust covered a significant amount of the sticky surface.

In the third study, a 0.1-ha parcel of land was plowed and worked into 0.75-m wide ridges and furrows. The area was divided into two 30 m × 20 m plots. Each plot was transplanted to 6-week-old bulb onion seedlings. Immediately after transplanting, a 2-m high nylon net barrier was erected along all sides of one parcel, whereas the other parcel was maintained as such as a check. The top 10-cm area of the nylon net was coated with Tangle Foot glue to prevent BAW adults that landed on net from crawling inside the planted area. The number of BAW adults trapped in the glued area was recorded once a week. In order to see whether BAW adults are present in the area, once a week for six consecutive weeks we placed in each parcel one winged trap baited with 10 µg of sex pheromone of BAW and one with an equal amount of pheromone of CAW. The following morning we recorded the number of moths trapped. Once a week for six weeks we selected at random, four 2 m × 1.5 m areas (two 2-m long lines) and assessed, on a scale of 0 to 5, the BAW larval damage to the foliage, where 0 = no damage, 5 = 100% damage. At harvest, we sampled four 5 m × 4.5 m areas (5-m long, 6 rows) and recorded the bulb yield in each area.

Results of the monitoring of BAW and CAW adults by sex pheromone traps in treatment and check parcels of onion plantings are summarized in Table 23. A day

Table 23. Trapping of *Spodoptera exigua* and *Spodoptera litura* male adults by sex pheromone traps placed in two onion fields, AVRDC, autumn-winter 1996-97

Date of observation	Number of adults trapped per trap overnight: Check field exigua	Check field litura	CD field[a] exigua	CD field[a] litura
18 Nov. 96	83	16	45	14
25 Nov. 96	55	17	0	1
2 Dec. 96	86	18	0	0
9 Dec. 96	33	15	0	0
16 Dec. 96	46	11	1	0
23 Dec. 96	18	1	0	0
30 Dec. 96	15	0	0	0
6 Jan. 97	82	3	1	0
13 Jan 97	3	0	0	0
20 Jan. 97	20	0	0	0
27 Jan. 97	17	1	0	0
3 Feb. 97	8	0	0	0
11 Feb. 97	4	0	0	0
17 Feb. 97	6	0	0	0
24 Feb. 97	3	0	0	0
3 Mar. 97	6	0	0	0

[a] CD = Communication disruption by the use of high concentration of a single component sex pheromone (Z9, E12-14:OAc) was initiated on 19 Nov. 1996. 20 µg chemical on rubber septum was placed just above plant canopy at the junction of 4 x 4 m grid. Plot size: 20 m x 30 m. Cultivar = California 606.

before the pheromone treatment was begun, both the check parcel and designated treatment parcel had a substantial number of insects; 83 exigua and 16 litura in the check field and 45 exigua and 14 litura in the designated treatment field. In subsequent monitoring at weekly intervals, however, we failed to trap adults of either species in the communication disruption trap, or trapped only one stray individual when many adults of both species were trapped in the check field. This indicated successful communication disruption by (Z9, E12)-14:OAc.

When onion plants were observed for pest damage, however, the damage in the treatment parcel was only marginally lower than the damage in the check plot. The same was found in 1995-96, when we were able to bring about mating communication distruption of both BAW and CAW using (Z9, E12)-14:OAc. In both years, the armyworm damage to onion treatment parcel was only marginally lower than to check parcel. It appears that mated females from elsewhere are migrating to both plots and initiate pest infestation. This is inevitable in a multiple cropping system where vegetables are grown, especially with pests like *Spodoptera* which feed on a number of crops. Sex-pheromone, whether full blend or one component, does not affect behaviour of female adults. In addition to the use of (Z9, E12)-14:OAc for mating communication disruption, we need to devise means to reduce migration.

The results of the flying height study are summarized in Table 24. Over 92% of the adults were trapped on sticky boards placed 1 and 2 m above the soil surface. Two thirds of them were caught 1 m above ground. Over 92% of the insects trapped at this height were females. In last year's experiment, over 90% were caught at the 1 and 2 m heights combined, and 95% of them were females. This implies that females, being the heavier of the two sexes, cannot fly very high or that they are in search of crop on which to lay eggs, hence they fly close to the ground. Whatever the reason, it indicates that a 2-m high barrier could largely eliminate migration of BAW and reduce damage to onions.

Results of the monitoring of BAW and CAW adult populations in the plot surrounded by nylon net and the open check plot are summarized in Table 25

In the treatment field, despite a 2-m high barrier, some BAW adults were also caught. However, their number was barely 20% of those trapped in the open-field check plot. This indicates that a 2-m high barrier reduces adult migration substantially. BAW moths were found trapped on all four sides of the enclosure. This indicates the insects migrate from all sides.

Results of the weekly damage observation are summarized in Table 26. At most observation intervals, BAW damage in the protected area was significantly less than in the open area. Thus, nets hold potential for reducing BAW infestation. The insect damage inside

Table 24. Capture of beet armyworm adults in sticky traps placed at various heights in the field, AVRDC, spring 1997

Trap height (m)	No. of adults trapped	% adults trapped	% females
1	11.17	62.06	92.31
2	3.83	20.05	0
3	2.00	13.08	7.69
4	0.83	4.82	0
LSD 5%	4.87	12.34	10.73

Trap size: 21.5 x 21.5 cm, white. Observation dates: Once a week from 9 Dec. 1996 to 27 Feb. 1997. Data are totals of 11 observations at each height.

Table 25. Trapping of BAW and CAW male adults by sex pheromone traps placed in two onion fields, AVRDC, autumn-winter 1996-97

Date of observation	Number of adults trapped per trap overnight: Check field		2-m net	
	exigua	litura	exigua	litura
18 Dec. 96	8	0	1	0
26 Dec. 96	10	0	3	0
31 Dec. 96	18	1	5	0
8 Jan. 97	24	0	7	0
15 Jan.97	4	0	2	0
22 Jan. 97	20	0	6	0

the net was indeed less than in open field. However, this difference in damage was not reflected in yield, as there was no significant difference in bulb yield from the check plot and treatment plot, 19.03 t/ha and 16.12 t/ha, respectively. (During the experimental period, there was heavy infestation by onion thrips, *Thrips tabaci,* on the onion foliage all over the AVRDC experimental farm. This substantially affected the crop stand and yield.)

Because of the small size of vegetable fields in Asia, most smaller than 0.1 ha, this technique has potential. Before adopting this technique, however, one must make sure that there are no BAW pupae hibernating in the soil of the planted area, or else the pest problem inside the net could be higher than outside. A net and pheromone combination will be tested next year.

Screening of *Allium* germplasm for resistance to beet armyworm

Beet armyworm (BAW), *Spodoptera exigua* (Huebner), is a polyphagous insect that attacks a wide variety of crop species, including onion, shallot, soybean, tomato, cotton, asparagus, grapes, and several species of weeds. The insect larvae feed mainly on leaves, at times defoliating whole plants. In onions and shallots, adults lay eggs on the tubular leaves. Soon after hatching, the larvae bore inside the leaves and feed voraciously, while remaining concealed, unaffected by natural mortality factors such as rainfall, predators and parasites, and insecticides used to control the pest. At AVRDC, therefore, we have been screening *Allium* germplasm for resistance to BAW with a view to identifying genetic sources of resistance to the pest. In 1996-97, we screened 124 entries, including five entries that were least damaged in last year's test for resistance to BAW.

A parcel of land was roto-tilled and worked into 0.75-m wide raised beds. These beds were further divided into 2 m × 1.5 m plots. Seeds or vegetative planting materials of 124 *Allium* accessions were obtained from the AVRDC *Allium* breeder. Five-week-old seedlings or vegetative planting materials were transplanted in a single row on the top of individual plots. Soon after transplanting, the whole planted area was confined on all sides and over top by nylon net. Approximately 10 weeks after transplanting, we released BAW adults inside the net cage. Thereafter, we released BAW adults inside the cage at irregular intervals to increase pest population pressure to avoid any accession escaping from BAW damage. When the BAW feeding damage was very high, we evaluated 20 plants of each entry for severity of pest damage. The damage was rated on a scale where 0 = no damage, 1 = 20% of leaf area damaged, 2 = 40%, 3 = 60%, 4 = 80%, and 5 = 100% leaf area damaged by the pest. The damage rating data were analyzed by a statistical procedures based on mean and standard deviation (SD) of mean of all entries to classify accessions into various resistance rating classes. Entries with damage ratings of less than mean – 2 SD were considered highly resistant (HR); those between mean – 2 SD and mean – 1 SD, moderately resistant (MR); between mean – 1 SD and mean, with low resistance (LR); between mean and mean + 2SD, susceptible (S) and more than mean + 2SD, as highly susceptible (HS).

All entries suffered from BAW larval feeding damage. The mean damage rating for the first screening was 2.76 ± 0.39, and for the second, 3.14 ± 0.54. Dis-

Table 26. BAW larval damage to onion foliage in open check field and nylon net surrounded field. AVRDC, autumn-winter 1997

	Damage rating		
Date	Treatment field	CK field	t value
15 Jan.97	0.44	0.45 ns	0.18
22 Jan. 97	0.64	0.64 ns	0.00
29 Jan. 97	0.43	0.53	3.25 *
5 Feb. 97	0.54	0.62	6.55 *
12 Feb. 97	0.55	0.62	6.08 *
19 Feb. 97	0.12	0.32	3.78 *
26 Feb. 97	0.19	0.31 ns	2.57

tribution of the entries in various resistance rating categories is summarized in Fig. 2. Four out of five least-damaged entries that were judged as highly resistant during the second rating, when overall damage was higher than in first rating, were rated as MR (4 entries) or HR (1 entry) in the first rating. These materials, AC430, AC570, AC584, AF537, and FC27(S), were considered highly promising for BAW resistance. *Allium cepa* entry AC570 was rated as HR in both screenings. FC27(S) is the product of a cross made by AVRDC's *Allium* breeder, between *A. cepa* and *A. fistulosum*. Resistance ratings of these entries are summarized in Table 27. The five entries with the least damage in last year's tests were rated as MR or LR. Their damage was not as low as the five above-selected entries. These five entries will be tested again in a multi-replicate test in the 1997-98 season.

Table 27. Performance of selected *Allium* entries for resistance to BAW, AVRDC, spring 1997

	Damage rating (DR) and resistance rating (RR)			
	1st evaluation		2nd evaluation	
Entry	DR	RR	DR	RR
AC430	2.00	MR	1.95	HR
AC570	1.79	HR	1.79	HR
AC584	2.00	MR	2.10	MR
AF537	2.00	MR	2.00	HR
AF27(S)	2.00	MR	2.00	HR
AC687	3.35	S	4.00	S

Transplanting date: 11 Nov. 1996. Damage rating dates: 12 March 97

In 1996-97, there was unusually heavy damage due to onion thrips. Since both insects cause discoloration and drying of foliage, the rating of BAW damage was affected by thrips.

Screening of *Allium* germplasm for resistance to onion thrips

Onion thrips, *Thrips tabaci* Lindermann, is a polyphagous thrips that attacks a wide variety of crops, mainly vegetable species, throughout the world. Onion seems to be its major host. (Onion is infested specifically by onion thrips wherever this crop is grown.) Thrips larvae and adults rasp the leaf surface and feed on oozing sap. As a result of its feeding, the leaves take on a blotchy appearance and the plant is severely damaged. The leaves become shriveled and dry, starting from the apex. Bulb yield, in the case of *Allium sepa*, is severely reduced. In the case of green onion, marketability of the leaves is reduced. This insect is especially important in the dry season. Its high fecundity and concealed feeding – it feeds in crevices or depressions rather than on smooth plant surfaces – make this insect difficult to control. At AVRDC we have been screening *Allium* germplasm for resistance to onion thrips with the aim of eventually breeding resistant lines. In 1997, we screened 123 accessions, including two entries that showed promise in past tests.

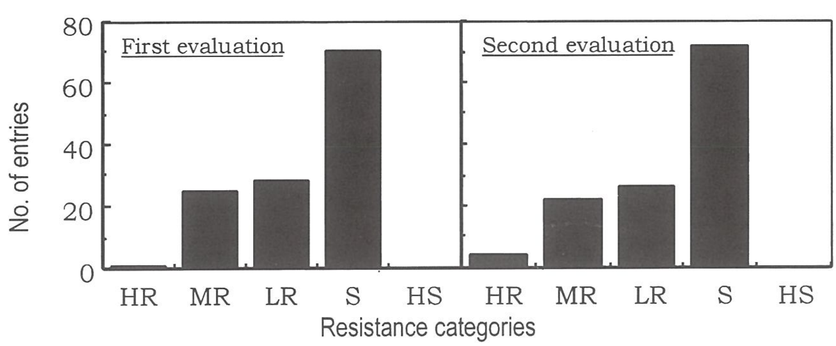


Fig. 2. Distribution of 124 *Allium* entries into various resistance rating classes during two evaluations, AVRDC, spring 1997

Seeds of 123 *Allium* accessions were sown in a soil-compost mixture in 6-cm diameter plastic pots, 8 pots per accession. After emergence, the plants were thinned to maintain one plant per pot. Six-week-old plants were then placed in a greenhouse room where a population of onion thrips was maintained continuously on potted onion plants. When thrips damage was at a maximum, each plant was rated on a scale, where 0 = no damage, 1 = 20% leaf area damaged, 2 = 40%, 3 = 60%, 4 = 80%, and 5 = 100% leaf area damaged.

Thrips moved readily from the older damaged plants to the test entries. All entries were damaged by the pest. However, there was considerable variation in the extent of damage. Two entries found resistant in past tests, TA189 and TA243, were included as resistant checks. They were far less damaged than other entries (Table 28). There were three entries, however, which were consistently less damaged than all others in each of the three observations. Their ratings were comparable or superior to TA189 and TA243.

These three new entries; AC521, AC525, and AC584, along with TA189 and TA243 will be evaluated rigorously in 1997-98 to confirm their resistance to thrips.

Table 28. Reaction of selected *Allium* accessions to onion thrips, AVRDC greenhouse, spring 1997

Accession	Resistance rating [a]		
	First	Second	Third
AC521	1.13	2.00	2.00
AC525	1.25	2.25	1.88
AC584	1.13	2.00	2.13
TA189 [b]	1.38	2.00	2.00
TA243 [b]	1.13	2.00	2.13
AF538 [c]	2.29	3.86	4.00
TA1 N-N [c]	3.00	4.00	4.00
Mean [d]	1.80	2.81	3.08

[a] Observation dates: first - 15 Jan; second - 22 Jan.; third - 29 Jan., 1997
[b] Resistant checks
[c] Susceptible entries

Crucifer Improvement

The goal of crucifer improvement at AVRDC has been to develop heat-tolerant, high-yielding, and early maturing Chinese cabbage (*Brassica rapa*) and common cabbage (*B. oleracea*) varieties with disease and stress tolerance, suitable for the tropics and subtropics.

The crucifer program has been very successful in the past two-and-a-half decades. The Center has developed high-yielding, heat-tolerant Chinese cabbage varieties which have been widely adopted in many tropical and subtropical countries, where otherwise, reliable production of crucifers would be impossible.

Inspired by this success, common cabbage was added as a principal crop in 1992 in the hope of breeding heat-tolerant varieties through a similar breeding protocol. Work on that crop has also produced considerable results, including selection of medium heat-tolerant varieties. Further breeding work on cabbage, however, would be very difficult in the climate at AVRDC: high temperatures during the winter result in unreliable vernalization of seed plants and rainfall during the seed harvesting period hinders seed collection. Given its success to date and the difficulties associated with achieving further gains, the Center has decided to conduct less breeding work on crucifers in the near future.

In 1997, advanced Chinese cabbage lines with preferred elongated-head shape were evaluated based on their performance in top-cross trials. A total of 18 lines were selected out of 70 lines. Several top-crossed progenies were found very promising.

A backcross breeding program was undertaken to incorporate cytoplasmic male sterility (CMS) into heat-tolerant Chinese cabbage lines. A CMS line provided by Cornell University has proven to have no chlorotic problem as suffered by the previous *ogura* CMS lines under low-temperature conditions. No reversions to male fertility or other defects, including chlorosis, were observed in backcross progeny. Further backcrosses were made between three recurrent parents. A backcross program for incorporation of turnip mosaic virus (TuMV) resistance was also continued in 1997, along with efforts at identification of resistant lines and monitoring of new TuMV strains. New TuMV strains and a new strain of radish mosaic virus (RaMV) were found and resistant lines were sought.

As part of a heat-tolerant cabbage breeding program, collection and evaluation of cabbage varieties continued. Six cabbage varieties were selected for their high-yield during the hot-wet season, and several early maturing cabbage varieties were selected for their exceptional heading ability, which makes this crop ideal for lowland summer peri-urban production.

Major activities in 1997 included (1) development of elongated Chinese cabbage, (2) development of heat-tolerant populations of Chinese cabbage through population improvement, (3) introduction of CMS and TuMV resistance into heat-tolerant Chinese cabbage, (4) evaluation of common cabbage varieties for early flowering and heat tolerance, and (5) investigation into the interaction of TuMV strains and inheritance of resistance to TuMV.

Genetic resources enhancement and varietal development

Genetic resources activities

The *Brassica* germplasm collection at AVRDC totals 1540 accessions, 26 of which were acquired in 1997 (Table 1). The new acquisitions included mustard, kale, common cabbage, and saishin. Thirty-six accessions of the *B. rapa* cvg Chinese cabbage were regenerated. The seeds were germinated, vernalized, and transplanted inside net cages. One accession was planted inside one net cage together with one accession each of pepper, eggplant, tomato, and onion. Honeybees were used as pollinators. Thirty-three flowered and produced seeds. The vernalization treatment for the three accessions that did not flower might not have been sufficient. In addition, black-rot-resistant lines of common cabbage were regenerated at the Mei-fong station of National Taiwan University, which is about 2000 m above sea level. Rains during the flowering and seed development stage caused low seed yield. A total of 591 *Brassica* accessions have been regenerated, 31% of which have enough seeds for long-term preservation. Characterization was continued for seedling, leaf, and silique traits based on a standard set of descriptors.

Table 1. The *Brassica* germplasm collection at AVRDC, 1997

Species	No. of accessions: Acquired in 1997	Total
B. juncea	3	39
B. napus		9
B. oleracea		7
B. oleracea cvg acephala	4	4
B. oleracea cvg alboglabra		10
B. oleracea cvg botrytis	1	7
B. oleracea cvg capitata	9	26
B. oleracea cvg gongyloides		1
B. rapa		859
B. rapa cvg Chinese cabbage		26
B. rapa cvg Pak Choi		1
B. rapa cvg Saishin	1	1
B. sp.	8	550
Total	26	1540

Registration, passport, distribution and seed inventory databases were updated.

Based on characterization data, rare traits noted include white, pink, and purple hypocotyl, purplish-green seedling leaf color, entire and undulate leaf margin, sparse and abundant seedling pubescence, lanceolate leaf shape outline, absence of leaf blade blistering, presence of leaf bloom, reddish-green and purple silique color, and silique constricted between seeds. Rare traits were exhibited by Sten Yu Bai Tsai, Beijing #75, Lu-Bao, Hybrid M4, Darkutz, October Red #1, Shia Fong Cabbage, TB275, and TB188. In terms of silique traits, extreme values were exhibited by Yamatoneon, Kai Choy, BP058, Tung Ann Bai Tsai, Beijing #70, Taao Huang Bai S Line, Darkutz, October Red #1, Taoyuan #4, TB188, and TB370.

Requests for germplasm were served. A total of 684 seed packets, 71% of the total *Brassica* distribution, were sent to 33 countries. Center scientists requested crucifer germplasm for leafy vegetable observation trials, variety evaluation, TuMV testing, and accession B40 as heat sensitive check in sets for distribution, and accession TB605 for heat tolerance evaluation (Table 2). A total of 258 packets, 27% of the total distribution, went to the Center's regional programs, and 24 packets, 2%, went to scientists at AVRDC headquarters.

Development of heat-tolerant populations of Chinese cabbage with preferred elongated head

The development of heat-tolerant Chinese cabbage with elongated head shape would help make this crop more popular in many tropical countries where consumers are more familiar with cultivars with an elongated head. Advanced lines of S_6 generation were developed from two populations derived from maternal line selection and another intercrossed progeny of cylindrical-headed inbred lines. The lines are at the stage of line selection, and can be used as parents for hybrid breeding.

During the cool season of 1996-97, selfed progenies were produced from 1996 selections. At the same time, top-crosses were made between the selections and three open pollinated (OP) varieties, B129, 7252, and BCB020. Selection of selfed progeny was based on the performance of top-crossed progenies of the selfed progeny and the testers. Top-crossed progeny were sown on 15 August and transplanted on 9 September in the field. Ten plants were planted in a plot, and an RCBD with two replications was used. Evaluation of head shape and data collection on head characters (weight, length, and diameter) were made at maturity (42 to 48 days after transplanting, depending on the testers used). The best lines were determined based on the performance in the top-cross trial. Phenotypic selection was conducted to select seed parents among the selfed progeny of superior lines.

Table 2. Recipients of *Brassica* germplasm from AVRDC, 1997

Country	No. of samples	
External		684
Cambodia	78	
Ghana	71	
Bangladesh	57	
Lao PDR	51	
Vietnam	50	
Taiwan	49	
India	38	
Poland	35	
Belize	24	
Korea	24	
Others[1]	207	
ARC		230
ARP		28
Headquarters		24
Country Program	17	
Breeding	6	
Virology	1	
Total		966

[1] Bhutan, Canada, China, Congo, Costa Rica, Ethiopia, Fiji Islands, Gabon, Guinea-Bissau, Haiti, Indonesia, Kenya, Liberia, Mauritius, Myanmar, Nepal, Netherlands, Pakistan, Philippines, Portugal, Thailand, United Kingdom, and Zaire.

Two criteria were adopted for the selection of elite top-crossed progeny: head shape index ≥1.5, and head weight >1000 g. The head weights of selected top-crossed progeny were larger than the respective testers and ASVEG #1 (Table 3). Head length ranged from 23 to 24.4 cm, and head shape indices ranged from 1.48 to 1.65. The heads had about 35 wrapper leaves.

Eight lines were selected out of 15 lines evaluated in batch 1, and seven lines were selected from 36 lines in batch 2. In batch 3, which appeared less promising than the other batches, only three lines among 19 were selected. Several top-crossed progenies were found very promising. A hybrid variety of Chinese cabbage with elongated head could easily be bred by adopting the selected lines and testers as parents. Self-incompatibility should be checked for lines to be used as parents for hybrid breeding. Seeds of selected lines will be multiplied during the cool season and will be distributed to national partners upon request.

Incorporation of cytoplasmic male sterility into Chinese cabbage through backcrossing

Commercial production of F_1 hybrid seeds of Chinese cabbage has exclusively employed the sporophytic self-incompatibility mechanism. This system requires rather complicated breeding procedures and is unreliable in high temperatures. Since it is very likely that hybrid Chinese cabbage will be well accepted and that hybrid seed production will become common practice in tropical countries, it is strongly suggested that a simpler and more stable system of hybridity over self incompatibility be developed. A CMS accession, NY8481, kindly provided by Cornell University, has proven to have no chlorotic problem as suffered by the previous CMS lines (*ogura* lines) under low temperature conditions. This research was designed to incorporate the male sterility of NY8481 into tropical Chinese cabbage lines.

Three BClFl CMS families and 1 F_1 hybrid were sown on 9 December 1997 and transplanted in the field on 6 January 1998. Plants were spaced 50 cm between rows on beds, and 40 cm between hills in rows. Survey of plants for horticultural and reproductive traits began six weeks after transplanting. Backcrossing of the selected plants to four maintainers is being carried out.

Table 4 shows the horticultural and reproductive traits of CMS families during the growing stage in the field. Two families with N4-2 and 180 as recurrent parents, respectively, showed high similarity to their recipients and excellent within-family uniformity. On the other hand, the family with CT1-32 as recurrent parent showed low recovery rate and high within-family variation. Size of nectar glands, amount of nectar secretion, and petal size were comparable to those of respective recurrent parents so that no difficulties are expected in using the lines in hybrid seed production. No reversions to male fertility or other defects, such as chlorosis, were observed. Response to downy mildew disease was similar to that of recurrents, but one family with CT1-32 as recurrent showed an exceptionally high level of resistance. Slightly faster bolting and flowering were observed in all the families compared to their male-fertile counterparts. This might have been due to hybrid vigor.

Considering all the traits of concern, 45 plants from three backcross progenies and two plants from one F_1 hybrid were selected to be further backcrossed in the next generation.

Evaluation of common cabbage germplasm and development of heat tolerant varieties/lines

Several commercial varieties of common cabbage have been selected for head formation and yield potential under hot-wet conditions.

Table 4. Horticultural and reproductive characters of backcross families of CMS Chinese cabbage

	Recurrent parent		
	CT1-32	N4-2	180
No. of selections	20	9	16
Uniformity within family[a]	4 - 7	8	8
Nectar secretion	Yes	Yes	Yes
Downy mildew resistance[b]	3 - 9	3	8
Bolting/Flowering[c]	E-ME	ML	M

[a] 1 (poor) - 9 (excellent).
[b] 1 (susceptible) - 9 (resistance).
[c] E = early; M = medium; ME = medium early; ML = medium late

Table 3. Progeny test and selection for elongated shape in Chinese cabbage families derived from three different sources

Tester	Families derived from	No. of lines tested	No. of lines selected	Performance of selected cross		
				HW[a]	HL[b]	Index[c]
B129	Cylindrical type	12	5	1317	23.4	1.53
	ML-27	29	2	1383	23.3	1.48
	ML-35	18	0	-	-	-
	B129 (check)			1103	16.9	1.10
	ASVEG #1 (check)			1250	17.5	1.15
7252	Cylindrical type	10	8	1048	22.9	1.63
	ML-27	30	7	1331	24	1.50
	ML-35	18	1	1385	23.8	1.55
	7252 (check)			1084	17.5	1.14
	ASVEG #1 (check)			1176	17.4	1.18
BCB020	Cylindrical type	13	9	1441	24.4	1.65
	ML-27	29	11	1403	24.3	1.59
	ML-35	20	5	1545	23.8	1.52
	BCB020 (check)			1119	19.0	1.37
	ASVEG #1 (check)			1136	16.5	1.18

[a] Mean head weight (g) of selected crosses between tester and lines.
[b] Mean head length (cm) of selected crosses between tester and lines.
[c] Mean head shape index (head length/head width) of selected crosses between tester and lines.

A total of 48 varieties were collected from commercial sources for evaluation in 1996-97. These varieties, along with 26 varieties slated for re-examination, were grown in the field during the hot-wet season. Four varieties, KK-Cross, KY-Cross, Shiafong #1, and Choon Chiou, were included in all of the observational trials as the standard checks.

Six common cabbage varieties, categorized as 'early maturing varieties' in 1996, were re-evaluated for their earliness and yield potential. All entries were planted twice (June 11 and August 15) during the hot-wet season.

Evaluation of common cabbage varieties

Headed varieties matured from 47 to 81 DAT. In consideration of earliness and yielding ability, six varieties were selected: Good Season (Known You, Taiwan), Tropical Delight (Known You, Taiwan), Southern Treasure (Takii, Japan), Tropicana II (Nong Chaan, Taiwan), Shia Bao (Source unknown, Japan), and Mighty Top (Source unknown, Japan) (Table 5). These varieties matured as early as KK-Cross and yielded more than 15 t/ha.

Evaluation of early maturing common cabbage

The first planting was severely damaged by a typhoon in the early growth stage. Golden Cross (Takii, Japan) matured in 51 DAT, while two standard varieties, Shiafong #l and KY-Cross, matured in 66 DAT and 64 DAT, respectively. Yields, however, were very low, less than 16 t/ha (Table 6). In the second planting, Golden Cross and E0102 (CAAS, China) matured in 39 DAT and 40 DAT, respectively, while standard varieties required 54 days. Yields of the early-maturing cabbage varieties were as high as those of standard varieties; Golden Cross and E0102 yielded 25 and 36 t/ha, respectively. The varieties are not tolerant to high soil moisture, so it is advised that they be grown under a rain shelter.

Interactions of TuMV strains and inheritance of resistance to TuMV

Turnip mosaic virus is considered the most important virus of *Brassica* crops. The presence of many

Table 5. Performance of selected commercial varieties of common cabbage in hot-wet season, 1997.

Variety	Acc. No.	DAT [a]	Head weight (g)	Yield (t/ha)	Remarks
First trial [b]					
Southern Treasure	BB115	58.0 de	733 a-e	19.0 a-b	Newly selected
Tropical Delight	BB191	59.0 de	746 a-d	19.9 a-c	Newly selected
Tropicana II	BB226	59.3 d-f	696 a-f	19.6 a-e	Newly selected
Good Season	BB228	59.8 d-f	806 a	21.5 a	Newly selected
KS Cross	BB155	58.9 d-f	778 a-c	18.1 a-f	Re-selected
Tropicana	BB197	59.4 d-f	662 b-j	17.7 a-f	Re-selected
Shiafong #1	BB006	60.3 d-f	618 d-l	14.5 f-k	Heat-resistant check
KK-Cross	BB112	58.7 d-f	795 ab	17.8 a-f	Heat-resistant check
C.V.		3.30	10.2	12.4	
Second trial [c]					
Mighty Top	BB231	62.6 a	592 e	15.8 de	Newly selected
Shia Bao	BB235	62.7 a	695 c-e	18.5 b-d	Newly selected
Shiafong #1	BB006	64.2 ab	605 e	16.1 de	Heat-resistant check
KK-Cross	BB112	65.9 a-c	800 bc	21.3 a-c	Heat-resistant check
	C.V.		3.95	9.91	13.2

Mean separation within columns in each trial by Duncan's multiple range test at P=0.05.
[a] Days after transplanting to harvest.
[b] Date sown: 17 June 1996. Date transplanted: 17 July 1996.
[c] Date sown: 9 July 1996. Date transplanted: 1 August 1996.

strains in Asia, some of which are not known to occur in Europe or the Americas, cause very severe symptoms, such as stunting of the plant, leaf crinkling, and black spots, seriously affecting not only yield but also market quality. Resistance is considered the most effective control. So far, commercially available cultivars are susceptible to this virus or only carry resistance to one or two strains of the virus. The objectives of this activity were to 1) identify sources of stable resistance to all strains of the virus, 2) to monitor the occurrence of new TuMV strains and other potentially serious viruses in the region, and 3) to assist the breeders in incorporating resistance into AVRDC breeding lines.

For resistance screening, host range studies, and testing of isolates, 24 seedlings of each line were twice mechanically inoculated with TuMV isolates/strains. This was followed by two ELISA tests conducted at two weeks after the first inoculation and at five weeks after the second inoculation.

To monitor the occurrence of new strains/viruses, field samples showing typical virus symptoms were first tested by DAS-ELISA with TuMV antiserum. In the case of negative reactions, leaf extracts were examined in the electronmicroscope for presence of virus particles. Agar gel immodiffusion tests were done by the standard method (0.85% agar plus 0.85% NaCl) with undiluted, clarified leaf extracts.

Twenty-six Korean Chinese cabbage inbred lines of diverse parentage were tested for their resistance to five Taiwan TuMV strains and 13 TuMV isolates from Korea. Only one Korean line (A 91) was identified as resistant to all five Taiwan TuMV strains. One of the parents of this line is O-2, an AVRDC line known to be resistant to all five Taiwan TuMV strains. Two lines were resistant to four Taiwan strains: Wonyae 20020, was resistant to strains 1, 2, 3, and 4, and JA 10 was resistant to strains 1, 3, 4, and 5. Four lines were resistant to two strains (strains 1 and 3), and eight lines were resistant to strain 1. All other lines were susceptible.

The Korean line, A 91, and the AVRDC accession, BP 58, were also resistant to all 13 Korean TuMV isolates (Table 7). Two Korean lines, JA 5 and JA 10, were resistant to seven of the 13 Korean TuMV isolates.

Table 6. Performance of several early maturing cabbage varieties in hot-wet season

Variety	September, 1996 [a]			June, 1997 [b]			August, 1997 [c]		
	DAT [d]	HW [e] (g)	Yield [f] (t/ha)	DAT	HW (g)	Yield (t/ha)	DAT	HW (g)	Yield (t/ha)
Golden Cross	38.5 a	338 de	22.6 d	50.8 a	136 d	5.1 c	39.3 a	375 d	25.0 d
T-621	47.3 d	490 a	32.7 a	62.6 c-e	239 c	15.6 a	50.0 d	539 b	35.9 a
BSS50	49.9 e	482 a	32.1 ab	59.5 b-d	194 cd	12.7 b	50.4 d	468 bc	31.2 bc
V0410	43.2 bc	450 a-c	30.0 a-c	56.6 b	192 cd	10.3 b	45.9 c	520 bc	34.7 a
E0102	42.3 b	402 b-d	26.8 b-d	58.3 b-d	192 cd	12.0 b	39.9 a	501 bc	33.4 ab
Sprint Ball	-	-	-	57.8 bc	176 cd	9.6 b	42.1 b	427 cd	28.5 cd
Copenhagen Market	52.3 f	377 cd	25.1 cd	-	-	-	-	-	-
Alaska Cabbage	45.1 cd	274 e	18.3 e	-	-	-	-	-	-
Shiafong #1	-	-	-	66.1 e	509 a	10.2 b	54.1 e	938 a	25.0 d
KY-Cross	-	-	-	63.8 de	357 b	6.1 c	53.8 e	984 a	26.2 d
CV	2.67	10.89	10.89	5.23	13.82	16.13	1.06	8.49	6.24

Mean separation within columns by Duncan's multiple range test at P=0.05.
[a] Date sown: 6 Sept. 1996. Date transplanted: 3 Oct. 1996.
[b] Date sown: 11 June 1997. Date transplanted: 11 July 1997.
[c] Date sown: 15 Aug. 1997. Date transplanted: 11 Sept. 1997.
[d] Days after transplanting.
[e] Head weight.
[f] Yield potential was based on the planting density of 50 x 30 cm for early maturing cabbage and 50 x 50 cm for normal type cabbage, respectively.

Seven of the Korean lines, Gikyae, 60 days (263-3), Naebyung 60 days, Seoulbaechu, Kyungdu No. 3 (143), Hasanchunse (345), and TFFL, were susceptible to all Korean TuMV lines.

By their host reactions on 26 Korean breeding lines, and three TuMV strain differential hosts, the Korean isolates can be grouped into 11 strains, only two of which, AN 7 and AN 2, appear to be identical to Taiwan strains, i.e., TuMV C-4 and TuMV C-5, respectively. None of the Korean TuMV isolates reacted like the Taiwan TuMV C-1, C-2, and C-3 strains and might, therefore, represent new TuMV strains.

Detection and identification of Radish Mosaic Virus

Spherical particles of approximately 30 nm were detected under the electronmicroscope (EM) in infected leaf tissue. The particle morphology strongly resembled that of RaMV. This was confirmed in EM decoration tests, in which the particles decorated equally strongly with radish mosaic virus antisera to both the Campbell neo-type strain of California (and Japan) and to the NZ strain of Europe. In DAS-ELISA tests, the Taiwan RaMV reacted very strongly with California neo-type strain antiserum and weakly with the European strain antiserum (Table 8). In agar gel diffusion tests using antiserum against the European strain, the Taiwan RaMV reacted like the neo-type strain. When antiserum against the neotype isolate was used, however, the Taiwan isolate spurred over the European isolate and the neotype isolate spurred over the Taiwan isolate.

Based on these results, the Taiwan RaMV is serologically closely related, although not identical to the neotype strain which so far has only been reported to occur in California and Japan.

One of the Chinese cabbage lines, BP 58, was found immune to RaMV. This line, which is also resistant to all TuMV strains/isolates from Taiwan and Korea,

Table 7. Reactions of Chinese cabbage (*Brassica campestris* ssp. *pekinensis*) inbred lines to strains of turnip mosaic virus

Line	Turnip, cqs, CJ	AN 2	AN 8	AC 18a	AN 3	AN 7	AC vq	AN 9	RH	Stock	RG
Chungbang (26-)	S	S	S	S	S	S	S	S	S	S	R
Miho No.1(7302-)	S	S	S	S	S	S	S	S	S	S	R
SSD63	S	S	S	S	S	S	S	S	S	S	R
Haekbaechu	S	S	S	S	S	S	S	S	R	S	R
A91(HSX02-1)	S	S	S	S	R	S	R	S	S	S	S
AVRDC(7322-)	S	S	S	S	S	S	S	S	S	R	R
Yaki No.2(350-)	S	S	S	S	S	S	R	R	R	R	S
Sambo(82-)	S	S	S	S	S	S	R	S	S	R	R
Daehyunggarak(400-2-)	S	S	S	S	S	S	R	S	R	R	R
Kyungdo No.2(350-)	S	S	S	S	S	S	S	R	R	R	R
JA 20	S	S	S	S	S	S	R	S	R	R	R
Wonyae20020	S	S	S	R	S	S	R	S	R	R	R
Palweolje(8303-)	S	S	S	S	S	S	R	R	R	R	R
90-21-3-2-1-1	S	S	S	S	S	S	R	R	R	R	R
JA 2	S	S	R	R	S	S	R	S	R	S	R
JA 10	S	R	S	S	S	R	R	R	R	R	R
JA 5	S	S	S	S	R	R	R	R	R	R	R
Wonyae20031	R	S	R	R	R	R	R	R	R	R	R
A91(SSD31X02-1)	R	R	R	R	R	R	R	R	R	R	R
BP 058	R	R	R	R	R	R	R	R	R	R	R
Tropical Delight	S	S	S	S	S	S	R	R	R	R	R
Crusader	S	S	S	S	S	S	R	R	R	R	R
PI 419105	S	S	S	S	S	S	R	S	R	S	R

Lines TFFL, Gikyae, 60 days (263-3-), Naebyung 60 days (72), Seoulbaechu (212), Kyungdo No. 3 (143-), and Hasanchunse were susceptible to all isolates.

should be very useful in breeding for stable virus resistance in Chinese cabbage. This is the first report of the occurrence of RaMV in Taiwan.

Table 8. ELISA reactions of the Taiwan RaMV with RaMV-Europe and RaMV USA antisera

Dilution of Antigen	Antiserum: RaMV USA	Antiserum: RaMV Europe
RaMV Taiwan		
1:10	2.479	0.154
1:50	1.469	0.057
1:250	1.350	0.033
1:1250	1.132	0.027
1:6250	0.417	0.023
1:31250	0.154	0.009
Healthy *Nicotiana benthamiana* (ck)		
1:10	0.008	0.003
1:50	0.005	0.000

[1] RaMV-USA (Campbell neotype strain) antiserum was used at 1:1000 for coating and conjugate. Substrate incubation 15 min.

[2] RaMV-Europe antiserum was used at 1:500 for coating and conjugate. Substrate incubation 1.5 h.

Eggplant Improvement

The goal of eggplant (*Solanum melongena*) improvement at AVRDC is to develop stable and high-yielding varieties/lines with improved fruit quality attributes and to develop integrated pest management for major diseases and insect pests, such as bacterial wilt (BW) (*Ralstonia solanacearum),* phomopsis blight (*Phomopsis vexans*), fruit and shoot borer (*Leucinnodes orbonalis*), and cotton leafhopper (*Amrasca biggutulla biggutulla*), with emphasis on host resistance/tolerance and biological control in the tropics and subtropics.

Observation and evaluation of collected commercial cultivars, landraces, and other germplasm are aimed at identifying desirable genotypes for use in the eggplant breeding program or for recommendation to NARS.

In 1996-97, observational and elite variety trials were conducted on 115 accessions and 78 selected eggplant varieties. A large diversity in yield and horticultural characteristics, such as plant type, maturing time, fruit size, and fruit number was observed, while significant differences in marketable yields were found in the elite variety trials. Eggplant genotypes with desirable traits were identified for use in the breeding program. Eight elite varieties were identified to have stable and high yield over different crop seasons.

Seventeen new sources of BW resistance were identified from the Philippines. In addition, eight Indian eggplant varieties were confirmed to exhibit consistently high levels of resistance to BW. Screening and selection of hybrid progenies using the pedigree method were carried out, and progress was made toward the development of BW-resistant lines. Six BW-resistant hybrids, developed from variety crosses, produced marketable yields of more than 40 t/ha in a field trial.

Field screening found four *Solanum* accessions highly resistant to cotton aphid, *Aphis gossypii*.

Genetic resources enhancement and varietal development

Genetic resources activities

Sixty *S. melongena* accessions from 13 countries were planted for regeneration in 1996-97. Germplasm accessions for regeneration were selected based on the requirements of AVRDC's eggplant breeder and the need for long-term preservation. Net cages were used to prevent cross-pollination by insects. To enhance seed set, supplementary hand-pollination using mass sibbing was done for each accession. Morphological characterization was done based on a standard set of descriptors. Samples of fruits were analyzed for dry matter, sugar, fiber, vitamin C, and beta carotene. Requests for germplasm were served. Registration, passport, distribution and seed inventory databases were updated.

The eggplant germplasm collection at AVRDC now totals 2256 accessions belonging to 42 species (Table 1). Ten accessions were acquired in 1997. Among the 60 accessions regenerated, one accession, (TS209) KG Begun, from Bangladesh, failed to germinate. TS1380 from China flowered at a very early age (53 days after sowing). Some fruits had no seeds at all. Therefore, hand pollination was done twice to increase seed set.

Variation was observed in all traits with the exception of two. All accessions exhibited upright growth habit and intermediate branching. Rare traits included light violet cotyledonous leaf color, very low and very high cotyledonous leaf length to width ratio, plant height of more than 100 cm, narrow leaf blade, obtuse leaf blade tip angle, very many leaf prickles, white corolla, short style length, low pollen production, fruit as long as broad, snake-shaped fruit, fruit green at commercial ripeness, fruit purple-black at commercial ripeness, mottled fruit color distribution at commercial ripeness, fruit calyx very long, fruit calyx prickles absent, and fruit calyx prickles plentiful.

Highest dry matter (9%) was noted in TS1585A, from India. This accession had fruits in clusters with fruit length of 15 cm. Sugar was highest (36%) in TS1594, from India. This accession also had the highest fiber content (10%). However, this accession was

Table 1. The eggplant germplasm collection, AVRDC, 1997

	No. of accessions	
Species	Acquired in 1997	Total
S. melongena	8	1409
S. aethiopicum		77
S. aculeatissimum		39
S. torvum		34
S. indicum		27
S. nigrum		18
S. parkinsonii		16
S. xanthocarpum		14
S. linociera		11
S. sisymbriifolium		10
Others[1]	2	601
Total	10	2256

[1] *S. americanum, anguivi, atropurpureum, aviculare, capense, capsicoides ciliatum, eleagnifolium, ferox, incanum, juglandifolium, laciniatum, linnaeanum, lycopersicoides, macrocarpon, mammosum, nodiflorum, ocranthum, petinatum, pseudocapsicum, quinquangulare, rigescentoides, repandum, rickii, rostratum, sepium, sessiliflorum, spinosissimum, stramonifolium, suaveolens, surattense, and viarum.*

Table 2. Recipients of eggplant germplasm from AVRDC, 1997

Recipient	No. of samples	
External (top 10 countries)		1356
	USA	532
Costa Rica	218	
Cambodia	74	
Taiwan	61	
Brazil	58	
Ghana	43	
China	26	
Lao PDR	25	
Belize	22	
Zaire	21	
Others [1]	276	
ARC		37
ARP		7
Headquarters		405
Breeding	291	
Entomology	114	
Total		1805

[1] Bangladesh, Bhutan, Guinea-Bissau, Honduras, India, Indonesia, Ivory Coast, Liberia, Mauritius, Moldova, Namibia, Nepal, Pakistan, Philippines, Senegal, Seychelles, Sri Lanka, Sudan, Thailand, Tonga, Turkey, and Vietnam.

later noted to be segregating. Variation in vitamin C and betacarotene were also noted. The highest value for vitamin C was 10.4 mg/100g in TS1742 (Kemer), from India. It had long and purple fruits. The highest value for betacarotene (0.31 mg/100 g) was noted in TS1570, from India. This accession had distinctive bluish-violet corolla and ovoid fruits.

A total of 1805 seed packets were distributed to 33 countries (Table 2), 44 to AVRDC's regional programs, and 405 to units at headquarters. Center scientists used the requested materials in screening for resistance to BW, leafhopper, and aphids and for performance evaluation.

Evaluation of eggplant cultivars and germplasm

Observation trial

An observation trial (OT) consisting of 115 accessions, including six check varieties, was planted in the field without replication. These entries were collected from the Philippines, Turkey, Iran, Canada, Inner Mongolia, China, India, and other countries. The entries were planted in a single-row plot of 9 m^2 consisting of 12 plants with 1.5 × 0.5 m spacing. Standard cultural practices and crop management were employed.

Horticultural characteristics and yield varied widely among the 115 entries. Thirty-six accessions were found, in fact, to be a mixture of at least two phenotypes. For fruit shape, 52 entries had cylindrical fruit, 23 had round fruit, 39 had teardrop-shaped fruit, and one was a novelty type. Eighty-three percent of entries had purple fruit, the rest had green fruit. The entries matured from 65 to 111 days after transplanting (DAT) with an average of 87 DAT. S397sib was the earliest at 65 DAT. Yield ranged from 7.5 to 56 t/ha with a mean of 32.9 t/ha. Six accessions, S383sib, S389sib, S381sib, S378sib, S136, and S152A, produced yields of more than 50 t/ha. Number of fruits per plant ranged from 6.0 to 46.4, with an average of 25.6. S385sib had the most fruits per plant. Average fruit weight ranged from 17 to 253 g. About 55% of accessions had fruit weights between 50 and 100 g. Genotypes identified with desirable traits are given in Table 3. They will be selected for further testing and/or use in the eggplant breeding program.

Elite variety trials

Three elite variety trials (EVTs) for 38 entries in 1996 and one EVT for 40 varieties in 1997 were completed. The experimental design was RCBD with four replications. The single-row plot size was 9 m^2 (1.5 × 6.0 m) consisting of 12 plants with 1.5 × 0.5 m spacing. The trials were conducted in spring, summer, and autumn 1996, and in spring 1997. Standard cultural practices and crop management were followed.

Significant differences in yields among entries were observed in each EVT in 1996. The average yields of the 25 long-fruit (LF) type entries in spring, summer, and autumn were 25.5, 30.0, and 51.4 t/ha, respectively (Table 4). The mean yield in autumn was twice the spring mean yield. Best yields were recorded by EG80 (39.5 t/ha), EG75 (43.8 t/ha), and S82 (83.7 t/

Table 3. Genotypes identified for desirable traits from 1996 OT

Trait	Genotypes
Erect plant type	S131, S135, S222sib, S359sib, S376sib, S397sib, S402sib, EG253
Early maturity	S397sib, S398sib, S403sib, S395sib, EG254, EG255
Less branching	S407sib, S403sib, EG255, S406sib, EG256, EG254
High no. of fruits/plant	S385sib, S141, S156, S158, S150, S384sib
Fruit size (big)	S358sib, EG253, S381sib, S391sib
High yielding	S383sib, S389sib, S381sib, S378sib, S136, S152A

ha) in spring, summer, and autumn, respectively (Table 5). EG 75 had the highest average yield, 50.2 t/ha, across the three seasons. S82 produced an extremely high yield of 83.7 t/ha in autumn, and the second highest mean yield, 47.5 t/ha, across the three seasons. Irrespective of season, the five top yielders of the LF type were EG75, S82, EG60, EG73, and EG214 or EG117 (check). EG63 had the most fruits per plant (61) but its average fruit weight was only 49 g. EG75, a green-fruited eggplant, produced the largest fruit, 137 g on average, in the LF group. The average time to maturity in spring, summer, and autumn was 87, 96, and 149

Table 4. Mean yield and horticultural characters of eggplant varieties in various seasons, EVTs 1996[a]

Trial season	Fruit type[b]	Mean yield (t/ha)	Plant ht. (cm)	No. of branches	Days to maturity	No. of fruits/plant	Fruit wt. (g)
Spring	LF	25.5	117	6.8	87	27	78
	RF	28.6	108	6.4	77	23	128
Summer	LF	30.0	85	6.6	96	28	84
	RF	26.7	77	6.6	94	22	121
Autumn	LF	51.4	95	8.8	149	42	98
	RF	48.1	90	8.2	144	31	157

[a] No. of entries: 25 LF, 13 RF

[b] LF: long fruit type, RF: round or teardrop fruit type

Table 5. Eggplant Elite Variety Trial (long fruit type), 1996[a]

Acc. no.	Days to maturity (DAT) SP	SU	AU	Mean	Fruit weight (g) SP	SU	AU	Mean	No. of fruits/plant SP	SU	AU	Mean	Mkt. yield (t/ha) SP	SU	AU	Mean
EG55	85	95	147	109	81	109	115	102	18.0	16.7	29.8	22	18.8	24.5	44.8	29.4
EG74	115	94	171	127	65	77	92	78	22.8	20.6	36.4	27	19.6	21.1	44.5	28.4
EG75	80	94	146	107	112	132	169	137	19.7	25.1	34.1	26	29.2	43.8	77.5	50.2
EG60	83	91	160	112	97	107	119	107	25.9	23.8	44.4	31	33.4	33.3	66.2	44.3
EG62	87	88	163	113	43	47	52	47	47.4	45.5	80.0	58	27.1	28.3	55.5	37.0
EG63	84	95	140	106	41	52	53	49	55.2	59.2	68.1	61	30.4	40.8	48.0	39.7
EG67	78	98	142	106	91	84	125	100	22.0	17.3	30.8	23	25.5	20.1	51.8	32.5
EG70	92	92	142	109	72	91	98	87	19.9	30.3	39.5	30	18.4	35.1	51.1	34.9
EG73	72	95	147	105	55	72	64	64	52.3	39.3	65.5	52	38.1	36.1	56.0	43.4
EG77	87	100	140	109	67	77	92	79	29.4	29.8	31.8	30	26.4	30.7	38.7	31.9
EG78	95	97	162	118	87	103	110	100	14.1	20.6	34.1	23	16.3	27.9	49.9	31.4
S33	88	102	144	111	101	100	126	109	22.4	28.0	32.8	28	29.8	37.2	54.1	40.4
EG80	82	97	133	104	76	84	88	82	38.9	30.7	36.5	35	39.5	33.9	42.7	38.7
EG81	-	98	147	-	-	89	88	-	-	26.0	37.2	-	-	30.8	43.9	-
EG101	102	97	165	121	93	89	100	91	12.9	22.4	34.2	23	15.6	24.1	45.7	28.5
EG116	90	100	144	111	60	70	94	74	24.0	34.1	33.0	30	19.0	31.7	41.1	30.6
EG117	85	94	151	110	80	92	110	94	23.9	28.3	43.0	32	24.9	34.1	62.6	40.5
EG119	79	95	138	104	65	74	74	71	33.0	31.7	51.4	39	28.3	31.4	50.6	36.7
EG169	83	102	142	109	78	68	74	73	16.8	25.9	29.3	24	17.2	23.5	29.1	23.2
EG197	81	93	159	112	59	65	65	63	31.6	13.4	58.1	34	24.9	10.9	50.2	28.7
EG205	87	93	133	104	66	61	77	68	31.8	45.7	45.9	41	28.0	37.0	46.5	37.2
EG207	102	102	165	123	82	81	116	93	15.7	20.8	28.5	22	17.1	22.2	43.1	27.5
EG214	80	97	156	111	110	111	124	115	11.6	24.8	41.0	26	17.2	36.5	67.7	40.5
S24	83	104	142	109	107	98	94	100	25.1	19.9	32.1	26	36.1	26.0	40.1	34.1
S82	79	99	153	110	93	87	134	105	24.2	24.6	46.6	32	30.0	28.7	83.7	47.5
Mean	87	96	149	111	78	84	98	8.7	26.6	28.2	41.8	32	25.5	30.0	51.4	35.7
CV (%)	4.7	3.6	5.0	4.7	11.3	10.9	12.8	12.0	22.9	23.1	22.2	22.8	20.1	19.9	25.0	24.0
LSD (5%)	5.7	5.0	10.6	12.3	12.5	13.0	17.7	15.8	8.6	9.2	13.1	10.5	7.2	8.4	18.1	13.0

[a] Planting dates: SP: sowing: 10 April; planting: 16 May; SU: sowing: 18 July; planting: 23 Aug.; AU: sowing, 22 Oct.; planting, 21 Nov. 1996

DAT, respectively. EG80 and EG119 were the earliest varieties. They matured at 104 DAT on average. Among the 25 entries, four varieties, EG75, S82, EG60, and EG73, were identified as stable and high yielding over the three crop seasons.

Performances of the 13 round-fruit (RF) type entries were more stable than the LF type entries. The three best yielders were EG65 (42.3 t/ha), EG66 (42.0 t/ha), and EG164 (61.3 t/ha) for spring, summer, and autumn, respectively (Table 6). Again, the autumn crop performed better than the spring and summer crops. The mean yields of the spring, summer, and autumn crops were 28.6, 26.7, and 48.1 t/ha, respectively. EG218 produced a mean of 75 fruits per plant, the highest among the entries, however, it had the smallest fruit, with an average weight of 28 g. EG84, a variety collected from China, matured at 97 DAT and was the earliest among the entries. The four top performers in the RF group were EG65, EG164, EG66, and EG76. They had average marketable yields ranging from 45.4 to 38.7 t/ha across the three seasons. No significant difference was observed between yields of these entries. Furthermore, they produced stable high yields over different seasons.

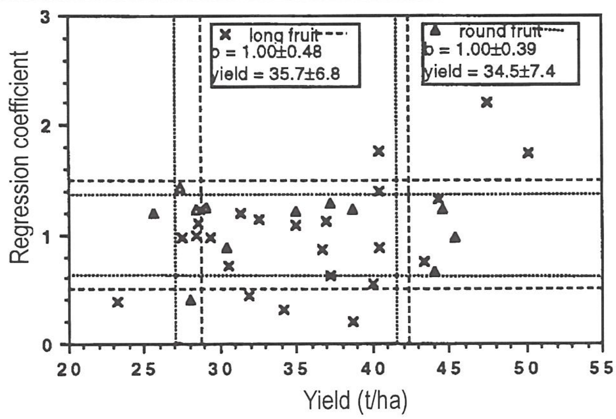


Fig. 1. The relationship of regression coefficients and mean yields of 12 round and 24 long eggplant accessions in three season.

The relationships of regression coefficients and mean yields were analyzed on the 24 LF and 12 RF entries in three crop seasons (Fig. 1). The results indicated that 10 varieties of the LF type and six entries of the RF type exhibited good stability in yields with their regression coefficient (b) within b = 1.00 ± 0.48 and b = 1.00 ± 0.39, respectively.

Marketable yields were highly associated with ma-

Table 6. Eggplant elite variety trial (round fruit type), 1996[a]

Acc. no.	Days to maturity (DAT) SP	SU	AU	Mean	Fruit weight (g) SP	SU	AU	Mean	No. of fruits/plant SP	SU	AU	Mean	Mkt. yield (t/ha) SP	SU	AU	Mean
EG218	79	85	137	100	24	27	33	28	74.9	73.8	77.0	75	24.0	26.6	33.4	28.0
EG65	76	99	127	101	121	129	184	145	26.5	20.9	24.0	24	42.3	35.8	58.1	45.4
EG66	77	95	134	102	151	119	122	131	18.4	26.5	32.9	26	36.7	42.0	53.2	44.0
EG69	82	93	135	103	188	237	409	278	7.1	7.0	8.3	8	17.9	22.0	45.2	28.4
EG76	75	94	151	106	108	108	122	113	23.5	20.6	33.7	26	33.6	27.6	55.0	38.7
EG82	75	-	166	-	173	-	183	-	10.6	-	21.8	-	24.5	-	52.3	-
EG84	71	90	129	97	133	130	151	138	12.1	8.5	23.1	15	21.4	14.5	46.3	27.4
EG85	69	93	157	106	183	168	234	195	7.6	10.2	14.7	11	18.5	22.6	46.0	29.0
EG164	74	98	139	103	177	158	216	184	14.5	18.5	21.1	18	33.6	38.8	61.3	44.6
EG166	82	97	154	111	138	125	122	128	13.7	14.6	25.6	18	25.1	24.0	42.3	30.5
EG172	70	93	136	100	132	109	94	112	16.0	14.8	22.2	18	27.9	21.2	27.8	25.6
EG203	81	93	145	106	54	62	66	61	44.5	26.9	57.5	43	31.8	22.4	50.5	34.9
S3	85	96	159	113	78	79	104	87	33.5	22.2	39.2	32	34.8	23.3	53.8	37.3
Mean	77	94	144	104	128	121	157	133	23.3	22.0	30.9	26	28.6	26.7	48.1	34.5
CV (%)	5.1	4.9	4.7	4.9	11.3	12.7	12.8	12.3	15.8	22.2	26.4	23.0	17.8	21.5	25.0	24.0
LSD (5%)	5.6	6.6	9.6	11.6	20.7	22.1	28.9	60.1	5.3	7.0	11.7	8.3	7.3	8.3	17.3	9.3

[a] Planting dates: SP: sowing: 10 April; planting: 16 May; SU: sowing: 18 July; planting: 23 Aug.; AU: sowing, 22 Oct.; planting, 21 Nov. 1996

turing time, branching, number of fruits per plant, and fruit weight. In fact, the high yields obtained from both the LF and RF entries in autumn were attributed to the plants producing more branches and fruits, and maturing in a longer time, with larger fruit sizes compared to other seasons.

Dry matter, sugar, and fiber content were determined in the autumn crop. Among the 38 entries, dry matter averaged 7.1% (range 5.6-9.5%); the mean sugar content was 26.7% (range 13.0-36.0%); and the mean fiber content was 9.5% (range 8.0-10.4%). S3 had the highest dry matter, while EG75 gave the highest sugar content.

In spring 1997, 40 promising accessions were selected based on the results of OT and EVTs in 1996, and further evaluated in an EVT. The entries consisted of 18 LF accessions and 22 RF accessions. The results revealed that differences in yields and some horticultural characteristics among the entries were significant. For the 18 LF entries, yields of eight varieties exceeded 50 t/ha. EG237 (Long Tom), a commercial hybrid, produced the highest yield, 60.4 t/ha, produced 50 fruits per plant, with an average fruit weight of 90 g, and matured at 81 DAT. The other high yielders were EG73 (58.9 t/ha), S357A (55.1 t/ha), EG119 (52.4 t/ha), and S24 (51.9 t/ha.). For the 22 RF entries, the mean yield was 32.4 t/ha, which was lower than that of the LF type (45.6 t/ha). EG224 (Cica), a variety from Brazil, had the highest yield, 59.6 t/ha. The second highest yielder was EG66 (Pusa Kranti), at 50.3 t/ha.

Evaluation of germplasm for resistance to bacterial wilt

More than 300 accessions of eggplant have been screened for BW resistance. Seventeen are confirmed to have a high level of resistance under both greenhouse and field conditions. These 17 accessions have been distributed to collaborators in South Asia for multilocation trials.

In 1997, 102 eggplant accessions were screened for BW resistance at the seedling stage in the greenhouse using the soil drenching and root severing method. Twenty-four-day-old seedlings of the entries were inoculated with bacterial suspension (10^8 cfu/ml) of *Ralstonia solanacearum* PSS97 in the greenhouse. After inoculation, plants were kept in the greenhouse where temperatures ranged from 25 to 35°C. Disease reading was undertaken up to 30 days after inoculation.

Among the 102 entries, 17 accessions, all from the Philippines, showed resistance, with a disease index less than 10% (Table 7). Another 14 accessions, from the Philippines, Thailand, Japan, and Sri Lanka, were moderately resistant (DI 10-20%). Seeds of these resistant accessions are being multiplied in the greenhouse. Their resistance to BW will be further tested next year.

In addition, 14 previously screened Indian accessions were tested to confirm their resistance and stability. Eight varieties, EG191, EG192, EG193, EG195, EG196, EG197, EG219, and EG221, had consistently high resistance, with disease indices less than 10%.

Breeding for bacterial wilt resistance

Sources of BW resistance have been used in the eggplant breeding program to cross with the selected parents having other desirable horticultural traits. The progenies of the crosses were screened at the seedling stage for resistance to BW. Nonsymptomatic seedlings were transplanted to the field (diseased nursery) for further selection for resistance and desirable horticultural traits. Following this protocol, a total of 218 F_2 and 108 F_3 resistant plants were selected last year.

Selection for bacterial wilt resistance in hybrid progenies

A total of 3349 plants of 70 F_4 lines derived from the cross CSB8 were screened for BW resistance at the seedling stage in the greenhouse. The 2750 non-symptomatic plants were transplanted to the field for further observation and selection. Besides the BW resistance, the selection criteria included plant type, maturity, fruit color, shape, and size, number of fruits per plant, yielding potential, fruit appearance, disease and insect tolerance, and others. A total of 89 plants were selected and selfed from 33 family lines for advancing to F_5 generation. In addition, a total of 4064 plants from 17 F_2 populations were screened for resistance to BW in the greenhouse in September 1997, and 2123 seedlings were found symptomless. Among the nonsymptomatic seedlings, 1938 plants were transplanted to the field for further selection.

Evaluation of bacterial wilt resistant hybrids

As reported in 1996, 92 eggplant hybrids were developed from cross combinations of six BW-resistant varieties and other promising varieties. Forty-one of them exhibited a high level of resistance to BW at the seedling stage. A yield trial consisting of 56 hybrids and four check varieties was conducted in autumn 1996. The experimental design was RCBD with four replications. The entries were planted on a single-row plot of 9 m^2 consisting of 12 plants with 1.5 × 0.5 m spacing. Yield data were collected by sampling five plants within a two-month harvesting period.

The yields of 60 entries ranged from 17.7 to 51.1 t/ha, with an average yield of 33.4 t/ha (Table 8). The differences in yields among the entries were statistically significant. Eleven hybrids out-yielded all the four check varieties. Moreover, no significant differences in yield were found between the top nine hybrids. However, only five of these top yielders were classified as highly resistant to BW, and the rest were moderately resistant. Two hybrids, CS149, an RF type, and CS128, a cylindrical fruit type, produced the best yields, 51.1 t/ha and 51.0 t/ha, respectively. CS149 was moderately resistant to BW (DI 14%). In general, the fruit weights

Table 7. New sources of resistance to bacterial wilt in eggplant germplasm[a]

Acc. no.	Source	Disease index[b] (%)	Non-sympt. plant (%)	Bacterial wilt reaction[c]
S129	Philippines	10	71	R
S130	Philippines	4	89	R
S131	Philippines	5	91	R
S132	Philippines	1	95	R
S133	Philippines	6	84	R
S134	Philippines	7	78	R
S135	Philippines	1	95	R
S136	Philippines	9	89	R
S137	Philippines	8	82	R
S141	Philippines	4	91	R
S147	Philippines	5	87	R
S148	Philippines	2	91	R
S149	Philippines	5	91	R
S150	Philippines	3	96	R
S154	Philippines	4	93	R
S155	Philippines	8	87	R
S157	Philippines	4	91	R
S56B (R. ck)	Indonesia	4	86	R
EG203 (R. ck)	India	2	91	R
EG120 (S. ck)	Taiwan	79	16	S

[a] Sowed on 13 June 1997; inoculated on 9 July 1997 with *Ralstonia solanacearum* PSS97 for 30 days.
[b] Disease index % = $(\sum n_i \times i)/(N \times i_{max})$, where n_i = no. of plants at reading i, i = 0-5, i_{max} = 5, N = total plants tested
[c] R = DI% less than 10%; S = more than 40%

of these 60 entries were relatively low (74 g), but they produced good numbers of fruits per plant (36) in an average of 104 DAT.

Six hybrids, CS128, CS169, CS127, CS115, CS117, and CS166, were considered promising, having both high yielding potential (>40 t/ha) and high resistance to BW (<10% DI). Seventeen of these hybrids were selected and evaluated again in the bacterial wilt nursery in summer 1997. The result of this trial will be reported in 1998. Four to five of the most promising hybrids will be selected and released to NARS for further evaluation in multilocation trials as new BW-resistant varieties.

Aphid resistance in eggplant

Cotton aphid, *Aphis gossypii*, is a polyphagous pest that attacks eggplant during the cool dry season. Both nymphs and adults feed on eggplant foliage which weakens the plant. They also excrete sugars in the form of droplets of honey dew which can cover most of the leaves. This promotes growth of a black fungus which cuts down photosynthesis, contributing to further weakening of the plant. AVRDC has been screening *Solanum* germplasm for resistance to cotton aphid.

Five-week-old seedlings of 156 *Solanum* accessions were transplanted between aphid spreader rows in single 8-m-long row plots. Routine cultural practices were followed, such as weeding, irrigation, fertil-

Table 8. Yields and horticultural characters of 20 BWR eggplant hybrids and three check varieties[a]

Hybrid code	Plant height (cm)	No. of branches	DTM (DAT)	Fruit Shape[b]	Fruit Color[c]	Fruit Wt (g)	No. of fruit /plant	MKT yield (t/ha)	BW reaction (DI %)
CS128	85	8.3	96	C	DP	63	60.7	51.0	2
CS169	70	6.9	93	R	PGW	135	26.3	46.9	0
CS127	82	7.7	98	C	DP	57	60.2	45.9	9
CS115	76	7.2	103	C	P	62	51.9	42.6	0
CS117	87	7.9	102	C	P	83	38.6	42.4	5
CS166	85	7.9	104	C	DP	63	47.6	39.8	0
CS192	83	7.3	99	C	RB	96	29.9	36.9	3
CS155	85	7.6	108	C	B	66	41.6	35.9	8
CS180	87	7.7	107	C	DP	60	43.5	34.4	7
CS191	85	8.6	114	C	B	59	43.0	33.8	5
CS114	79	7.5	109	C	P	77	32.1	32.7	0
CS116	71	7.8	103	C	P	71	33.9	32.1	2
CS137	95	8.4	109	C	DP	64	37.8	31.7	7
CS140	93	7.7	105	C	B	65	36.4	30.9	9
CS151	89	7.4	103	C	B	59	39.5	30.4	6
CS187	89	7.9	107	C	B	63	36.1	29.7	4
CS167	85	7.4	107	C	P	58	38.5	29.6	0
CS165	80	7.8	107	C	DP	52	42.1	28.7	1
CS150	90	7.8	103	C	DP	64	33.4	28.4	7
CS164	82	8.4	114	C	DP	54	40.3	28.0	0
EG117 (ck)	78	6.6	108	C	DP	89	23.7	27.1	42
EG203 (ck)	64	7.0	96	R	DP	81	29.3	31.3	0
EG064 (ck)	71	9.2	90	C	RB	64	47.5	41.1	?
Mean of 60 entries	85	7.6	104			74	35.6	33.4	
CV (%)	4.6	7.7	3.8			11.4	22.7	18.9	
LSD (5%)	5.5	0.8	5.6			11.9	11.3	8.8	

[a] Planting dates: sowing 11 Sept.; transplanting 17 Oct. 1996

[b] Fruit shape: C: cylindrical; R: round

[c] Fruit color: B: black ; DP: dark purple; P: purple; PGW: purple with green and white stripes; RB: red brown

izer application, and fungicide sprays to control diseases, but no insecticide was applied. When the aphid population was very high in mid January 1997, we recorded the approximate number of aphids per plant for each test entry. The plants were rated on a scale of 0 to 5, where 0 = no aphids, 1= 1-10 aphids/plant, 2 = 11-100 aphids/plant, 3 = 101-500 aphids/plant, 4 = 501-1000 aphids/plant, and 5 = more than 1000 aphids/ plant. Mean infestation rating and standard deviation (sd) of damage rating of each entry were subjected to a statistical analysis to classify resistance as highly resistant (HR), moderately resistant (MR), having low resistance (LR), susceptible (S), and highly susceptible (HS). In another test, 13 entries were planted in three replicates in RCBD and were rated for aphid infestation in the same manner as above. The damage rating was statistically analyzed by ANOVA and means were compared by the test of least significant difference (LSD).

Aphids moved readily from source-row plants to test entries. All test entries were damaged by the pest. There were 4 HR, 22 MR, 43 LR, 64 S, and 10 HS entries. Among the four HR entries, two were *Solanum viarum* accessions (Table 9). *S. viarum* was also found to be highly resistant to cotton aphid in a confirmation screening in which three replicates were used. The other two entries were S219 and S318.

The results of the confirmation screening are presented in Table 10. In this test, *S. viarum* and accession TS207 were significantly less damaged than the susceptible checks, Pingtung Long, S00214, S00239, and S00244. We will investigate mechanisms of resistance of S207 and *S. viarum* accessions, and if proven to be antibiosis, will advise eggplant breeders to initiate resistance breeding research to transfer resistance of one of these accessions into cultivated high-yielding horticultural eggplant varieties.

Table 9. Aphid resistance rating of selected accessions, AVRDC, autumn-winter, 1996-97

Accession	Damage Score	Resistance rating
S 219	1.625	HR
S. viarum [a]	0.750	HR
S 318	1.250	HR
S. viarum [a]	1.250	HR
S 237A	4.875	HS
S 257	5.000	HS
S 300	5.000	HS
S 332	4.875	HS
Mean (156 entries)	3.533	
SD	0.934	

[a] Seeds of *S. viarum* came from different sources.

Table 10. Resistance of selected *Solanum* accessions to cotton aphids, AVRDC, autumn-winter, 1996-97

Accession #	Aphid rating[a]
TS 6	2.984bcd
TS 18	1.895defg
TS 43	1.792defg
S 130	2.500cde
S 140	3.333bc
S 166	1.440efg
TS 207	1.075g
S00 214	4.875a
S00 239	4.625a
S00 244	4.083ab
S00 273	1.189fg
S. viarum	0.943g
Pingtung Long	2.453cdef
LSD (5%)	1.2652

Pepper Improvement

The goal of the pepper project is to enhance chili and sweet pepper yield and quality in existing production areas and to promote adoption of pepper as a high-value crop for poor farmers in new regions of the hot, humid tropics.

In 1996, a core collection was formed for each of the following *Capsicum* species: *annuum*, *baccatum*, *chinense*, and *frutescens*. Approximately 10% of the accessions of each species were included in the core for that species. Selection of the core was based on morphological data. A subset of the core was selected for analysis via RAPD markers to determine if morphological differences reflected genetic distances as measured by RAPD genotypes.

The 6th International Chili Pepper Nursery (ICPN), consisting of 20 inbred lines and landraces, was assembled, and seed sets were sent for evaluation to more than 40 cooperators in more than 22 countries. Several entries possessed multiple-disease resistance, including PBC972 and PBC556B. Large genotype-by-environment interactions were observed for yield. A few lines, such as PBC367, PBC585, PBC634, and PBC972, consistently performed better in most environments.

Broad mites (*Polyphagotarsonemus latus*) are a destructive pest of chili and sweet peppers throughout Asia. Mite damage is characterized by bronzing and crinkling of new leaves, followed by necrosis of growing points. Therefore, preliminary screening for resistance to broad mites was initiated in 1996, and several entries in the AVRDC *Capsicum* germplasm collection were identified for further testing.

Bacterial wilt (BW) (*Ralstonia solanacearum*) is not as serious a pest in peppers as it is in tomatoes, but it is still a problem in many tropical countries, particularly for sweet peppers. A set of 17 pepper lines identified in preliminary screening as resistant to BW was tested in multiple locations to see if the resistance was stable. The lines seemed to fit two categories: highly resistant over all locations (10 lines) and moderately resistant or unstable (7 lines). The 10 lines with stable resistance are being tested in more locations.

Three races, or pathotypes, of phytophthora blight (PB) (*Phytophthora capsici*) were identified by their reaction on differential host lines F_1 Blue Star (susceptible to all three races), PBC137 (resistant to race 1 but susceptible to races 2 and 3), PBC602 (resistant to races 1 and 2, but susceptible to race 3), and PBC178 (resistant to all three races).

Other pepper project activities for 1997 included varietal improvement, studies on management of major pests and diseases, and strategic and supporting studies, such as inheritance studies.

Genetic resources enhancement and varietal development

Genetic resources activities

Twenty-six new accessions were donated by Laos and Vietnam in 1997, bringing to 6883 the total number of *Capsicum* accessions at AVRDC (Table 1). Some 338 accessions of *Capsicum* belonging to eight species from 46 countries were regenerated inside net cages. These were characterized based on a standard set of descriptors. Samples of fruits were sent to the analytical laboratory for analysis of capsaicin, sugar, and oil content. Based on a taxonomic key used at the Center, several were reclassified as to species. The *Capsicum pubescens* were checked for black seed color.

Seedling, vegetative, inflorescence, and fruit traits were noted. Although all species showed variation, it was widest in *C. annuum*. Dry matter ranged from 8% in Konika, a *C. annuum* from Yugoslavia, to 25% in C2677, a *C. chinense* from Peru. Zero capsaicin was noted in eight accessions of *C. chinense*, three accessions of *C. baccatum*, and two accessions of *C. chacoense*. Relatively high values (4.18-4.92 mg/g) for capsaicin were observed in three accessions of *C. annuum* (Chanca, Hodoninska Previsla, and Zitavska) and one accession of *C. chinense* from the Maldives. Oil content ranged from 5.33 to 17.86%.

In 1997, 5965 seed packets were distributed: 5469 (92%) to 50 countries and 316 (5%) to AVRDC's regional programs (Table 2). Center scientists used 180 (3%) samples for experiments on grafting, screening for resistance to bacterial spot, anthracnose, pepper mild mottle virus (PMMV), tomato mosaic virus (ToMV), and tobacco mosaic virus (TMV), and for performance evaluation.

Table 1. Pepper germplasm collection at AVRDC, 1997

Species	No. of accessions	No. acquired in '97
C. annuum	4125	22
C. baccatum	359	--
C. chacoense	30	--
C. chinense	381	1
C. eximium	4	--
C. frutescens	365	--
C. praetermissum	4	--
C. pubescens	25	--
C. sp.	1590	3
Total	6883	26

Evaluation and multiplication of germplasm

An integral part of any breeding program is observation and multiplication of germplasm. The objective of germplasm screening trials is to identify sources of desirable traits. The objective of multiplication trials is to maintain unique accessions for future use.

In 1997, seed multiplication of pepper accessions with desireable traits was performed in the field and

Table 2. Recipients of AVRDC pepper germplasm, 1997

Country	No. of samples	
External		5469
USA	889	
Indonesia	559	
Taiwan	510	
India	460	
Nepal	320	
Ghana	270	
Bangladesh	226	
Sri Lanka	219	
Pakistan	201	
Vietnam	184	
Others[1]	1631	
ARC		243
ARP		73
Headquarters		180
Breeding	68	
Crop management	6	
Virology	52	
Mycology	34	
Bacteriology	20	
Total		5965

[1] Australia, Belize, Bhutan, Brazil, Cambodia, Canada, Chile, China, Congo, Costa Rica, Ecuador, Ethiopia, Gabon, Haiti, Hungary, Israel, Ivory Coast, Japan, Korea, Lao PDR, Liberia, Malaysia, Mauritius, Mexico, Moldova, Namibia, Netherlands, Papua New Guinea, Philippines, Senegal, Seychelles, Tanzania, Thailand, Togo, Tonga, Turkey, United Kingdom, Yugoslavia, Zaire, and Zambia.

screenhouse (437 and 40 accessions, respectively). Field-sown accessions were covered with nylon nets prior to flowering to prevent outcrossing. A total of 378 accessions were successfully multiplied. The others were lost due to poor germination, plant death, or failure to set fruit. Forty-seven duplicates in the collection were visually identified and removed. Data were collected on plant and fruit traits, including species, days to maturity, fruit type, fruit color, fruit size, and pungency.

Since the hot rainy season is our target environment, a summer survival trial was conducted with 328 accessions. Ten plants were grown per plot (one replication), and data were recorded on plant and fruit traits and survival. Data indicated that only 12 of 24 accessions rated in 1996 as having good summer survival also had good summer survival in 1997, indicating the importance of multi-year testing. The lines were C00377, I-13-1-1, I-7-1 PeMV-Nic-1, PBC 993, Hybrid Huarena-3-2, VC16a No. 1-4-4-1, VC16a No.2-4-1-1, VC16a No. 2-4-4-1, VC 16a No. 5-1-1-1, PBC 149A-2-4, PBC 370-1-1, and VC 36a-4. Seventy-four new accessions had good summer survival in 1997 and will be tested again in 1998. Lines confirmed as having good summer survival will be used in crosses to develop improved chili and sweet pepper lines for the hot, rainy season.

Fifty-six accessions of sweet pepper were screened for fruit quality traits (10 plants/plot, two replications). Immature and mature fruits were evaluated for dry matter, oil, and sugar content. Immature fruits were analyzed for vitamin C, and mature fruits were analyzed for provitamin A, expressed as retinol equivalents (RE). Analysis of variance (ANOVA) revealed significant ($p \leq 0.05$) variation among the entries for each trait measured. The range, mean, coefficient of variation (CV), and least significant difference as determined by Duncan's Multiple Range Test (DMRT) for each trait are shown in Table 3. Accession PBC1023 had the highest vitamin C content, followed by PBC1372 (Morgold). Accession PBC 438 (California Wonder) had the highest sugar content, followed by PBC 379, which also showed very high levels of provitamin A (900 RE, compared to the trial mean of 100 RE). PBC 466 also showed high levels of provitamin A at 397 RE. Lines with relatively high values for each trait will be retested and those confirmed will be used in crosses to develop sweet pepper lines with improved nutritional content.

Thirteen commercial sweet pepper hybrids were screened for heat tolerance. Plants were grown in 21-cm pots in a greenhouse (one plant per replication, five replications) during the summer and evaluated for fruit number, fruit size, and total yield (three harvests) under high temperature and humidity (mean 33°C and 66% RH). The ANOVA revealed significant variation among the entries for each trait measured. The three entries with the best heat tolerance, as indicated by high fruit number per plant, were F_1 New Ace, F_1 Volcani Center 859, and F_1 Andalus. The three entries with the largest fruits were F_1 Boynton Bell, F_1 X3R Camelot, and F_1 Blue Star. The three entries with the highest

Table 3. Chemical analysis of 56 sweet pepper varieties, using immature and mature fruits, for % DM, % oil, % sugar, vitamin C, and provitamin A (retinol equivalents)

	Immature fruits				Mature fruits			
	DM %	Oil %	Sugar %	Vitamin C mg 100g^{-1}	DM %	Oil %	Sugar %	Provitamin A (RE)
Minimum	5.9	1.5	23.6	57.1	5.2	4.5	25.9	21.7
Maximum	8.3	6.2	31.1	139.5	12.2	13.5	37.1	900.0
Mean	6.4	4.0	27.3	95.5	8.4	7.7	30.2	100.0
C.V.(%)	5.0	17.4	4.6	16.9	6.4	18.8	9.1	64.4
$DMRT_{0.05}$	0.3	0.7	1.2	15.9	0.6	1.7	3.2	66.7

yield were F_1 X3R Camelot, F_1 Boynton Bell, and F_1 New Ace. The top-ranked entries will be retested next summer, and lines with confirmed heat tolerance will be used in crosses to develop sweet pepper lines with improved heat tolerance.

Development of improved inbred lines

Pepper production in the tropics is limited by several biotic and abiotic stresses. Sources of resistance or tolerance to many of these stresses have been identified, and incorporation of the resistance or tolerance into improved inbred lines is ongoing. The objective is to develop tropically adapted chili and sweet pepper inbred lines with multiple disease resistance and good fruit quality in order to stabilize yields.

The starting point of any breeding program is cross-pollination to generate segregating materials. For example, in 1997, interspecific crosses were made between *C. annuum* and *C. baccatum* or *C. chinense* to begin transfer of anthracnose resistance into *C. annuum*. Because these interspecific crosses do not produce seeds, embryo rescue and tissue culture were performed on immature F_1 embryos to generate F_1 plantlets. Several F_1 plants were obtained, and were selfed, backcrossed, or crossed to a third parent.

At the other end of the breeding process, one AVRDC chili pepper line, PBC362, will be released in Sri Lanka, probably in 1998, and four other chili pepper lines (PBC585, PBC586, PBC601, and PP921206) are under final evaluation in Vietnam. Eighty-one lines with resistance to one or more diseases and with acceptable fruit type were chosen from advanced generation nurseries for preliminary yield evaluation as candidates for the 8th International Chili Pepper Nursery (ICPN).

Approximately 15 requests for male-sterile chili lines were received in 1995-96 from several countries, including the Philippines, India, China, and Thailand. Therefore, introgression of cytoplasmic male sterility (CMS) into tropically adapted chili pepper lines with good disease resistance has begun. Initially, six lines were test-crossed to a CMS line to assess their ability to maintain CMS, and backcrosses were made onto three maintainer-type parents, while an additional 13 new lines were test-crossed to a CMS line. Two lines, PBC716 and PBC950, gave hybrids which were sterile, and thus appeared to be maintainers. However, when the BC_1F_1 plants from each line were tested, many or all were fertile, probably due to heterogeneity in the lines. One line, PBC534, gave a sterile hybrid and sterile BC_1F_1 plants, indicating it is a pure maintainer. Three lines, PBC142, PBC715, and PBC743, gave hybrids which were fertile, indicating they are restorers.

Surveys in Asia consistently identify chili veinal mottle poty virus (CVMV) as a major disease in chili pepper production areas. Four years ago a backcrossing program was begun to introduce CVMV resistance into tropical chili lines. In 1997, final selections for plant and fruit type were made from 10 different BC_4F_3 lines bred for CVMV resistance, four of which carry resistance to other diseases as well. CCA2334@-3 is resistant to potato virus Y (PVY) and PB, CCA2322@-3 and CCA 2341@-2 are resistant to BW, and CCA 2336@-1 is resistant to BW and PVY. Data on their fruit length, width, and weight are given in Table 4. They will be multiplied in preparation for the 8th ICPN in 1998.

As part of the AVRDC systems approach to optimizing chili pepper production, two experiments were performed to determine the optimum method of weed control and the optimum plant density. A split-plot design was used to test method of herbicide application and type/rate of herbicide. The whole plot treatment tested two application methods, pre-transplant vs. post-transplant, with two replications, while the split-plot treatment tested four herbicide types/rates, Amex (butralin) 47.4%EC and Lasso (alachlor) 43%EC at 250× and 500× dilution each, with three replications.

Variables measured included weed number per plot and weed severity (weed size × weed number). Post-transplant application gave significantly ($p \leq 0.05$) better weed control than pre-transplant application, and Lasso (250× dilution) gave significantly better weed control than Lasso at 500× dilution or Amex at either rate. Therefore, Lasso 43% EC sprayed at 250× dilution may be recommended for post-transplant weed control.

Optimum plant density was tested using a split-plot design. The whole plot treatment tested four densities, 36,000, 48,000, 60,000, and 72,000 plants/ha, with two replications, while the split-plot treatment tested two varieties, PBC534 and PBC972, with two replications. Days to maturity, plant height, lodging, fruit traits, fruit number per plant, and fruit yield were measured. Varieties responded differently to different plant densities, as shown in Table 5. PBC972 had a linear increase in yield as plant density increased, while PBC534 showed no yield increase as plant density increased because fruit number per plant decreased linearly. Plant height was significantly higher for each variety at the highest density, but other traits were unchanged as plant density increased. This indicates that a new variety should be tested at several plant densities to determine its optimum planting density.

Many farmers retain chili pepper seeds to sow their next crop, but poor germination is a problem. The optimum time to harvest chili pepper fruits to obtain maximum percent germination was unclear from the literature. Therefore, a study was conducted to determine the average number of days after anthesis (DAA) to physiological maturity of chili pepper seeds. A randomized complete block design was used with three entries (PBC518, PBC534, and PBC972) and three replications. Plants were grown in 22-cm pots in a screenhouse at ambient temperatures (16-24°C). Fruit weight, fruit color (% red), seed moisture, seed dry weight, and percent germination were measured weekly. Under these conditions, chili pepper seeds reach physiological maturity at around 56 DAA as seed viability is reached and seed dry weight plateaus (Table 6). Maximum percent germination is highly correlated with fruit color development, and 100% ripe fruits indicates the optimum fruit maturity to extract seeds for maximum germination.

Table 4. Fruit traits of 10 AVRDC BC_4F_3 lines resistant to CVMV, BW, PC, and/or PVY

Code #	Resistant to:	Length (cm)	Width (cm)	Weight (g)
CCA 2319@-3	CVMV	10.1	1.1	10.2
CCA 2322@-3	CVMV, BW	8.1	1.1	12.2
CCA 2323@-1	CVMV	9.4	0.9	4.1
CCA 2324@-4	CVMV	12.0	1.2	7.3
CCA 2333@-2	CVMV	3.9	0.6	1.4
CCA 2334@-3	CVMV, PVY, PC	4.3	1.0	1.7
CCA 2336@-1	CVMV, BW, PVY	12.5	1.9	15.1
CCA 2340@-2	CVMV	8.6	1.2	9.1
CCA 2341@-2	CVMV, BW	11.5	1.6	13.9
CCA 2348@-1	CVMV	6.8	1.3	13.4

Table 5. Effect of plant density on plant and fruit traits of two varieties, PBC534 and PBC972

Entry	Density plants/ha[1]	Lodg. %	Anth DAT	Mat. DAT	Plant height (cm)	Fresh yield (t/ha)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. (per plant)
PBC534	36,000	0	44	103	93	6.0	10.2	1.2	6.6	25.7
PBC534	48,000	0	43	98	86	6.4	10.7	1.3	6.7	19.8
PBC534	60,000	0	44	101	96	7.0	10.1	1.4	6.8	17.1
PBC534	72,000	3	44	106	102	6.9	11.3	1.3	7.5	12.8
PBC972	36,000	11	43	97	88	9.0	9.7	1.6	8.1	29.5
PBC972	48,000	15	44	94	83	9.5	9.1	1.6	7.6	26.4
PBC972	60,000	24	44	95	93	13.9	9.9	1.6	8.0	30.4
PBC972	72,000	5	41	94	109	16.2	10.1	1.6	8.3	27.2

DAT = days after transplanting

International Chili Pepper Nursery

An integral part of any breeding program is testing promising genotypes in multiple environments. The objective of the 7th ICPN was to test adapted, disease-resistant chili peppers in tropical production regions and to gather information on pathogens. Diseases and insects are the main limiting factors in chili pepper production in the tropics and farmers spray exorbitant amounts of pesticides to combat them. Introduction of disease- and insect-resistant lines, therefore, should help stabilize yields and reduce damage to the environment. To date, six ICPN nurseries have been distributed to researchers in at least 48 countries.

Table 6. **Fruit and seed traits as indicators of seed physiological maturity in chili pepper**

DAA	Fruit wt. (g)	Seed Fruit color (% red)	Seed Fresh wt. (g)	Dry wt. (g)	Seed moisture. (%)	Seed germ. (%)
28	5.4	0	0.68	0.14	77	0
35	8.2	0	0.71	0.32	55	0
42	8.8	9	0.78	0.41	46	0
49	9.0	34	0.85	0.48	40	0
56	9.1	82	0.78	0.53	36	83
63	9.5	100	0.75	0.54	25	95
70	10.3	100	0.71	0.55	20	95
C.V. (%)	7.0	7	17.00	17.00	12	8
$DMRT_{0.05}$	0.6	3	0.10	0.05	5	3

Table 7. **The 7th ICPN disease screening results for BW (causal agent *Rolstonia solanacearum*), BS (causal agent *Xanthomonas campestris* pv. *vesicatoria*), CMV, CVMV, PVY, TMV, ToMV, PMMV, anthracnose (causal agent *Colletotrichum capsici* and *C. gloeosporioides*), and PC (causal agent *Phytophthora capsici*)**

Ent No.	PBC No.	BW	BS	CMV	CVMV	PVY	TMV	ToMV	PMMV	A	PC
1	PBC 137 (ck)	23*	1.0**	S	H(59)+	S	R	R	S	52*	85*
2	PBC 142 (ck)	56	2.3	H(46)	H(38)	H(88)	S	S	S	63	100
3	PBC 534 (ck)	6	5.5	R	H(54)	R	S	S	S	83	67
4	PBC 091	96	5.6	S	S	S	R	R	S	44	100
5	PBC 161	14	6.0	R	H(29)	R	S	S	S	51	96
6	PBC 369	55	2.9	H(17)	H(13)	R	S	S	S	42	62
7	PBC 386	39	2.9	H(33)	S	R	S	S	S	73	100
8	PBC 390	68	2.9	S	S	H(17)	R	R	S	56	100
9	PBC 482	4	2.1	H(50)	H(21)	R	S	S	S	80	100
10	PBC 579	55	3.2	H(32)	H(46)	H(33)	S	S	S	76	85
11	PBC 581	0	1.6	H(38)	H(42)	R	S	S	S	30	89
12	PBC 904	35	5.7	H(63)	H(33)	R	S	S	S	8	96
13	PBC1474	0	2.8	H(21)	H(58)	R	S	S	S	52	100
14	PP9656-01	6	5.1	R	R	H(71)	S	S	S	41	100
15	PP9656-06	0	3.9	R	H(18)	R	S	S	S	54	100
16	PP9656-08	0	4.9	R	R	R	S	S	S	12	42
17	PP9656-11	0	5.8	H(25)	H(21)	R	S	S	S	33	92
18	PP9656-13	8	4.3	R	H(17)	R	S	S	S	52	100
19	PP9656-14	11	1.7	R	R	H(58)	S	S	S	50	100
20	PP9656-15	75	6.4	-	-	-	-	-	S	75	100

* Numbers refer to % susceptible plants for BW and PC, and % infected fruits for anthracnose.
** Rating was done with the Barrett & Horsfall scale (1-11) where 1=resistant.
+ H(59)=heterogeneous (59% of plants tested were susceptible), R = resistant, S = susceptible.
--- Not tested

The 7th ICPN tested for cucumber mosaic virus (CMV), CVMV, PVY, TMV, ToMV, PMMV, BW, bacterial spot (BS), PB, and anthracnose. The 7th ICPN was grown in a yield trial at AVRDC headquarters with four replications and five biweekly harvests. The following traits were measured: days to maturity, height at maturity, visual score at final harvest, marketable yield, fruit length, fruit width, fruit weight, capsaicin content, and fruit number per plant.

The 7th ICPN disease screening results are shown in Table 7. Several lines, such as PBC581, PP9656-06, and PP9656-08, were resistant to three or more diseases. None of the entries carried resistance to PMMV. For the other diseases, at least one line was as resistant as the resistant check (check data not shown). The 7th ICPN plant and fruit trait results are shown in Table 8. The top-yielding line was PBC581, which has medium-sized fruits, followed by PBC904 (small fruit size), PP9656-06 (medium fruit size), PP9656-08 (small fruit size), and PP9656-11 (medium-small fruit size). This was primarily due to their relative tolerance to anthracnose, which caused severe damage in most of the lines.

The entries could be grouped into two maturity classes, early (68-77 DAT) and late (>84 DAT). Late maturity was significantly ($p < 0.001$) correlated with plant height ($r = 0.54$), as is common in many crops. Visual scores were negatively correlated with maturity and plant height ($r = -0.47$ and -0.63, respectively), but visual scores were not correlated with marketable yield. Marketable yield was positively correlated with plant height ($r = 0.24$) and negatively correlated with fruit length and fruit weight ($r = -0.32$ and -0.27, respectively), indicating that tall plants with relatively small fruits gave

Table 8. The 7th ICPN plant and fruit trait results for maturity (days after transplanting, DAT), plant height, visual score (1-5 scale, 1=excellent), fruit length, width, and weight, marketable yield, capsaicin (Cap), and fruit number per plant

Ent. No.	PBC No.	50% Mat. DAT+	Plant Height (cm)	Visual Score 1-5	Fruit Length (cm)	Fruit Width (cm)	Fruit Wt. (g)	Mkt. Yield t ha^{-1}	Cap (mg g^{-1})	Fruit No. ($plant^{-1}$)
1	PBC 137	84	106	2.5	6.6	0.8	2.0	2.9	2.4	48.7
2	PBC 142	71	88	3.1	4.7	0.8	1.4	2.0	4.3	51.1
3	PBC 534	86	121	1.4	11.5	1.3	7.8	3.5	2.4	15.3
4	PBC 091	68	73	4.0	9.0	2.4	15.0	1.4	1.1	3.0
5	PBC 161	71	110	2.1	8.5	1.0	3.4	7.3	4.7	75.3
6	PBC 369	74	97	2.4	6.0	1.4	5.1	1.7	4.0	11.2
7	PBC 386	72	92	2.8	10.9	1.5	8.9	4.8	0.3	18.5
8	PBC 390	71	65	4.3	12.0	0.9	4.8	2.5	2.8	18.2
9	PBC 482	71	81	3.5	6.2	0.9	2.8	2.7	2.2	35.0
10	PBC 579	77	104	2.3	7.1	1.3	4.8	6.0	3.5	43.7
11	PBC 581	76	119	1.6	10.5	1.6	6.8	12.5	2.7	62.5
12	PBC 904	73	107	1.9	3.7	0.9	1.4	9.5	2.5	254.4
13	PBC1474	71	95	2.3	10.0	1.8	10.5	6.5	1.1	20.9
14	PP9656-01	72	66	2.1	5.2	0.9	1.5	4.1	7.1	103.4
15	PP9656-06	71	96	3.3	9.4	1.1	4.8	9.5	0.7	68.7
16	PP9656-08	74	91	2.3	2.9	0.8	1.0	9.2	4.6	309.1
17	PP9656-11	72	90	3.0	6.9	0.9	2.8	8.1	4.5	103.2
18	PP9656-13	71	81	3.5	5.4	0.9	2.0	5.1	5.7	87.9
19	PP9656-14	73	93	3.1	4.5	0.9	3.4	6.2	5.2	105.2
20	PP9656-15	72	78	2.9	6.9	0.9	2.6	2.0	5.9	26.6
Mean		73	93	2.7	7.4	1.1	4.6	5.4	3.4	73.1
Range		68-86	55-121	1.4-4.3	2.9-12	0.8-2.4	1-15	1.4-12.5	0.3-7.1	3-309
DMRT 0.05		5	12	0.7	0.9	0.3	2.0	1.5	0.6	43
CV (%)		5	9	17	8	16	31	20	12	42

higher yields in this trial. Capsaicin showed a negative correlation with fruit length (r = -0.57). Relatively high CVs were observed for fruit weight and fruit number per plant.

Genetics of resistance to major pepper diseases

It is useful to know the inheritance of resistance to a disease to determine what breeding strategy to use, particularly when the goal is to combine multiple disease resistance into a single line. The objective of these inheritance studies was to estimate how many genes are involved and their mode of gene action. A study in 1996 indicated that resistance to CVMV might be temperature-sensitive. To test this, 10 F_2:F_3 families (seven plants per family) from the cross Cheongryong (susceptible, S) × PSP-11 (resistant, R) and 10 F_2:F_3 families from the cross PerennialHDV [R] × Cheongryong [S], were grown in a growth chamber at 24 and 32°C (16 h light/8 h dark). The 20 F_2:F_3 families generally gave the same reaction at 24 and 32°C, as did the parents (Table 9).

Table 9. Reactions at two temperatures, 24 and 32°C, of 10 F_2:F_3 families from two crosses, Perennial x Cheongryong and Cheongryong x PSP-11, when inoculated at the three-leaf stage with CVMV

Code No.	Pedigree	24°C Rx+	32°C Rx
1	Perennial/Cheongryong	R	R
3	Perennial/Cheongryong	R	R
4	Perennial/Cheongryong	S	S
5	Perennial/Cheongryong	S	S
6	Perennial/Cheongryong	S	S
8	Perennial/Cheongryong	R	segr
9	Perennial/Cheongryong	R	R
10	Perennial/Cheongryong	segr	segr
11	Perennial/Cheongryong	S	segr
12	Perennial/Cheongryong	S	S
56	Cheongryong/PSP-11	segr	R
58	Cheongryong/PSP-11	R	R
61	Cheongryong/PSP-11	R	R
63	Cheongryong/PSP-11	segr	segr
65	Cheongryong/PSP-11	segr	segr
67	Cheongryong/PSP-11	segr	segr
70	Cheongryong/PSP-11	segr	R
71	Cheongryong/PSP-11	segr	R
73	Cheongryong/PSP-11	segr	segr
80	Cheongryong/PSP-11	segr	R
Susceptible parent Cheongryong		S	S
Resistant parent Perennial		R	R
Resistant parent PSP-11		R	R

+ R= all resistant, S= all susceptible, and segr=segregating for resistance; seven plants were tested for each family.

Resistance to PB was recently reported in literature to be controlled by several genes with additive and epistatic gene action. However, the source of resistance used, Perennial, was different from the sources used at AVRDC, and the strain of *Phytophthora capsici* used in the testing was also different. Therefore, 100 plants from each of six different F_2 populations segregating for resistance to PB were tested along with the resistant [PI201234 and Criollo de Morelos 331 (CM331)] and susceptible (PBC76, PBC163, PBC273, and PBC518) parents to estimate the mode of inheritance. The results indicated that inheritance was quantitative and depended on which susceptible parent was used. For example, the cross PBC76 × CM331 gave 39 resistant plants, while the cross PBC163 × CM331 gave five resistant plants. Individual resistant F_2 plants from each population were self-pollinated and the resulting F_2:F_3 families were tested. Survival of F_2:F_3 families ranged from 0-100% in each population. The mean survival of PBC76 × CM331 families was 45%, while the mean survival of PBC163 × CM331 families was 28%. This indicates that PB screening should be repeated on F_2:F_3 families to further eliminate susceptible plants.

Virus strain detection, characterization, and antiserum production

Viruses are one of the major constraints to pepper production in tropical Asia. AVRDC has accorded high priority to overcome this constraint, working in close collaboration with regional networks such as the Southeast Asian Collaborative Vegetable Network (AVNET) and the South Asian Vegetable Research Network (SAVERNET). The objectives are: (1) to characterize the most important pepper viruses, particularly regard-ing the occurrence of strains; (2) to conduct virus surveys in countries where no knowledge of pepper viruses exists; (3) to assist NARS in isolating the two most important viruses, CMV and CVMV, and to use them for multilocation resistance screening; and (4) to assure that AVRDC germplasm sent out is free from seed-transmitted viruses, particularly tobamoviruses.

CMV strain detection at headquarters and virus surveys in Asia

Eight lines previously confirmed as highly resistant to CMV were planted at headquarters and exposed to natural infection. At the end of the growing season, the plants were observed for typical CMV symptoms and tested by ELISA. Several pure CMV isolates were obtained by routine virus isolation methods. The eight previously confirmed CMV-resistant lines were then mechanically inoculated with the new CMV isolates, as well as the old one, and tested by ELISA. In AVRDC pepper fields, at least one new strain of CMV seems to be present, which infects plants which are resistant to the common strain (Table 10). New sources of resistance or tolerance to this new strain need to be identified.

Leaves of symptomatic plants collected by cooperators in India and Bhutan from farmers' fields were squashed on nitrocellulose membranes and processed at AVRDC by indirect ELISA.

Of 54 samples collected from farmers' fields in Bhutan, 61% were infected with CMV, 19% with CVMV, 18% with PVY, and 7% with ToMV and PMMV. This is the first virus survey in Bhutan, and results show that the virus incidence in peppers in Bhutan is quite similar to that in other countries in the region.

Of 15 samples collected from farmers' fields in South India, 80% were infected with CMV, 60% with CVMV, 27% with PMMV, and 7% with ToMV and PVY. These results confirm the presence of CVMV in India, as reported by AVRDC in 1992.

CMV and CVMV are the most important viruses addressed in AVRDC's chili breeding program, as shown by these surveys. Our AVNET results show that multilocation testing is important to determine whether the resistant lines developed at AVRDC will hold up against possible locally diverse strains of these two viruses.

Virus resistance (conventional) CVMV, PVY, ToMV, TMV, WSMV

AVRDC could make a great impact in Asia by developing multivirus-resistant lines. The objective was to identify stable sources of resistance to CVMV, CMV,

Table 10. Detection of putative new CMV strain(s) in pepper lines resistant to P522 CMV strain

Line[1]	No. of resistant plants/No. of Inoculated plants (%) P 522[2]		P 3613		P 3616		P 3617		P 3621		Average (%)
PBC 370-2-2-1-1 (cccc)	0/23	(0)	13/23	(60)	0/22	(0)	5/24	(21)	3/23	(13)	
PBC 521-2-1-1-1 (c5cc)	0/18	(0)	2/8	(25)	0/25	(0)	7/23	(30)	5/10	(50)	21
PBC 549-3-2-1-1 (55cc)	0/22	(0)	15/24	(63)	0/18	(0)	10/24	(42)	6/24	(25)	26
PBC 569-5-2-1-1 (c5cc)	0/24	(0)	10/22	(45)	3/21	(14)	5/15	(33)	6/20	(30)	24
VC 16a No. 5-1-1-1-1 (cccc)	0/24	(0)	15/20	(75)	2/24	(8)	14/24	(58)	9/22	(41)	23
VC 41a 3-1-1-1 (5cccc)	0/24	(0)	12/24	(50)	2/24	(8)	5/24	(21)	4/24	(17)	19
VC 232-1-4 (5ccc)	2/20	(10)	20/24	(83)	0/10	(0)	7/24	(29)	12/24	(50)	19
VC 237-3-2-1 (5cccc)	1/24	(4)	23/23	(100)	5/24	(21)	10/24	(42)	5/24	(21)	38
VC 6a (susc. ck)	8/8	(100)	4/4	(100)	6/6	(100)	8/8	(100)	8/8	(100)	100
Average (w/out susc.ck)	3/179	(2)	110/168	(66)	7/168	(7)	63/182	(35)	50/171	(29)	

[1] Confirmed resistant to isolate P 522 in previous screenings.
Sown in the greenhouse June 16, 1997. Inoculated July 9 (cotyledon); July 16, Aug. 5, ELISA: July 30, Aug. 26, Sept. 25.

[2] P 522 is the previous type isolate; all others are new isolates.

PVY, and three tobamoviruses (TMV, ToMV, and PMMV), but especially CVMV and CMV.

Self-pollinated seeds of resistant plants were collected and subjected to a first confirmation test. The screening protocols were those described previously: mechanical inoculation (2-3x) of seedlings, followed by ELISA (3x) of 24 plants per entry. Self-pollinated seeds of resistant plants from the first confirmation test were saved for a second and third confirmation test. To help avoid inconsistent screening results (a problem in the past for CVMV and CMV), a number of segregating breeding lines, together with susceptible and resistant checks, were mechanically inoculated and observed for infectivity at two different temperatures (24/24°C day/night and 32/23°C day/night).

ICPN lines

Among 19 lines from the the 7th ICPN, five were highly resistant (0% infection) to CMV, two were highly resistant to CVMV, nine were highly resistant to PVY, and three were highly resistant to ToMV and TMV. Four lines were resistant (0-8% infection) to more than one virus.

Confirmation screening

Seventy lines were subjected to a second and third CVMV confirmation screening. Twenty-seven were found to be highly resistant (0% infection): C 00265, C 01664, PBC 122, 149, 340, 521, 522, 523, 524, 569, 693, VC 16a, 33a, 35a, 37a, 39a, 40a, 41a, 58a, 160, 208a, 211, 223, 236, 237, 240, and 241. Four were found to be resistant (<10% infection), VC 230, 232, 239, and 258.

Twelve lines were subjected to a second and third CMV confirmation screening. Six were found to be highly resistant (0% infection): PBC 370, PBC 521, PBC 549, PBC 569, VC 16a, and VC 41a. And two lines were found to be resistant (<10% infection): VC237 and VC232.

Effect of temperature on infectivity of CMV and CVMV

CVMV infectivity was compared at 24 and 32°C. The lower temperature resulted in slightly higher infectivity (Table 11). Similar results were found for CMV. The lower temperature resulted in 14% and 19% higher infection rates in plants inoculated at the cotyledon and third-leaf stage, respectively (Table 12).

Establishment of a regeneration system for pepper transformation and immature seed rescue of F_1 hybrid seeds from interspecific crosses

Pepper production suffers great losses due to infection by various diseases. Plant genetic engineering is a new technology with the potential to transfer useful genes between different species. This requires an efficient and reliable transformation and regeneration protocol. The first objective of this project was to establish a reliable Agrobacterium-mediated transformation and regeneration protocol for chosen pepper varieties.

Wild species are often full of useful genes and interspecific crosses have long been used to introduce

Table 11. Effect of temperature on CVMV infectivity in F_3 families segregating for CVMV resistance

Code #	No. of Families tested	Pedigree	No. of plants infected/total no. tested (%) 24°C	32°C
CCA 369	20	Perennial/Cheongryong	58/123 (47)	55/125 (44)
CCA 372 R-6	18	Cheongryong/PSP-11	45/124 (36)	21/113 (19)
		Cheongryong (susc. parent)	2/ 2 (100)	NT
		Yolo Wonder L (susc. ck)	6/ 6 (100)	7/7 (100)
		Perennial (res. parent)	0/ 7 (0)	0/7 (0)
Total			111/262 (42)	83/252 (33)

useful traits from wild species into cultivated crop varieties. However, the success of the introduction depends on the viability of seeds produced from interspecific pollination. Thus, the second objective of this project was to transfer useful genes from *C. baccatum* and *C. chinense* into *C. annuum* via immature seed rescue.

Transformation experiment

Chili varieties PBC075 and PBC137 were used for the regeneration experiment. Seeds were surface sterilized with 20% chlorine bleach and rinsed with sterile water three times before being cultured for germination on Murashige and Skoog (MS) medium at 25°C with a 16/8 (day/night) light regime. Cotyledons were harvested from germinated seedlings before the full expansion of first leaves and cultured on MS medium supplemented with various concentration combinations of growth regulators indole-3-acetic acid (IAA; 0, 0.25, 0.5, 1, and 2 mg/l) and 6-benzylaminopurine (BAP; 0, 2.5, 5, 7.5, and 10 mg/l) for shoot initiation. Cotyledon explants with adventitious shoot buds were then transferred to different media for shoot elongation. *Agrobacterium tumefaciens* LBA4404 with the *GUS* reporter gene was used for transformation with the established regeneration method. Explants were cultured on regeneration medium with 75 mg/l of kanamycin after agrobacterium infection to select resistant plantlets.

Of the 25 tested regeneration media, MS medium supplemented with a low concentration of IAA and a relatively high concentration of BAP was found to be the best shoot induction medium for PBC075 and PBC137. Shoot buds were obtained from more than 90% of cultured cotyledon explants. However, the elongation of buds was more difficult. Regeneration medium supplemented with gibberellic acid (GA_3) was best for shoot elongation, but only 15% of the shoot buds were able to elongate. Several recent publications describe regeneration of pepper, but shoot elongation of buds from cultured explants is still the limiting factor for the application of genetic engineering. More study is required to learn whether the shoot elongation rate can be improved using the existing regeneration protocol.

Agrobacterium-mediated transformation was done

Table 12. Effect of temperature on CMV infectivity in F_1 hybrids, F_2 plants, F_3 families, and pure lines

	No. of crosses tested	No. of plants infected/Total no. tested (%)			
		24°C		32°C	
		cot.[1]	3rd	cot.	3rd
Generation					
F_1	3	3/16 (19)	Not tested	2/12 (17)	Not tested
F_2	10	16/71 (23)	Not tested	5/68 (7)	Not tested
F_3	10	26/119 (22)	36/118 (31)	4/120 (3)	8/119 (7)
Code #					
VC 41a-3-1-1-1		2/12 (17)	1/12 (8)	0/11 (0)	2/12 (17)
VC 237-3-1		1/12 (8)	3/12 (25)	0/12 (0)	0/12 (0)
VC 211-1-2		1/12 (8)	2/12 (17)	0/12 (0)	0/12 (0)
VC 223-1-1-1		4/12 (33)	2/12 (17)	0/12 (0)	0/12 (0)
C 03853-3-1		5/12 (42)	8/12 (67)	4/12 (33)	3/12 (25)
PBC 521-2-1-1		0/11 (0)	0/12 (0)	0/12 (0)	0/12 (0)
PBC 569-5-1-2		3/12 (25)	3/12 (25)	2/12 (17)	0/12 (0)
PBC 495 (Res. ck)		0/6 (0)	0/8 (0)	0/11 (0)	0/12 (0)
PBC 275 (Sus. ck)		10/10 (100)	10/10 (100)	12/12 (100)	12/12 (100)
Total		71/305 (23)	65/220 (30)	29/306 (9)	25/227 (11)

[1] cot = plant inoculated at cotyledon stage; 3rd = plant inoculated at third leaf stage.

with *A. tumefaciens* LBA4404 containing the *GUS* reporter gene for both pepper varieties using the above established regeneration protocols. Cotyledon explants resistant to 75 mg/l kanamycin in the regeneration medium have been subcultured and putative transgenic plants will be confirmed when the regenerated plants are transferred to the greenhouse.

Immature seed rescue experiment

Fruits were harvested from interspecific crosses of *C. annuum* varieties (CCA187A, PBC142, PBC204, PBC323, PBC534, PBC535, PBC715, PBC950, and PBC972) × *C. baccatum* (PBC81) and *C. chinense* (PBC932) approximately one month after pollination. Immature seeds were dissected from sterilized fruits and cultured on MS medium for germination. Germinated seedlings were transferred to Magenta boxes with the same medium, acclimatized, and then moved to the greenhouse.

The germination rate of immature seeds from fruits appoximately one month old is better than the germination rate of younger seeds (14-22 days). The response of each interspecific cross to immature seed rescue was different. There were 324 seedlings obtained (Table 13). Endogenous bacterial contamination was observed in several crosses, which complicated the germination of immature seeds. The addition of carbenicillin (100 mg/l) in the germination medium effectively eliminated the bacteria. The seedlings were transferred to the pepper breeding unit for confirmation of interspecific hybridization and for breeding purposes.

Table 13. Results from the immature seed rescue of interspecific crosses

Cross	Fruit	Seed	Seedling
PBC142 x PBC932	7	278	0
PBC204 x PBC81	9	615	0
PBC204 x PBC932	6	251	12
PBC323 x PBC81	9	615	0
PBC323 x PBC932	13	1116	30
PBC534 x PBC81	9	476	38
PBC534 x PBC932	8	320	6
PBC535 x PBC81	19	709	1
PBC535 x PBC932	1	71	30
PBC715 x PBC81	9	286	3
PBC715 x PBC932	2	27	4
PBC950 x PBC81	7	347	19
PBC950 x PBC932	3	125	4
PBC972 x PBC932	2	33	8
CCA187A x PBC81	6	245	14
CCA187A x PBC932	7	256	155

Pepper resistance to phytophthora blight

Phytophthora blight, caused by *Phytophthora capsici*, occurs in most pepper production areas of the world. It is associated with warm wet periods in rainfed crops and irrigation water in arid areas. Resistant pepper accessions have been identified, but thus far no resistant commercial varieties are available. The objectives of this study were (1) to test the reactions of known resistant pepper lines against three apparant pathotypes of *P. capsici*, (2) to identify host differentials to confirm the occurrence of three pathotypes, and (3) to assess the PB reactions of entries in the 7th ICPN.

The screening method was as follows: 30-day-old pepper plants were inoculated by pipetting 5 ml of a zoospore suspension (5x10^4/ml) into a peat moss potting medium at the base of each plant. Disease severity ratings were made at 7, 14, and 21 days after inoculation (DAI), and the percentage of susceptible plants was determined at 21 DAI.

Reactions of 45 reported resistant pepper lines and a known susceptible variety were determined by inoculating with three isolates of *P. capsici*. Pepper lines were classified as resistant to a given isolate if <20% of the plants in that line developed symptoms by 21 DAI. Using this standard, 39 pepper lines were resistant to isolate Pc-1E, 11 lines were resistant to Pc-33E, and four lines were resistant to Pc-17E (Table 14). Four pepper lines were resistant to all three isolates; seven lines were susceptible to isolate 17 E, moderately resistant to isolate Pc-33E, and resistant to Pc-1E; 28 lines were susceptible to isolates Pc-33E and Pc-17E, but resistant to isolate Pc-1E; and six lines were highly sus-

Table 14. **Reactions of previously reported Phytophthora blight-resistant Capsicum accessions to three single zoospore isolates of *P. capsici***

Rank[a]	*Capsicum* accession	Susceptible plants, %[b]		
		Pc-1E	Pc-33E	Pc-17E
1	PI 201234, mycol. sel.	0	0	0
2	Peto 2258, Petoseed	0	3	6
3	PI 201232, C 00226-1 (Smith 491)	0	6	9
4	PI 201234, C 01176-1 (Smith 493)	0	13	19
5	Fidel, Texas A & M, Villalon	0	28	21
6	IR, PBC 535 (LEHRI)	0	17	21
7	PI 201234, C00352 (INRA, PM217)	0	12	22
8	Criollo de Morelos 328, Petoseed	10	12	23
9	Criollo de Morelos 331, C 03289-A	0	18	23
10	PI 201234, C 01176-A	0	19	24
11	HDA-336, PBC 120 (INRA)	0	0	25
12	PE 502 F1, Choong Ang	0	4	33
13	Criollo de Morelos 334, C 01175	0	26	35
14	PBC 370	9	45	43
15	HDA-832, PBC 122 (INRA)	0	44	46
16	PI 189550, C 02230	5	44	53
17	PE 64 F1, Choong Ang	0	33	54
18	Anaheim F-6, C 00263 (INRA, PM 751)	0	21	63
19	PI 201238, C 02289-A	19	42	63
20	PBC 602, Taiwan	4	54	71
21	PBC 371, Thailand	10	50	75
22	HDA-248, C 00284 (INRA)	2	54	77
23	PI 105339, C 01784	4	81	81
24	Szechuan 8, PBC 074	2	42	82
25	PI 201238, C 02289-B	15	62	83
26	PE 49 F1, Choong Ang	0	38	84
27	Perennial HDV, PBC 495 (INRA)	0	34	84
28	CNPH 1149, PBC 710	15	100	93
29	Tumpang, PBC 534 (LEHRI)	6	41	94
30	Chinda 2, PBC 743	6	86	94
31	Tit Paris, PBC 380	10	92	94
32	PBC 593, Thailand	6	84	96
33	HDA-295, C 00290 (INRA)	10	92	98
34	Szechuan 921207, PBC 075	2	84	100
35	HDA-323, PBC 119 (INRA)	0	91	100
36	PE 501 F1, Choong Ang	0	100	100
37	Revival F1, Choong Ang	0	100	100
38	CNPH 703, PBC 137	9	100	100
39.	Unknown 6, C 00551	17	100	100
40.	PI 244670, PBC 619	35	100	100
41.	PI 224433, C 02284	83	100	100
42.	PBC 473, Indonesia	90	100	100
43.	Var. U-Kimba, PBC 480	96	100	100
44.	PI 188478, C 02227-A	96	100	100
45.	Capriglio, C 01187	100	100	100
46.	Blue Star F1, Susc. ck.	100	100	100

[a] Rank based on reaction of pepper lines to isolate Pc 17E.
[b] Percentage of susceptible plants based on the reactions of 24 or more plants of each line.

ceptible to all three isolates. These results clearly demonstrate the occurrence of races within our *P. capsici* isolates that we tentatively have designated as follows: Pc-1E = Race 1, Pc-33E = Race 2, and Pc-17E = Race 3.

Purification of resistant pepper lines was necessary because all of the original pepper accessions reported to possess PB resistance expressed 9-100% susceptible when tested with isolate Pc-17E. Progeny derived from individual resistant plant selections expressed, however, substantially lower percentages of susceptible plants than the original accessions (Table 15). For example, there were no susceptible plants among the progeny of selections from PI 201232, PI 201234, and CM 331. Several breeding populations have been developed with these resistance sources in their pedigrees. Some of these populations were screened with isolate Pc-17E in 1997 and resistant plants were selected for generation advance. It is clear that progress is being made in the introgression of resistance into commercial pepper varieties.

Phytophthora blight reactions of the 20 pepper entries in the 7th ICPN were evaluated in the greenhouse 21 DAI with isolate Pc-17E (Table 16). The entries with the highest levels of resistance were PP 9656-08, PBC 369, and PBC 534, with percent-susceptible plants recorded at 42, 62, and 67, respectively. Susceptibility rates among the other entries ranged from 85 to 100%.

Pepper resistance to anthracnose

Anthracnose, caused by *Colletotrichum* spp., occurs worldwide wherever pepper is grown under warm temperatures and overhead irrigation or rain-fed conditions. It occurs as a preharvest or postharvest fruit rot, causing extensive losses in pepper grown during the warm, wet season in tropical and subtropical climates. No highly resistant pepper accessions have been identified and confirmed, due to the lack of reliable laboratory inoculation methods to assess anthracnose reactions. The objectives of this study were (1) to develop reliable laboratory anthracnose resistance screening protocols,

(2) to assess the anthracnose fruit reactions of pepper lines representing major species of *Capsicum*, and (3) to assess the anthracnose fruit reactions in the laboratory for entries in the 6th ICPN and in both the field and laboratory for entries in the 7th ICPN.

Green and ripe fruits of 168 pepper accessions, including *annuum*, *baccatum*, *chinense*, and *frutescens* species, were collected from observational and seed increase fields at AVRDC during the spring of 1997. All fruits were tested for their anthracnose reactions in the laboratory by injection inoculation, and most of them were also tested by drop inoculation. Laboratory reactions of fruit from the 6th ICPN entries were determined by injection inoculation of green and ripe fruit, and drop inoculation of ripe fruit. Anthracnose field reactions of the 7th ICPN entries were determined based on percentage of infected fruits in a field inoculated with *C. gloeosporiodes*, isolate *Cg*-153. Subsequently, laboratory reactions of the 7th ICPN entries were determined by both injection and drop inoculation of green and ripe fruit.

Laboratory protocols to assess anthracnose reactions were developed during 1997 to evaluate pepper fruits for their reactions to *Colletotrichum* species. Drop-inoculation of fruit requires placing a 6 μl drop of a 1×10^6 conidia/ml suspension on the surface of pepper fruit. Use one inoculation site if fruits are ≤4 cm in length, and two sites on fruit >4 cm long. Incubate inoculated fruits at 25°C in the dark. During the first 24 hours, keep the fruit in a saturated atmosphere to prevent drying of the inoculum drops, then allow the inoculum drops to dry. Maintain the RH at ≥95% to prevent fruit desiccation, but do not allow free water to form on the fruit. Record lesion development at 10-12 DAI; a necrotic area ≥4 mm in diameter at the site of inoculation is considered positive for disease development.

Injection-inoculation requires using a syringe fitted with a 22-gauge needle 0.60 to 0.75 mm in length.

Table 15. Selection to increase percentage of resistant plants in reported phytophthora-blight-resistant Capsicum lines

Name/Variety	Accession Selection	Origin	Percent Susceptible Plants[a] Acc.	Sel.
PI 188478	C 02227-A	Mexico	100	
	Pc res '92 sel			20
PI 189550	C 02230	Mexico	53	
	Pc res '92 sel			34
PI 201232	C 00226-1 (Smith 491)	Mexico	9	
	Pc res '93 sel			0
PI 201234	C 01176-1 (Smith 493)	Mexico	19	
	C 01176-A		24	
	Pc res '87 sel (Mycol ck.)			1
	Pc res '87, '96 sel			13
	Pc res '92 sel			0
PI 201238	C 02289-B	Mexico	83	
	C 02289-A		63	
	Pc res '92 sel			10
	Pc res '92, '96 sel			4
Criollo de Morelos 331	C 03289-A	Mexico	23	
	Pc res '92 sel			0
	Pc res '92, 96 sel			4
Criollo de Morelos 334	C 01175	Mexico	35	
	Pc res '95, '96 sel			6

[a] 30-day-old plants inoculated with 5 ml/plant of a 10^5 zoospore/ml suspension of isolate Pc-17E. Results based on means from 1 to 3 experiments in which 24 plants of each entry were inoculated.

Inject a 1- μl drop of a 1×10^5 or 1×10^6 conidial suspension into the wall of the fruit. Incubate the inoculated fruit under the same conditions as for the drop inoculations, but omit the 24-hour period of saturated atmosphere. Record lesion development at 4-6 DAI.

Laboratory evaluation of pepper lines was performed on more than 100 pepper lines from the AVRDC observational trials, including *annuum*, *baccatum*, *chinense*, and *frutscens* species. They were evaluated by inoculating detached green and ripe fruits by drop and injection methods. Twenty two lines with measurable resistance were identified by one or more of the tests. Green fruits of 68 pepper accessions from the GRSU seed increase field were injection-inoculated to assess their anthracnose reactions. Fourteen lines, including *baccatum*, *chinense*, and *frutescens* species, were identified as possible sources of anthracnose resistance.

Laboratory anthracnose reactions of detached fruits of the 20 entries in the 6th ICPN were evaluated for their anthracnose reactions following injection-inoculation of both green and ripe fruit and drop-inoculation of ripe fruit. The entries were compared based on the percentage of inoculation sites at which lesions developed. Incidence of lesion development on injected green fruit ranged from 10 to 100% among lines. Tabasco and MC-003 at 10 and 25% lesion development, respectively, had significantly ($p \leq 0.05$) lower percentages of lesion development on green fruits than all other lines. None of the entries appeared resistant to ripe fruit injection-inoculation with entries ranging from 65 to 95% lesion development. Incidence of lesion development following drop-inoculation of ripe fruit ranged from 3 to 70% among entries; the lines with lowest incidence of lesion development were Tabasco and MC-003, which had 13 and 5%, respectively. These results are in agreement with field evaluations of the 6th ICPN entries made in 1996, which showed Tabasco and MC-003 to have the lowest incidence of infected fruits.

Table 16. Phytophthora blight reactions[a] of entries in the 7th ICPN

Entry	Name	Origin	Survival (%), 21 DAI
PBC 137	CNPH 703	Brazil	15
PBC 142	Pant C-1	India	0
PBC 534	Tumpang	Indonesia	33
PBC 091	New Mexico 6-4	USA	0
PBC 161	Kilinochi	Sri Lanka	4
PBC 369	PBC 369	Indonesia	38
PBC 386	PBC 386	Malaysia	0
PBC 390	PBC 390	AVRDC	0
PBC 482	B.L. 44	Sri Lanka	0
PBC 579	PBC 579	Sri Lanka	15
PBC 581	PBC 581	Malaysia	11
PBC 904	Kaswaswa	Tanzania	4
PBC 1474	Merah	Indonesia	0
PP 9656-01	Chan Man Kan No. 1-2-4	AVRDC	0
PP 9656-06	I-7-1 PeMV-Nic-1	AVRDC	0
PP 9656-08	Taiwan 83-168-1-1	AVRDC	58
PP 9656-11	Hybrid Huarena-3-2	AVRDC	8
PP 9656-13	PBC 521-2-1-1	AVRDC	0
PP 9656-14	PBC 549-3-2-1	AVRDC	0
PP 9656-15	73 KA11-1 9113825@	AVRDC	0
Blue Star, susc. ck.			0
PI 201234 res. ck			100

[a] 30-day-old plants were inoculated with 5 ml/plant of a 10^5 zoospore/ml suspension of isolate Pc-17E. Results based on four replications of six plants for each entry.

Field and laboratory anthracnose reactions of the 20 entries in the 7th ICPN were evaluated based on the mean percentage of infected fruit from two harvests. The plants in the field were inoculated with isolate *Cg*-153 of *C. gloeosporiodes* two weeks prior to the first harvest. The mean percentage of fruit in each line showing anthracnose symptoms at the time of the harvests ranged from 8 to 83% (Table 17). The incidence of infection in two lines, Kaswaswa and selection 83-168-1-1, at 8 and 12%, respectively, were significantly ($p < 0.05$) lower than all but one of the other lines. Laboratory evaluations of the fruits showed that none of the entries were resistant to injection inoculation at either the green or ripe stage. A reduced incidence of lesion development was observed, however, in both the green and ripe drop-inoculated fruits of 83-168-1-1.

Table 17. Incidence of anthracnose-affected pepper fruit among the 7th ICPN entries in a field trial at AVRDC during summer 1997

Entry	Name	Mean % fruit with anthracnose[b]
PBC 904	Kaswaswa	8 a[c]
PP 9656-08	83-168-1-1	12 ab
PBC 581	Malaysia	30 bc
PP 9656-11	Hyb. Huarena-3-2	33 cd
PP 9656-01	Chan Man Kan No. 1-2-4	41 c-e
PBC 369	Indonesia	42 c-e
PBC 091	New Mexico 6-4	44 c-e
PP 9656-14	PBC 549-3-2-1	50 c-f
PBC 161	Kilinochi	51 c-f
PBC 1474	Merah	52 c-g
PP 9656-13	PBC 521-2-1-1	52 c-g
PBC 137	CNPH 703	52 c-g
PP 9656-06	I-7-1 PeMV-Nic-1	54 d-h
PBC 390	AVRDC	56 d-h
PBC 142	Pant C-1	63 e-i
PBC 386	Malaysia	73 f-i
PP 9656-15	73 KA11-1 9113825@	75 g-i
PBC 579	Sri Lanka	76 hi
PBC 482	B. L. 44	80 i
PBC 534	Tumpang	83 i

[a] Transplanted to the field 23 June in a RCBD with four replications of 20 plants each; inoculated with isolate *Cg*-153 of *C. gloeosporiodes* on 30 September; harvests made on 14 and 28 October were the third and fourth harvests, respectively.

[b] The percentage of anthracnose-infected fruit from each pepper entry was estimated using (a) the percentage of culls showing anthracnose symptoms (based on inspection of individual fruit in a 100-fruit sample); (b) the number of cull fruit; and (c) the number of marketable fruit in each plot. Values are an average from two harvests.

[c] Means separation by DMRT, $p \leq 0.05$.

Broad mite resistance in chili pepper germplasm

Broad mite, *Polyphagotarsonemus latus* Banks, is a polyphagous pest that attacks chili pepper worldwide, especially in the dry season. Adults and nymphs feed on tender foliage, weakening the plant. The foliage becomes crinkled and withers away. At times, vegetative buds become atrophied and drop off or produce new growth, which delays harvest, if the new leaves remain free of mite damage. Since 1996, we have been screening AVRDC pepper germplasm for resistance to broad mites during the summer months. In 1997, we screened two batches of new germplasm and conducted one confirmatory test on selected germplasm identified as resistant in preliminary tests in 1996.

Preliminary single-replicate screening was done in two batches in an identical manner, with186 entries in the first, and 160 entries in the second. Seeds were sown in 7.5-cm diameter plastic pots containing a soil compost mixture. The plants were maintained for six weeks in a mite-free room and then were moved to a greenhouse room where broad-mite-infested chili pepper plants were maintained as an infestation source. When the mite population was high, we evaluated each plant for damage weekly for four weeks. Mite damage was rated on a scale of 0 to 5, where 0 = no damage and 5 = highest damage. The average damage rating from the four observations was subjected to a statistical test based on mean and standard deviation (sd) of mean damage of the entire population. Entries with damage ratings < mean – 2sd were considered highly resistant (HR); damage ratings of mean – 2sd to mean – 1sd were considered moderately resistant (MR); mean – 1sd to mean were considered as having low resistance (LR); mean to mean + 2sd were considered susceptible (S); and > mean + 2sd were considered highly susceptible (HS).

In the confirmatory screening, nine accessions selected from 1996 preliminary screening tests were evaluated with two susceptible entries in a multi-replicate test for resistance to broad mite. Standard procedures for growth and maintenance of plants, exposure to mites, and evaluation of mite damage were followed. In this test, each entry had at least three replicates, with six plants per replicate, arranged in RCBD. All entries were observed once, when mite populations were highest.

In the first 1997 preliminary screen, two entries, PBC725 and PBC901, were consistently least damaged and were ranked as HR in each of the four observations. Table 18 summarizes performance of these entries compared with a susceptible check. We consider PBC725 and PBC901 to be promising and will confirm their resistance in the summer of 1998 before recommending their use in breeding for resistance.

In the second preliminary screening, mite-resistance evaluation was carried out five times during the season. One entry, PBC1398, was ranked HR in the last two observations when the mite population was especially high (Table 19), and ranked MR in the first three observations. Another entry, PBC1482, was ranked MR in all five observations. These two entries appear to be promising sources of mite resistance. Resistance must be confirmed.

Of the nine entries found promising in 1996 preliminary tests, only one entry, PBC629, proved to be resistant in confirmatory screening. Broad mite population pressure was very high, and susceptible checks, as well as the putative resistant entries, were severely damaged. The resistance level of PBC629 is not adequate, and AVRDC needs to continue screening germplasm to find higher levels of resistance to broad mite.

Cotton aphid resistance in chili pepper

Cotton aphid, *Aphis gossypii* Glover, feeds on a wide range of economically important crops, such as cotton, soybean, eggplant, chili pepper, and others. The insect sucks plant juices, weakening the plant and stunting plant growth, which results in reduced yield. In 1996-97, AVRDC began screening pepper germplasm for resis-

Table 18. Broad mite damage to selected entries in first preliminary test, AVRDC greenhouse, 1997

Entries	Damage rating (DR) and resistance rating (RR)[a] on four observation dates							
	97/6/20		97/6/27		97/7/4		97/7/11	
	DR	RR	DR	RR	DR	RR	DR	RR
PBC725	0.00	HR	0.00	HR	0.75	HR	1.00	HR
PBC901	0.00	HR	0.00	HR	0.50	HR	1.67	HR
PBC777[b]	3.12	S	4.00	S	5.00	HS	5.00	HS

Sowing date: 2 May 1997.
[a] MR = moderately resistant, HR = highly resistant, S = susceptible, HS = highly susceptible.
[b] Susceptible.

Table 19. Broad mite damage to selected entries in second preliminary test, AVRDC greenhouse, 1997

Entries	Damage rating (DR) and resistance rating (RR)[a] in five observations									
	97/9/11		97/9/18		97/9/25		97/10/2		97/10/9	
	DR	RR	DR	RR	DR	RR	DR	RR	DR	RR
PBC1398	0.33	MR	1.00	MR	1.83	MR	1.83	HR	2.00	HR
PBC1482	0.33	MR	0.67	MR	2.00	MR	2.33	MR	2.50	MR
PBC1263[b]	1.67	S	3.00	HS	4.00	HS	4.00	S	4.00	S
Avg DR[c]	1.19±0.47		1.28±0.61		2.90±0.54		3.17±0.46		3.37±0.50	

[a] MR = moderately resistant, HR = highly resistant, S = susceptible, HS = highly susceptible.
[b] Susceptible.
[c] Average of 160 entries.

tance to this pest in order to identify sources of resistance.

In two preliminary resistance screening experiments, seeds of pepper germplasm accessions were sown in small plastic cartons containing a soil compost mixture with six plants per accession. Five-week-old seedlings were moved into a greenhouse in which a cotton aphid population was maintained on chili pepper plants. Starting four weeks after transfer of plants into the greenhouse, each plant was observed and the approximate number of aphids feeding on it was recorded. Each plant was categorized as having 0, 1-100, 101-1000, or >1000 aphids per plant. The weighted number-of-aphids data for each accession were subjected to a statistical analysis based on the mean number of aphids per plant for all entries included in the screening. A standard deviation scale, like the one used for mites, was used to classify their resistance reactions into highly resistant (HR), moderately resistant (MR), having low resistance (LR), susceptible (S), and highly susceptible (HS) categories.

In a confirmatory screening, seeds of four promising resistant entries from the preliminary screen, and one susceptible entry, were planted in plastic cartons. This test had six replicates of six plants each. At eight weeks after emergence, when aphid populations were highest, we observed the plants and recorded the number of aphids feeding on each. The mean-number-of-

Table 20. Cotton aphid infestation of selected pepper accessions in AVRDC greenhouse during spring 1997

Entry	Number of aphids per plant[1] and resistance rating[2] on						
	97/1/27	97/2/3	97/2/10	97/2/17	97/3/10	97/3/17	97/3/24
PBC726	20.25 LR	5.0 MR	5.0 MR	5.0 MR	7.07 MR	6.12 MR	6.12 LR
PBC732	20.62 LR	10.8 MR	5.77 MR	10.00 MR	6.45 MR	5.77 MR	5.00 LR
PBC785	11.18 MR	14.14 MR	13.84 MR	16.06 MR	7.07 MR	7.07 MR	7.07 LR
PBC681	13.54 LR	10.8 MR	16.33 MR	13.53 MR	14.14 LR	11.18 LR	7.07 LR
PBC897[3]	35.36 S	44.72 S	59.16 S	70.71 S	44.72 HS	22.36 S	22.36 HS

[1] Weighted mean number of aphids per plant. Each entry had 6 plants.
[2] MR = moderate resistance, LR = Low resistance, S = susceptible. HS = Highly susceptible.
[3] Susceptible entry.

Table 21. Cotton aphid infestation of selected pepper accessions in AVRDC greenhouse during spring 1997

Entry	Number of aphids per plant[1] and resistance rating[2] on					
	97/2/17	97/2/24	97/3/3	97/3/10	97/3/17	97/3/24
PBC880	5.00 MR	4.08 MR	7.07 MR	7.07 MR	7.07MR	7.07 LR
PBC100[3]	20.62 HS	44.72 S	70.71 S	65.19 HS	65.19 HS	70.71 HS

[1] Weighted mean number of aphids per plant. Each entry had 6 plants.
[2] MR = moderate resistance, LR = Low resistance, S = susceptible, HS = Highly susceptible.

Table 22. Performance of selected pepper accessions for resistance to cotton aphid in AVRDC greenhouse during spring 1997

	Mean number of aphids/plant on		
Entry	97/3/10	97/3/18	97/3/24
PBC18	99.50 ± 33.75	89.83 ± 56.75	19.00 ± 17.80
PBC30	202.80 ± 40.42	137.83 ± 52.56	19.83 ± 15.18
PBC151	446.80 ± 279.35	256.17 ± 119.17	123.00 ± 81.80
PBC84	1145.30 ± 394.02	110.67 ± 31.83	49.00 ± 51.88
CCA316[a]	2626.70 ± 1015.54	1045.33 ± 278.33	221.50 ± 80.71
LSD	655.80	183.68	77.23

[a]Susceptible check.

aphids data for each entry were analyzed by ANOVA and means were compared by least significant difference (LSD).

In the first preliminary resistance screening, none of the entries escaped from aphid infestation. Four entries (PBC681, PBC726, PBC732, and PBC785), were consistently less damaged than others in all six observations. Performance of these accessions compared to selected susceptible entries is shown in Table 20. Entries PBC681 and PBC785 are *C. baccatum*. The remaining three entries and the susceptible entries are all *C. annuum*.

In the second preliminary resistance screening, among 36 entries tested, one entry, PBC880, was least damaged in each of the six observations. Its performance in relation to a susceptible check is summarized in Table 21. Entry PBC880, a *C. baccatum* accession, represents a putative source of resistance to cotton aphid. We will study its resistance mechanism in winter-spring 1997-98 before recommending it for aphid resistance breeding.

Results of the second confirmatory screening experiment are summarized in Table 22. All four resistant entries were always significantly less damaged than the susceptible check, CCA316. Accession PBC18 was always the least damaged, followed by PBC30. Infestation of PBC84 and PBC151 varied between three observation dates. The aphids per 10 cm^2 leaf area were counted during the final observation; PBC18 had 1.76 ± 1.46 aphids, PBC30 had 7.11 ± 8.57, PBC151 had 7.59 ± 13.53, PBC84 had 5.20 ± 5.52 and the susceptible check had 11.13 ± 3.68 aphids. PBC18 represents a reliable source of resistance. We will study its resistance mechanism to determine its suitability for breeding cotton aphid resistant pepper varieties.

Tomato Improvement

The general objective of the tomato improvement project is to increase year-round tomato supply in tropical countries, focusing on development of tomato lines adapted to high temperatures and humidities. Consequently, high-temperature fruit set, bacterial wilt (BW), fusarium wilt (FW), and gemini virus resistance, as well as good fruit quality are major specific objectives.

We have made progress in developing fresh market and cherry tomato inbred lines combining heat tolerance and BW resistance with improved fruit quality. New sets of determinate inbred lines and cherry tomato lines have been selected for international distribution.

Research to map tomato yellow leaf curl virus (TYLCV) resistance genes in H24, a highly resistant tomato line from India, was initiated. Restriction fragment length polymorphism (RFLP) probing of H24 revealed *L. hirsutum* introgressions on chromosomes 8 and 11, which might condition resistance. F_3 families carrying single or multiple introgressions in homozygous or heterozygous states were developed to confirm which introgressions are necessary for resistance. Potato virus Y (PVY)-resistant tomato lines with resistance derived from *L. hirsutum* have been multiplied and are available for distribution.

Progress toward transformation with the N-protein gene for watermelon silver mosaic virus (WSMV) resistance has been achieved. A chitinase gene under the control of the CaMV 35S promoter was introduced into tomato lines of L4783 by agrobacterium transformation. Field testing of tomato lines transformed with the coat protein gene from cucumber mosaic virus (CMV) strain T were evaluated for CMV reaction in a transgenic containment field.

Late blight (LB)-resistant *L. pimpinellifolium* accessions, L3707 and L3708, and *L. hirsutum* accessions, L3683 and L3684, were resistant in field tests conducted in Malawi, Tanzania, Nepal, Taiwan, and the USA for most or all trials. The *L. hirsutum* accessions showed resistance at all locations while resistance in the *L. pimpinellifolium* accessions broke down toward the end of the season in Taiwan and Nepal, and a new LB tomato race (T2) was isolated from L3708 plants in Taiwan. Tomato inbred lines with LB resistance derived from L3708 are available for international distribution.

Studies on the mechanisms of BW resistance indicated that resistance is not expressed in the roots, but occurs in the movement of the pathogen from the root to the stem base and pathogen multiplication in the stem. Bacterial wilt infection of two resistant tomato lines did not significantly affect yield. The population structure of the BW pathogen was studied in Taiwan tomato production fields and a field station disease nursery using two polymerase chain reaction (PCR)-based methods. Large pathogen strain genetic diversity was found, and in the disease nursery, host genotype and microenvironment were important factors in population differentiation. Eight tomato varieties differing in resistance levels were inoculated with six pathogen strains in one greenhouse and two field trials. Pathogen strains could be grouped into three aggressiveness groups, and four host resistance levels were detected. The pathogen-host interaction was environment dependent.

Genetic resources enhancement and varietal improvement

Genetic resources activities

Thirty-nine accessions of five species from 12 countries were regenerated inside net cages in 1996-97. Characterization was done based on a standard set of descriptors. Samples of fruits were sent to the Center's analytical laboratory for analysis of betacarotene, pH, and sugar.

A total of 204 accessions were added to the tomato germplasm collection, bringing the total to 7148 accessions (Table 1).

The cultivars (*L. esculentum*) varied in fruit size. Exterior color of the mature fruit ranged from yellow to orange to red. Variation in fruit shape was also noted. Lowest pH (3.95) was observed in TL1475 and highest (4.43) in TL1544. The former was Hawaii 7997, a round, 4.9 × 5.6 cm (l × w), red-fruited variety resistant to BW. The latter was Centennial, also known as West Virginia '63 (W. VA '63), a red-fruited, round-to-slightly-flattened, 4.9 × 6 cm, variety that carries the *Ph-2* gene for resistance to LB. Among the accessions planted, it also took the longest to flower (79 days from sowing). Highest betacarotene (4.48 mg/100gm) was observed in TL1568 Beta alcobaca, an orange-fruited variety with dark green back, 5.7 × 7.9 cm in size, and carrying the genes for long shelf life *dgdg, alcalc*.

Table 1. The tomato germplasm collection at AVRDC, 1997

	No. of accessions	
Species	Total	Acquired in 1997
L. esculentum	5254	204
L. pimpinellifolium	309	
L. peruvianum	126	
L. hirsutum	65	
L. pennellii	60	
L. chilense	30	
L. cheesmanii	27	
L. parviflorum	12	
L. glandulosum	11	
L. chemielewskii	11	
L. sp	1243	
Total	7148	204

Of the 3821 seed packets distributed, 2795 (73%) went to 57 countries, 905 (24%) to the Center's regional programs, and 121 (3%) to Center scientists for BW resistance screening (Table 2).

Genetic improvement of fresh market tomato

Activities at AVRDC to improve fresh market tomato encompass a wide range of objectives, including development of inbred lines targeted for production in the hot humid tropics and identification of large-fruited, dark-green shouldered tomato hybrids for the Taiwan market. In 1997 we carried out one advanced yield trial (AYT) and two preliminary yield trials (PYT) of fresh market tomato entries. The objective of the AYT was to select the best heat-tolerant entries for international distribution. The first preliminary yield trial (PYT 1) included F_1 entries and the objective was to identify crosses with potential to generate heat-tolerant and BW-

Table 2. Recipients of tomato AVRDC germplasm, 1997

Recipient	No. of samples	
External		2795
India	284	
Ghana	243	
Vietnam	160	
Philippines	158	
Sri Lanka	152	
Bangladesh	139	
Japan	112	
Pakistan	101	
Cambodia	91	
Thailand	87	
Others[1]	1268	
ARC		787
ARP		118
Headquarter		121
Bacteriology	121	
Total		3821

[1] Australia, Barbados, Bhutan, Brazil, Burma, China, Congo, Costa Rica, Ethiopia, France, Gabon, Germany, Guinea, Guinea-Bissau,Haiti, Honduras, Hong Kong, Hungary, Indonesia, Israel, Ivory Coast, Korea, Lao PDR, Liberia, Malawi, Malaysia, Martinique, Mauritius, Mozambique, Namibia, Nepal, Netherlands, Oman, Panama, Papua New Guinea, Senegal, Spain, Sudan, Taiwan, Tanzania, Thailand, Togo, Tonga, USA, Zaire and Zimbabwe

resistant lines. The second preliminary trial (PYT 2) was established to evaluate promising hybrids for the Taiwan market.

The AYT and PYT 1 were sown 5 June and 25 June, respectively, and transplanted 2 July and 29 July. Preliminary Yield Trial 2 was sown 4 March 1997, transplanted 8 April and harvested during 11-29 June. Preliminary Yield Trial 2 plots consisted of a single 1.5-m bed with two 4.8-m-long rows per bed. Between- and within-row spacings were 60 and 40 cm, respectively. Plot size and spacings for the AYT and PYT 1 were the same as for PYT 2, except that the AYT plots had two beds with one row per bed, and the PYT 1 plot included one row per bed. Entries in the AYT and PYT were replicated three and two times, respectively. (Results are summarized in Table 3.)

AYT. High temperatures and high rainfall prevailed during the trial, which depressed fruit set percent and consequently yield. Mean maximum/minimum temperatures during the main fruit-set period were 31.2/23.6°C and total rainfall was 1079 mm, including two periods of severe flooding. Marketable fruit yields ranged from 5.6-27.3 t/ha and the average yield of all entries was 20.4 t/ha. Nevertheless, four entries, CLN1811A, CLN1621F, CLN1621H, and CLN1621C, significantly out-yielded heat-tolerant check, CL5915-93D4-1-0-3, and also demonstrated high levels of BW resistance in a separate greenhouse trial. Fruit acidity of certain entries, notably CLN1811A and CLN1621H, was high. As a consequence, these entries have a sour taste, a characteristic appreciated in South Asia. High temperatures tend to reduce fruit size as well as fruit set. Consequently, fruit sizes ranged from medium to small. During the regular season, average fruit sizes increase 50% or more. Based on these data, entries CLN1621E, CLN1621C, and CLN1621F will be included among entries in our determinate set for international distribution.

PYT 1. Like the AYT, high temperatures and heavy rainfall resulted in lower fruit set and yield. In addition, BW infection reduced plant stands of certain entries, particularly the check line CL5915. Marketable yields of entries ranged from 2.5-25.8 t/ha and the trial mean was 14.2 t/ha. Five populations, CLN2327, CLN2294, CLN2293, CLN2323, and CLN2337, demonstrated relatively high yields, excellent vigor, medium-large to large fruit size, and good fruit quality. These crosses will be selfed to obtain inbred lines.

PYT 2. Marketable yields of hybrid tomato entries in PYT 2 ranged from 18.9 to 75.9 t/ha and the mean yield of all entries was 46.0 t/ha. The check variety, FMTT22, significantly out-yielded the other trial entries and achieved a brix content similar to other entries. However, entries FMTT698 and FMTT702 surpassed FMTT22 in the quality of the dark green shoulder, fruit firmness, and smoothness. They merit further evaluation.

Genetic improvement of cherry tomato

The tomato improvement project has developed cherry tomato lines showing superior yield and fruit quality, but lacking BW resistance. Such resistance is necessary for widespread production in the tropics. Consequently, incorporation of BW resistance into our cherry tomato lines is a major objective of our breeding program. Two cherry tomato observational trials (OT) were conducted at AVRDC in 1996-1997. Observational Trial 1 included F_1 hybrids. The objective was to identify high-yielding, BW-resistant crosses with the potential to produce superior inbreds. Entries in the second observational trial were inbred lines and the objective was to select high-yielding lines for additional testing and possible international distribution.

Observational Trials 1 and 2 were sown on 17 December 1996 and 21 January 1997, respectively, and transplanted to the field on 23 January and 28 February 1997. Observational Trial 1 was harvested during 27 March - 15 May 1997 and OT 2 was harvested during 14 May -25 June 1997. Plots consisted of two 4.8-m-long rows on a single raised bed. Spacing between beds was 1.5 m; between- and within-row spacings were 60 cm and 40 cm, respectively. Entries were not replicated.

Total yields and marketable yields in OT 1 ranged from 82-46 t/ha and 67-35 t/ha, respectively (Table 4). Fruit cracking was the major cause of unmarketability. Several crosses, such as CHT1081 and CHT1074, yielded almost twice as much marketable fruit as the check, CH154. However, it appears that higher yields were achieved at the expense of lower brix contents. Higher brix content is important because it has been associated with good taste. Bacterial wilt percent survival of the entries ranged from 0 to 94%. Entries

Table 3. Yield and other horticultural characteristics of tomato entries in the Advanced/Preliminary Yield Trials at AVRDC, 1997

Entry	My (t/ha)	Fruit Set (%)	Fruit Size (g)	Brix (%)	Acid (%)	Color (a/b)	pH	BW (%)
AYT								
CLN1811A	27.3	10	28	5.3	0.55	1.64	4.08	92
CLN1621F	25.9	11	37	5.1	0.51	1.65	4.14	83
CLN1621H	25.4	18	48	5.3	0.56	1.71	4.06	85
CLN1621C	24.9	18	27	5.2	0.55	1.94	4.11	92
CLN1621I	22.2	12	27	5.5	0.50	1.71	4.16	96
CLN1621L	21.2	15	24	5.7	0.50	1.78	4.19	83
CLN1621J	20.9	11	23	5.4	0.54	1.63	4.08	89
CLN1621P	20.7	18	26	5.7	0.53	1.76	4.18	85
CL5915-93D4-1-0-3 (ck)	17.8	13	28	5.6	0.54	1.60	4.15	29
Mean of all entries	20.4	16	28	5.46	0.50	1.65	4.15	83
CV%	17.9	21	9	4.64	7.17	6.30	0.62	10
LSD (p=0.05)	6.1	6	4.41	0.42	0.06	0.17	0.04	23
PYTI								
CLN2327	25.8	28	42	5.10	0.41	1.50	4.13	92
CLN2294	25.6	30	62	5.45	0.48	1.21	4.07	98
CLN2293	25.6	45	66	5.85	0.52	1.39	4.09	93
CLN2323	24.7	25	32	5.30	0.49	1.61	4.11	94
CLN2337	23.8	24	54	5.25	0.46	1.83	4.16	87
CLN2292	20.7	26	71	5.60	0.47	1.42	4.09	100
CLN2326	19.6	25	36	5.25	0.46	1.47	4.14	81
CL5915-93D4-1-0-3 (ck)	2.5	25	18	5.20	0.52	1.28	4.16	29
Means of all entries	14.2	27	41	5.51	0.45	1.44	4.12	87.0
CV%	28.0	21	17	8.20	10.50	13.80	0.84	11.0
LSD (p=0.05)	10.7	15	19	1.21	0.12	0.53	0.09	26.0
PYTII								
FMTT698	55.5	35	141	4.50	0.35	1.43	4.19	22
FMTT699	51.2	35	143	4.45	0.38	1.17	4.12	24
FMTT702	50.9	32	153	4.55	0.32	1.51	4.20	24
KY301(ck)	18.9	25	121	5.35	0.41	1.83	4.28	15
FMTT22 (ck)	75.9	40	140	4.60	0.37	1.48	4.18	19
FMTT553 (ck)	53.7	36	119	4.85	0.41	1.73	4.19	19
Mean of all entries	46.0	31	150	4.65	0.36	1.50	4.19	23
CV%	12.0	15	12	3.80	9.5	11.20	1.30	23
LSD (P=0.05)	11.9	10	40	0.38	0.07	0.36	0.11	12

AYT=Advanced yield trial; PYT=Preliminary yield trial

CHT1093, CHT1064, and CHT1084 showed survival of 80% or greater, although yields of CHT1064 and CHT1084 were low. CHT1093 might have the greatest potential to produce BW-resistant inbreds with good yield and brix contents.

Marketable yields of entries in the second observational trial were also high, ranging from 44 to 70 t/ha. Brix contents ranged from 4.2 to 6.8, and most entries achieved brix values of 5.0-5.5. The BW reactions of most entries fell below 50% survival, but, nevertheless, were superior to CH154, which had 0% survival. Entries CLN1555A, CLN1555B, and CLN1555C merit further consideration for international distribution because they demonstrate both adequate yields and BW resistance.

Studies on leaf curl virus

TYLCV has long been considered a major threat to tomato production in the Near East, South Asia, Central and South America, and parts of Southeast Asia. The disease has, therefore, been accorded high priority at AVRDC headquarters, as well as in its regional programs and in some research networks the Center facilitates. Host-plant resistance/tolerance combined with vector control is considered to give the best disease control. In order to develop stable and effective resistance, knowledge of the different geminiviruses causing TYLCV is essential. The objectives of this activity were (1) to characterize the different tomato geminiviruses, (2) to assist the networks and regional programs to set up and conduct effective TYLCV resistance screening, and (3) to identify sources of resistance.

Host range studies of TYLCV-TWN (the Taiwan strain) were done by continuous exposure of three-week-old seedlings to viruliferous whiteflies, followed by symptom recording, and nucleic acid hybridization tests up to approximately 80 days after exposure. Two melon cultivars, Cucumis melo 'Sky Rocket' and VC 472, and the following weed species were tested by the above method: *Ageratum houstonianum*, *Bidens pilosa*, *Celosia argentea*, *Amaranthus spinosus*, *A. mangostanus*, *Solanum indicum*, *S. incanum*, *S. nigrum*, *Physalis angulata*, and *Datura stramonium*. Another 14 weed species growing inside or on the borders of an AVRDC tomato field where TYLCV infection was

Table 4. Yield and other horticultural characteristics of cherry tomato in observational trials I and II at AVRDC, spring 1997

Entry	My (t/ha)	Fruit set (%)	Fruit size (g)	Brix (%)	Acid (%)	Color (a/b)	pH	BW[a] (%)
OTI								
CHT1081	67	65	26	4.6	0.43	1.62	4.09	20
CHT1074	67	77	23	3.8	0.35	1.34	4.05	44
CHT1067	64	71	21	4.3	0.38	1.56	4.09	53
CHT1060	64	79	21	3.9	0.40	1.22	4.04	56
CHT1093	47	80	28	5.1	0.35	1.69	4.04	80
CHT1064	29	87	21	44	0.37	1.74	4.09	81
CHT1084	18	24	26	4.9	0.39	1.59	4.09	94
CH154 (ck)	35	58	11	6.2	0.35	1.34	4.13	0
OTII								
CLN1561C	70	89	28	4.8	0.24	1.73	4.46	29
CLN1555C	60	74	54	5.1	0.33	1.73	4.46	44
CLN1561F	49	79	36	6.1	0.33	2.10	4.37	16
CLN1555A	49	64	40	5.2	0.38	1.66	4.40	60
CLN1558B	49	80	20	4.2	0.38	1.78	4.36	22
CLN1555B	48	56	50	5.4	0.33	1.59	4.36	63
CH154 (ck)	47	78	13	6.8	0.28	1.45	4.42	0

[a] Percentage of healthy plants four weeks after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial.

100% were tested by DNA hybridization. These weed species were: *Amaranthus spinosus* L., *Oxalis corniculata* L., *Euphorbia hirta* L., *Bidens pilosa* L., *Polygonum convolvulus* L., *Cynodon dactylon* Pers., *Artemisia princeps* Pamp., *Portulaca oleracea* L., *Ipomoea gracilis* R. Br., *Ageratum houstonianum* Mill., *Cardiospermum halicacabum* L., *Solanum nigrum* L., *Digitaria milanjian* Rendle, and *Echinochloa colona* (L.) Link.

Support of the research networks generally comprised the testing of samples by nucleic acid hybridization, the supply of resistant materials for multilocation testing, characterization of local TYLCVs by differential probing or by PCR, and cloning of the PCR fragments followed by sequencing and sequence comparisons with known tomato-infecting geminiviruses.

Characterization of a new tomato leaf curl virus from the Philippines

Fresh leaf samples, supplied by the University of Los Baños, failed to react with nucleic acid probes against Asian tomato infection geminiviruses. A 1.5-kb band was obtained by PCR which was cloned and sequenced. Pairwise comparisons of the AC1 (692 nt), the IR (173 nt), the precoat protein (357 nt) and the coat protein (251 nt) ORFs with the eight distinct subgroup III tomato-infecting geminiviruses showed only low nucleotide identities of <83%, <67%, <64%, and <75%, respectively (Table 5). Since isolates of the same geminivirus usually have nucleotide sequence identities of >90%, this Philippine tomato geminivirus is considered different from the above mentioned geminiviruses and most likely represents a new geminivirus.

Host range of TYLCV-TWN

Of the 11 weed species tested by exposure to viruliferous whiteflies in the screenhouse, only one, *Datura stramonium*, showed symptoms (vein clearing) and gave positive symptoms in hybridization tests using a DIG-labeled probe against the Taiwan tomato yellow leaf curl virus (TYLCV-TWN). Furthermore, none of the 14 weed species collected from the AVRDC field grown to tomato with 100% TYLCV-TWN infection incidence gave a positive signal in DNA hybridization tests. This further confirms the very narrow host range of TYLCV-TWN. So far, besides *Datura* and the previously found susceptible *Ageratum* sp., no other weed species seems to harbor TYLCV-TWN.

Surveys for tomato yellow leaf curl virus

Based on our results using different probes, our cooperators in Bangalore are dealing with at least two different tomato geminiviruses, i.e., TYLCV-Ban 1 and TYLCV-Ban 2. The leaf curl virus from Sri Lanka appears to be identical, or at least very closely related to one of the leaf curl viruses in Southern India, TYLCV Ban-2, based on preliminary sequencing of the CP re-

Table. 5 Nucleotide sequence homology (%) for pairwise comparisons

Virus	Rep ORF (ntl-nt692)	Common region (nt693-nt965)	Pre coat (nt966-nt1322)	Coat protein (nt1126-nt1377)
TYLCV-Isr	78	56	64	74
TYLCV-Sar	78	55	64	75
TLCV-Aus	83	59	62	69
TYLCV-Thai	75	58	60	68
TLCV-India II	77	63	62	66
TLCV-India III	73	56	60	63
Indian TLCV	76	55	61	63
Sri Lanka	77	67	59	70

gion of a Sri Lanka clone obtained by PCR. Survey results are shown in Table 6.

Development of multivirus resistant tomato

Cucumber mosaic virus, TYLCV, PVY, and WSMV are major diseases of tomato in the tropics and subtropics. There is no resistance to these viruses, singly or combined, in horticulturally acceptable tomato lines. Resistances to the first three viruses have been found in a few wild tomato species, such as *L. hirsutum* and *L. chilense*. The objectives of the project were to introgress resistance genes for TYLCV and CMV from wild tomato into cultivated tomato (*L. esculentum*) and to identify molecular markers linked with resistance genes. Agrotransformation with the N-protein gene was chosen for WSMV because host plant resistance was not available. Incorporation of the inserted gene in agrotransformed plants, and later in segregating populations in multivirus-resistant crosses, will be monitored by the use of primers flanking the inserted gene.

For RFLP probing, the protocol described by Bernatzky and Tanksley, 1986, was followed. DNA was extracted from bulked leaflets of 30-day-old plants and digested with restriction enzymes. The filters were then probed with RFLP markers previously found to be linked to wild species introgressions. In the case of TYLCV, 250 plants from the cross CL5915 (susc.) × H24 (res.) were probed using 15 replicate filters and 90 RFLP markers.

Virus inoculations were done by two mechanical inoculations (for CMV, PVY, WSMV) or by exposure to viruliferous whiteflies (TYLCV). Infectivity ratings for TYLCV were by nucleic acid hybridization (squash blots) using a digoxygenin-labeled probe of TYLCV-TWN. Enzyme-linked immunosorbent assay (ELISA) was used for the other viruses.

PCR for monitoring the insertion of the WSMV-N-protein gene was done from total genomic DNA ex-

Table. 6 Leaf curl virus survey of tomato and peppers, Asia, 1997

Country	Crop[1]	No. of samples tested	No. of samples positive	Probe[2]/Primer[3]
Bangladesh	T (12), P, MB, B	18	12	PCR
India	T	1	0	PCR
	P	12	0	PCR
	T	22	6 (I-B1)	I-B1, I-B3, Th
	T	46	4 (I-B1)	I-B1
	T	45	3 (I-B1)	I-B1, I-B3
	T	90	0	I-B1, Th
	P	182	9 (Sri Lanka)	I-B1, Sri Lanka
	T	343	21 (I-B1) 49 (Sri Lanka)	I-B1, Sri Lanka
Indonesia	T	4	0	PCR
	T	14	0	PCR
	T, P	6	0	PCR
Malaysia	T (2), P (1), A (1)	4	4	PCR
Nepal	T	20	0	I-B1, Th
Sri Lanka	T	17	3	PCR

[1] T = tomato, P = pepper, W = weed, MB = mungbean, B = Brinjal, A = Ageratum sp.

[2] Probes used for hybridization:
digoxigenin labelled probes I-B1 = TLCV-India, Bangalore I (AVRDC 16i); I-B3 = TLCV-India, Banglore III; Sri Lanka = TYLCV from Sri Lanka (very closely related, if not identical to TLCV-India, TLCV-Ban-2, described by Hong & Harrison, 1995.
Th = TYLCV-Thailand; the probes were used independently.

[3] Primer used for PCR in all cases AC1v1978/AV1c715.

tracted from three-month-old plants. Twenty plants of each line were tested (Table 7).

TYLCV. Research was initiated to map TYLCV resistance in H 24, a highly resistant line from India. TYLCV resistance in this line originated from *L. hirsutum*. RFLP probing of H 24 revealed *L. hirsutum* introgressions on chromosomes 8 and 11 which might condition TYLCV resistance. F_2 plants carrying single or multiple introgressions in homozygous or heterozygous conditions were identified by RFLP probing and transplanted to the field to produce F_3 lines.

CMV. Seventeen BC_1F_1 populations derived from *L. hirsutum* were tested for CMV by three mechanical inoculations using two local virus isolates and ELISA to identify resistant plants. A total of 177 ELISA-negative plants were transplanted to a net house and 50 BC_1F_1 plants were selected based on fruit and horticultural characteristics similar to *L. esculentum*.

PVY: Four RFLP markers, TG 499 (chrom 7), CT 16, CT 234, and CT 11 (chrom. 10), were found associated with *L. hirsutum* introgressions in *L. esculentum* (CLN808) which might condition PVY resistance. F_2 plants from the cross CLN808 (R) × CL5915 (S) were probed to identify plants with single or multiple introgressions.

WSMV. Resistance in seven R_2 lines derived from N-protein transformed R_1 of L4783-12 ranged from 50 to 93%. PCR of plants of the line with 93% resistance showed that all had a 0.7-kb insert, corresponding to the WSMV-N-protein gene. This line appears to be homozygous for the inserted gene. However, more R_2 plants will need to be tested to confirm this.

Table 7. ELISA and PCR of WSMV inoculated N-protein gene agrotransformed R_2 families

R_2 family	No. of symptomatic, ELISA-positive plants/total no. inoculated plants		PCR positive[2]/ no. Tested
L 4783-12-11-1	10/20	(50)[1]	
L 4783-12-11-3	2/21	(91)	17/21
L 4783-12-11-5	4/19	(79)	
L 4783-12-11-6	1/15	(93)	15/15
L 4783-12-11-7	10/21	(52)	
L 4783-12-11-8	10/21	(52)	
L 4783-12-11-10	2/22	(91)	17/22
L 4783 untransformed	9/22	(59)	0/22
Songchi (susc. ck.)	16/19	(16)	

[1] % resistant plants.
[2] PCR-positive: 0.7-kb insert of WSMV-N-protein gene is present.

Characterization of tomato CLN1639 F_7 recombinant inbred lines to verify heat tolerance for the identification of molecular markers linked to heat tolerance

The identification of molecular markers related to heat tolerance will be useful in the development of heat-tolerant tomatoes. Identification of RAPD markers related to heat tolerance was previously carried out with the bulked F_2 segregating population which was derived from the cross of heat-resistant CL5915-206 and heat-sensitive L4422. There was no marker co-segregated with the heat-tolerant trait after a total of 849 primers were tested. This might be due to high degrees of heterozygosity in the F_2 population.

The recombinant inbred line (RIL) is considered a better source of homozygosity after certain generations of selfing. The objective of this activity was to investigate the traits related to fruit setting and yield of CLN1639 F_7 RILs at high temperature for the development of molecular markers pertaining to heat tolerance.

Recombinant inbred lines, CLN1639 F_6, derived from the cross between CL5915-93 and L4422, were provided by the tomato breeding unit. Eighteen and 16 RILs recorded as heat-tolerant and susceptible, respectively, in the summer of 1996, were advanced to F_7 and investigated for yield performance in December of 1996. Six F_7 seedlings from each RIL, a total of 204 plants, were planted in a greenhouse in May of 1997 and scored from July to September for fruit setting, fruit weight, seed number, fruit yield, and fruit shape. Five clusters of each plant, from the second to the sixth cluster, were scored. Average day/night temperatures for July, August, and September were 34.5/23.7, 32.1/23.9, and 31.0/22.4 °C, respectively.

Various degrees of heterozygosity still existed in most of F_7 RILs as indicated by data collected for investigated traits among six individuals within each RIL. The variation within each RIL for the scored traits, such as fruit-setting rate, number of seeds per fruit, and yield, was still significant. Twelve heat-tolerant individuals were selected based on yield and fruit set ratio in the summer season (Table 8). It was also observed that the F_7 generation of CL5915-93 was still segregating and some RILs from the crosses between CL5915-93 and L4422 performed even better on fruit setting and yield, but not good for fruit size compared to the heat-tolerant parent CL5915-93 during summer. To develop molecular markers related to heat tolerance, 12 heat-sensitive individuals whose performance in the winter season was comparable to that of 12 selected heat-tolerant RILs in terms of yield, fruit set, and fruit size were selected. These materials are being advanced for identification of molecular markers related to heat tolerance.

Resistance evaluation of transgenic tomatoes and transformation for resistance to cucumber mosaic virus

Cucumber mosaic virus affects various important crop species. There are many strains of CMV and it has been estimated that at least 775 plant species, representing 85 families, are natural hosts of this virus. Transgenic tomatoes with the coat protein gene of CMV have been obtained, but their CMV-resistance levels have not been completely determined. The objectives

Table 8. Heat-tolerant F_7 RILs, heat-tolerant plants selected to advance F_8

Plant	Flower no.	Fruit no.	Fruit-set (%)	Seed no.	Seed no./fruit	Yield (g)	Fruit weight (g)	Max fruit weight.	Shape
31-1-6	77	23	31	540	23.9	98	4.2	8.2	2
31-2-6	81	42	51	771	19.2	120	2.8	5.2	2
44-3-4	33	25	82	528	22.3	111	4.6	4.9	2
53-3-4	66	45	81	1017	22.0	297	6.9	13.0	2
53-3-5	85	58	70	261	4.2	121	2.1	7.4	2
54-2-5	140	33	33	212	6.7	124	3.7	6.0	2
66-1-3	46	41	90	96	2.6	92	2.3	9.5	2
94-1-3	90	37	41	158	4.2	172	4.6	9.8	4
100-2-6	50	24	61	424	16.1	450	18.5	25.0	3
148-2-6	57	19	47	113	5.2	192	10.5	17.4	2
154-1-2	34	21	60	228	11.4	254	12.3	15.0	3
172-1-2	33	12	31	309	15.1	186	9.2	23.0	2
5915-93-1	73	11	13	234	16.1	257	18.1	37.5	3
5915-93-2	42	4	10	20	4.0	47	8.9	27.6	3
5915-93-3	47	13	32	210	14.9	251	17.0	26.4	3
5915-93-4	43	12	23	11	1.5	83	4.0	15.0	3
5915-93-5	51	20	35	41	1.3	177	7.2	28.0	3
5915-93-6	33	19	54	135	6.0	254	12.3	29.3	3
4422-1	31	0	0	0	0.0	0	0.0	0.0	0
4422-2	21	0	0	0	0.0	0	0.0	0.0	0
4422-3	42	1	4	0	0.0	1	0.2	0.9	2
4422-4	61	0	0	0	0.0	0	0.0	0.0	0
4422-5	69	0	0	0	0.0	0	0.0	0.0	0
4422-6	43	0	0	0	0.0	0	0.0	0.0	0

Flower no.: Total flower number from cluster two to six
Fruit no.: Total fruit number from cluster two to six
Fruit set: Average fruit set
Seed no.: Total fruit number from cluster two to six
Seed no./fruit: Average seed number per fruit
Yield: Total fruit weight from cluster two to six
Fruit weight: Average fruit weight per fruit
Max. fruit weight: Maximal fruit weight
Shape: The tendency of the fruit shape from 1 to 5 (1 = oblate, flat; 2 = globose, round; 3 = ovate, egg; 4 = square; 5 = pear; 0 = no fruit)

of this project were to evaluate the CMV resistance of transgenic tomatoes and to transform new tomato varieties with the CMV coat protein gene.

The transgenic R_1 tomatoes of variety L4783 used in this study were from 16 primary transformants previously generated through agrobacterium-mediated transformation with the coat protein gene of CMV strain T. Transgenic and control nontransgenic plants of variety L4783, as well as TK70, which shows typical CMV disease symptoms after infection, were used for the evaluation of resistance to CMV by CMV strain Peet's, NT9, and T, and by various combinations of the three virus strains. Greenhouse seedlings with four fully expanded leaves were dusted with corundum and rubbed with CMV dilution of tissue extracts from CMV-infected tobacco. CMV disease symptoms were recorded and ELISA was conducted to detect the presence and multiplication of CMV with antibody specific to CMV.

Efforts have also been initiated to transform CLN1462A, CLN1466D, CLN1558A, and PT4674C for CMV resistance following the previously described protocol with minor modifications to the regeneration method. Various concentration combinations of indole-3-acetic acid (IAA) and 6-benzylaminopurine (BAP) were evaluated for the regeneration of four tomato varieties.

R_1 seedlings (from 16 primary transformants [R_0]) with four fully expanded leaves were inoculated with CMV strain Peet's and NT9 in a greenhouse. Evaluation showed that having the coat protein gene of CMV strain T improved the transgenic seedlings' resistance to CMV infection (Table 9). The expression of CMV symptoms in transgenic progenies was delayed, and the

Table 9. Resistance evaluation of R_1 tomato seedlings derived from primary transformants containing the coat protein gene of cucumber mosaic virus (CMV) strain T by ELISA test and visual observation after inoculation with a mixture of CMV strain Peet's and NT9

	Days after initial CMV inoculation[z]		
Plant	30	60	90
Control			
L4783	48 / 52 (92)[y]	52 / 52 (100)	52 / 52 (100)
TK70	56 / 56 (100)	56 / 56 (100)	56 / 56 (100)
Transgenic			
CPT1	0 / 57 (0)	22 / 57 (39)	53 / 57 (93)
CPT3	2 / 52 (4)	26 / 52 (50)	47 / 52 (90)
CPT4	2 / 54 (4)	24 / 54 (44)	52 / 54 (96)
CPT5	11 / 55 (20)	30 / 55 (55)	54 / 55 (98)
CPT6	19 / 56 (34)	35 / 56 (63)	56 / 56 (100)
CPT7	20 / 60 (33)	53 / 60 (88)	59 / 60 (98)
CPT8	41 / 55 (75)	47 / 55 (85)	55 / 55 (100)
CPT9	35 / 49 (71)	38 / 49 (78)	49 / 49 (100)
CPT10	45 / 50 (90)	47 / 50 (94)	50 / 50 (100)
CPT11	52 / 52 (100)	52 / 52 (100)	52 / 52 (100)
CPT12	49 / 56 (88)	56 / 56 (100)	56 / 56 (100)
CPT13	51 / 53 (96)	53 / 53 (100)	53 / 53 (100)
CPT14	46 / 53 (87)	50 / 53 (94)	53 / 53 (100)
CPT15	48 / 53 (91)	51 / 53 (96)	53 / 53 (100)
CPT16	41 / 48 (85)	46 / 48 (96)	48 / 48 (100)
CPT17	48 / 48 (100)	48 / 48 (100)	48 / 48 (100)
Total	468 / 851 (57)	678 / 851 (80)	838 / 851 (99)

[y] Pooled number of plants showing CMV disease symptoms and/or ELISA positive / no. plants tested (%).

[z] Plants were inoculated with CMV strain Peet's, one week later the plants were inoculated with strain NT9. A month after the second inoculation, the plants were inoculated with a mixture of the two strains.

severity of symptoms was reduced compared to nontransgenic control plants (L4783 and TK70). This result confirmed the usefulness of pathogen-derived resistance (PDR) and illustrated that the transformation of tomato with the coat protein gene of one CMV strain could offer transformants a certain degree of resistance to other CMV strains. There were 13 plants identified by ELISA test, and visual observation found no CMV symptoms nor virus multiplication three months after the initial inoculation (Table 9).

A second round of resistance evaluation was done with cuttings of R_1 progenies to test their resistance to CMV inoculation by strain T and by the mixture of strain Peet's and NT9 (Table 10). In order to compare the resistance of transgenic progenies to different strains of CMV, cuttings instead of seedlings were used as trial materials in this experiment. Cuttings from the same plant were tested for different CMVs at the same time. The evaluation showed that CMV disease symptoms were much less than those in the first evaluation (Table 9). The inconsistency might be partially due to differences in the stage of development of the seedlings and cuttings. Mature cuttings might simply have more strength to tolerate virus inoculation than do seedlings.

Some R_1 seedlings were subject to CMV infection using an inoculum mixture of strain Peet's, NT9, and T. All control plants developed typical CMV disease symptoms between 20 and 40 days after the initial artificial infection (Table 11). R_1 seedlings showed an expected resistance to infection, and less than 50% of trial plants expressed disease symptoms. R_1 seedlings in-

Table 10. Resistance evaluation of R_1 tomato cuttings derived from primary transformants containing coat protein gene of cucumber mosaic virus (CMV) strain T by ELISA test and visual observation after inoculation with a mixture of CMV strain Peet's and NT9 and with CMV strain T, respectively

	CMV strain Peet's and NT9[z]		CMV strain T[y]	
Plant	20[x]	60	20	60
Control				
L4783	18 / 48 (38)[w]	48 / 48 (100)	46 / 46 (100)	46 / 46 (100)
TK70	22 / 49 (49)	48 / 49 (98)	48 / 48 (100)	48 / 48 (100)
Transgenic				
CPT1	3 / 52 (6)	19 / 52 (37)	13 / 43 (30)	31 / 43 (72)
CPT3	15 / 51 (29)	26 / 51 (51)	36 / 48 (75)	44 / 48 (92)
CPT4	4 / 52 (8)	23 / 52 (44)	24 / 48 (30)	37 / 48 (77)
CPT5	17 / 46 (37)	30 / 46 (65)	24 / 48 (30)	39 / 48 (81)
CPT6	6 / 45 (13)	29 / 45 (64)	27 / 46 (59)	38 / 46 (83)
CPT7	24 / 45 (53)	45 / 45 (100)	48 / 48 (100)	48 / 48 (100)
CPT8	25 / 48 (52)	39 / 48 (81)	42 / 49 (86)	47 / 49 (96)
CPT9	2 / 48 (4)	10 / 48 (21)	12 / 50 (24)	47 / 50 (94)
CPT10	5 / 47 (11)	20 / 47 (43)	19 / 48 (40)	35 / 48 (73)
CPT11	5 / 48 (10)	26 / 48 (54)	38 / 51 (75)	45 / 51 (88)
CPT12	3 / 49 (6)	30 / 49 (61)	34 / 48 (71)	41 / 48 (85)
CPT13	5 / 46 (11)	26 / 46 (57)	19 / 46 (41)	33 / 46 (72)
CPT14	2 / 45 (4)	15 / 45 (33)	14 / 47 (30)	26 / 47 (55)
CPT15	2 / 47 (4)	17 / 47 (36)	29 / 47 (62)	32 / 47 (68)
CPT16	3 / 49 (6)	25 / 49 (51)	26 / 48 (54)	43 / 48 (90)
CPT17	4 / 49 (8)	16 / 49 (33)	28 / 48 (58)	44 / 48 (92)
Total	125 / 767 (16)	396 / 767 (52)	433 / 763 (57)	630 / 763 (83)

[w] Pooled number of plants showing CMV disease symptoms and/or ELISA positive / no. plants tested (%).
[x] Days after the initial CMV inoculatioN.
[y] Plants were inoculated with CMV strain T three times. The inoculation schedule was the same as for Peet's and NT9.
[z] Plants were inoculated with CMV strain Peet's. One week later they were inoculated with strain NT9. And a month after the second inoculation, the plants were inoculated with a mixture of the two strains.

oculated with a mixture of the three CMV strains showed resistance levels much higher than were observed in the first two evaluations (tables 9 and 10). Further study would be required to determine whether the higher levels of resistance were due to the transformation of the CMV coat protein gene, or due to cross protection, or due to a combination of both. The identified resistant plants (270), as well as noninoculated transgenic seedlings, have been transferred to the field to evaluate their resistance performance.

Several critical factors relating to Agrobacterium-mediated transformation, including tissue culture medium, kanamycin level, and type of explant, were tested to optimize the transformation of four tomato varieties. Results showed that cotyledon explants produced the most shoots and responded to regeneration medium better than other explants (hypocotyl and leaf) for all genotypes. Among tested media, regeneration media containing 2 mg/l of BAP and either 0.5 or 1 mg/l of IAA were best for shoot formation of variety CLN1462A. Medium supplemented with 4 mg/l of BAP and 0.5 mg/l of IAA was found to be most effective for variety CLN1466D. Cotyledon explants from variety CLN1558A responded well to several regeneration media, but a medium containing 1 mg/l of BAP and 0.1 mg/l of IAA was a little better than the others. The sensitivity of tomato cotyledons to kanamycin was examined using a regeneration medium containing 0, 25, 50, 75, 100, 125, and 150 mg/l of kanamycin. The response of different tomato varieties to various concentrations was about the same. Normal shoots developed on the medium without kanamycin. With 25 and 50 mg/l, few explants produced calli and shoots, whereas with 75 mg/l or higher, growth of explants was inhibited. Conse-

Table 11. Resistance evaluation of R1 tomato seedlings derived from primary transformants containing the coat protein gene of cucumber mosaic virus (CMV) strain T by ELISA test and visual observation after inoculation with the mixture CMV strains Peet's, NT9, and T

	Days after initial CMV inoculation[z]		
Plant	20	40	80
Control			
L4783	38 / 39 (97)[y]	39 / 39 (100)	39 / 39 (100)
TK70	31 / 32 (97)	32 / 32 (100)	32 / 32 (100)
Transgenic			
CPT1	3 / 35 (9)	12 / 35 (34)	18 / 35 (51)
CPT3	25 / 46 (54)	30 / 46 (65)	30 / 46 (65)
CPT4	9 / 36 (25)	15 / 36 (42)	16 / 36 (44)
CPT5	11 / 43 (26)	11 / 43 (42)	13 / 43 (30)
CPT6	13 / 35 (37)	21 / 35 (60)	22 / 35 (63)
CPT7	25 / 27 (93)	26 / 27 (96)	26 / 27 (96)
CPT8	6 / 21 (29)	8 / 21 (38)	8 / 21 (38)
CPT9	0 / 23 (0)	2 / 23 (9)	3 / 23 (13)
CPT10	2 / 23 (9)	4 / 23 (17)	4 / 23 (17)
CPT11	10 / 48 (21)	14 / 48 (29)	15 / 48 (31)
CPT12	7 / 32 (22)	16 / 32 (50)	16 / 32 (50)
CPT13	2 / 18 (11)	2 / 18 (11)	2 / 18 (11)
CPT14	1 / 20 (5)	2 / 20 (10)	2 / 20 (10)
CPT15	0 / 4 (0)	1 / 4 (25)	1 / 4 (25)
CPT16	4 / 24 (17)	6 / 24 (25)	6 / 24 (25)
CPT17	4 / 24 (17)	6 / 24 (25)	7 / 24 (29)
Total	122 / 459 (27)	176 / 459 (38)	189 / 459 (41)

[y] Pooled number of plants showing CMV disease symptoms and/or ELISA positive/no. plants tested (%).

[z] Plants were inoculated with a mixture of CMV strain Peet's, NT9, and T. There was one week between the first and second inoculation. The third inoculation was done one month after the second inoculation.

quently, 75 mg/l of kanamycin was chosen for selection of transformed tissue. Based on the above studies, transformation of three tomato varieties, CLN1662A, CLN1466D, and CLN1558A, for CMV resistance with the coat protein gene will be carried out.

Transformation of tomato for resistance to fungal pathogens

It has been reported that the expression of a chitinase gene in transgenic plants results in enhanced fungal resistance, probably because chitin, one of the major cell wall components of many fungi, can be digested by chitinases. Previous results have shown that *Serratia marcescens* can digest chitin and inhibit the growth of *Fusarium oxysporum* f. sp. *lycopersici* (Fol), *Phytophthora capsici*, and *Rhizoctonia solani*, under in vitro conditions. The culture filtrate with chitinolytic activity of *S. marcescens* (but not intact *S. marcescens*) significantly reduced the severity of fusarium wilt on tomato in a greenhouse.

In order to investigate the role of chitinase in the anti-fungal activity and in order to develop horticultural varieties resistant to fungal pathogens, this study set out to clone and transfer an expressible chitinase gene from *S. marcescens* into tomato. The chitinase gene of *S. marcescens* was cloned and expressed in *Escherichia coli*, and then transferred to the *Agrobacterium tumefaciens* LBA4404 for plant transformation.

The DNA sequence of a chitinase gene from *S. marcescens* was determined by dideoxynucleotide sequencing method and analyzed through the SWISSPROT database searched using the FastA program. The chitinolytic culture filtrates from *S. marcescens* and *E. coli* JM109, harboring a plasmid, p19D-12, with the chitinase gene, were mixed with conidial suspensions (10^6 conidia/ml) of Fol, *P. capsici*, and *Colletotrichum gloeosporiodes* individually, and then incubated at 25°C in sealed petri dishes. Slides were removed at predetermined intervals and air dried. Small droplets of lactophenol with cotton blue were placed on the inoculation sites and the conidia were observed with a compound microscope.

A DNA fragment (1.7 kb) containing the chitinase gene was constructed into a binary vector pBI121-based plasmid, producing the plasmid pBXS1211, before being transferred into the *A. tumefaciens* disarmed strain LBA4404 by the freeze-thaw method. Cotyledons of tomato L4783 were infected with the transformed *A. tumefaciens* and selected for shoot formation on a regeneration medium containing 100 mg/l kanamycin. Regenerated shoots were then transplanted to a greenhouse after acclimation. The total genomic DNA of supposed transgenic plants was extracted from young leaves by the CTAB method and the transformation of the chitinase gene was confirmed by PCR and Southern blot analysis. A 2.4-kb *Bam*HI-*Hin*dIII fragment of the PR1a promoter (provided by Dr. Teruo Ishige of the National Institute of Agrobiological Resources, Japan) was constructed into the *Bam*HI-*Hin*dIII sites of the plasmid pBXS1211 to replace the CaMV 35S promoter and then transferred to *A. tumefaciens* LBA4404 as previously described.

DNA sequence analysis of the chitinase gene cloned from *S. marcescens* revealed a 1686-bp open reading frame encoding a 61-kD protein with a 3-kD potential signal peptide at its N terminus. The molecular weight of the translation product was in reasonable agreement with the size estimated by SDS-PAGE analysis of the chitinase from *S. marcescens*. The deduced amino acid sequence showed 92.9% identity with the other chitinase displaying resistance to some plant fungal pathogens.

Production of appressoria (specialized infection structures formed at the tips of germ tubes or hyphae on the outside of a host) of *C. gloeosporiodes* was completely inhibited after being treated with chitinolytic culture filtrates from *S. marcescens* and *E. coli* JM109 harboring the chitinase gene (Table 12). The chitinolytic culture filtrates were also found to be effective in reducing the conidial germination of *C. gloeosporiodes* and Fol for up to the first eight growth hours (Fig. 1), and in reducing zoospore formation, and in causing lysis of sporangia of *P. capsici* after four hours of incubation (Table 13). The filtrates should be regarded as fungistatic rather than fungicidal since they did not kill the fungi, except *P. capsici*. The sporangia lysis of *P. capsici* by the culture filtrate of transformed *E.coli* was less effective than by that of *S. marcescens*.

The *S. marcescens* chitinase gene under the control of the constitutive CaMV 35S promoter was introduced into tomato variety L4783 through *A. tumefaciens*. Among the 59 regenerated supposed transformants, 53 were confirmed by PCR and Southern blot analysis for the presence of the chitinase gene (Fig. 2). The expression of the gene in transgenic tomatoes, as well as responses of the transgenic tomatoes to fungal pathogens, will be tested.

In order to regulate the expression of the chitinase gene in transgenic tomatoes, the gene was fused with the stress-inducible PR1a promoter and confirmed by

Table 12. Effect of culture filtrates from chitinase-producing bacteria on appressorial production (%) by germinating conidia of *C. gloeosporiodes*.[z]

Strain	Incubation time (hour) 0	4	8	12
Control (10 mM glucose)	0	31	57	53
E. coli JM109 (p19D-12)	0	0	0	0
S. marcescens	0	0	0	0

[z] Based on observations of 45 conidia (3 replications, 15 conidia) per treatment.

Table 13. Effect of culture filtrates from chitinase-producing bacteria on sporangia of *P. capsici*.[z]

Strain	Zoospore formation (%)	Sporangia lysis (%)
Control (10 mM glucose)	92	0
E. coli JM109 (p19D-12)	34	58
S. marcescens	3	95

[z] Values are based on observation of 150 sporangia (3 replications, 50 sporangia) per treatment after 4 hours incubation at 25°C.

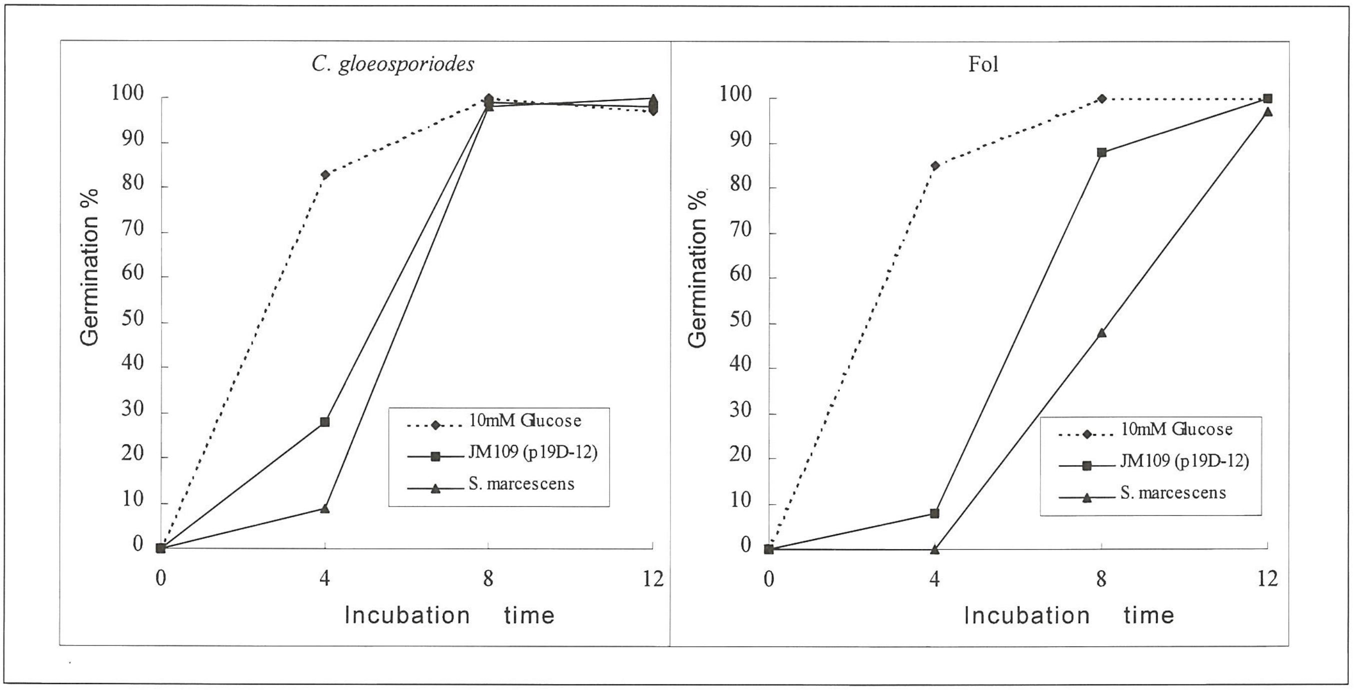


Fig. 1. Effect of culture filtrates from chitinase-producing bacteria on conidial germination of *C. gloeosporiodes* and *Fusarium oxysporum* f. sp. *lycopersici* (Fol).

restriction enzymes digestion (Fig. 3). The confirmed construct was transferred to *A. tumefaciens* LBA4404 for plant transformation (Fig. 4).

Mechanism of resistance to bacterial wilt caused by *Ralstonia solanacearum* in tomato

Resistance to BW of tomato is due to tolerance, not immunity to the pathogen. It has been reported that field resistance of tomato to BW is closely correlated with *Ralstonia solanacearum* (Rs) populations in the stem. In this study, we were to elucidate the resistance mechanism by tracing the internal change in Rs population in different plant parts over time, as well as the effect of latent infection on the yield of tomato.

Comparison of internal populations

Tomato varieties Hawaii 7997 (H7997), CL5915-93D4-1-0-3-0 (CL5915), and L390, which are resistant, moderately resistant, and susceptible to BW, respectively, were used in this experiment. Tomato seedlings (one month old) were transplanted into 7.5-cm pots containing infested soil of a single virulent Rs strain, Pss4 (about 10^7 cfu/g of air-dried soil). The experiment design was RCBD with three replications and 24 plants per replication. Eight of the 24 plants were used to record disease severity and four plants selected randomly were used to measure the internal population 3, 10, 17, and 24 days after transplanting (DAT). Entire root, and 2-cm segments of stem base, midstem (50% of total height), and topstem (the top of plant) were sampled from the same plant. The root samples were macerated directly and the stem samples were incubated in 10 ml of sterile distilled water for 16 hours at 20°C. Bacterial populations were measured by dilution plating method on SM-1 plates.

Yield trial

Tomato seedlings of CLN1621-156-3-0 and CLN1621-360-7-0, determinant type and resistant to BW, were transplanted into pots (10-inch diameter) with four levels of inoculum density of Rs, i.e., 0, 10^4, 10^6, and 10^8 cfu/g of air-dried soil. Each treatment had three replications and four plants per replication. The trial was conducted in the screenhouse from 28 April to 7 July (mean max./min.: 32.8/23.6°C). Disease severity was recorded weekly. Several horticultural traits were also recorded, i.e., date of flowering, fruit number per plant, fruit weight, fruit-set ratio, total fruit weight

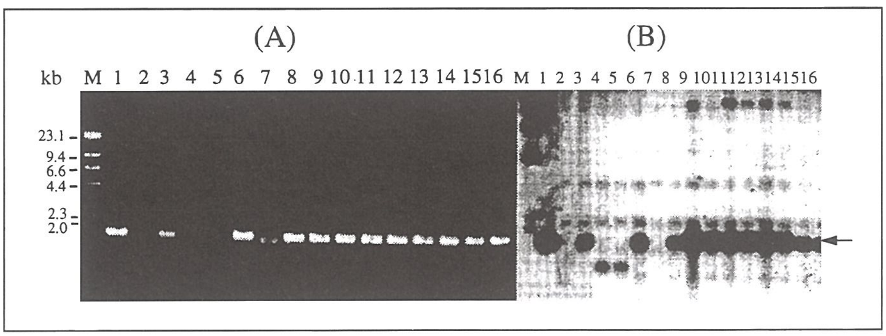


Fig. 2. PCR and Southern blot analyses of chitinase gene in the transgenic tomato plants. (A) PCR amplification products. (B) Southern blot of genomic DNA from putative transgenic tomato plants after digested with *XbaI/SacI* and probed with a DIG-dUTP labeled 1.7-kb DNA fragment of the chitinase gene. Lane M, *lHin*dIII DNA size markers; lane1, positive control, plasmid pBXS1211 was digested with *XbaI/SacI*; lane 2, untransformed control; lanes 3 to 16, putative transgenic tomato plants. The 1.7-kb fragment, as indicated by an arrowhead, was detected from most of the putative transgenic plants by PCR and Southern blot analyses, except samples from plants 4, 5, and 7.

per plant (yield), and final plant height. At the end of the trial, the internal Rs population in the stem base was measured with the method described above.

Measuring Rs population in various plant parts over time indicated that susceptibility of tomato to BW was correlated with the internal population of Rs in the stem base and midstem, but not in the roots. The final disease indices were 100, 66.2, and 10.8% for L 390, CL5915, and H7997, respectively. Samples of L 390 were not collected 24 days after transplanting, as the plants were wilted and dried. The Rs population in the roots of H7997 was lower than that in the other varieties, but no significant difference was observed among varieties at any time (Fig. 5 A, B, C, D). The more susceptible the tomato is to BW, the larger the Rs population detected in the stem samples. Ranking of the amount of Rs population in the three stem samples was correlated with the sampling position. Topstem always contained less Rs population than midstem and stem base. This was most obvious in CL5915 at 3 and 10 days after inoculation (DAI), and in H7997 at 3, 10, 17 DAI. Significant difference on internal population among varieties was observed in stem base 3 DAT and midstem 3 and 10 DAT. Therefore, resistance to BW in tomato is not related to root infection or multiplication in the roots. The suppression of movement of Rs from root to stem base and its multiplication in the stem seemed to be most related to the resistance which led to a delay in reaching maximum Rs population in the stem. Histology studies at the early infection stage (within three days after infection) on the movement of the pathogen and colonization of vascular bundles etc., would lead to a better understanding of the resistance mechanism. The variation in internal Rs population in the stem could be used for selecting resistant plants and for mapping genes associated with BW resistance in tomato.

The effect of latent infection of Rs on the yield of tomato was evaluated in pot trials. The results of the two tested varieties were very similar and only data on

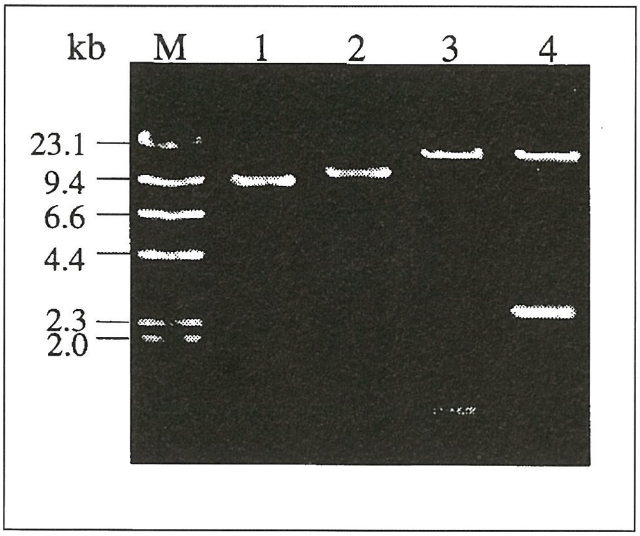


Fig. 3. Restriction enzyme analysis of recombinant plasmids carrying chitinase gene fused with CaMV 35S promoter or PR1a promoter. Lanes 1 and 2, circular plasmids with 35S and PR1a promoter, respectively; lanes 3 and 4, CaMV 35S and PR1a promoters fragments, 0.9 kb and 2.4 kb in size, respectively, created by double digestion (*Bam*HI/*Hin*dIII) of plasmids carrying chitinase gene; lane M, *l**Hin*dIII DNA size markers.

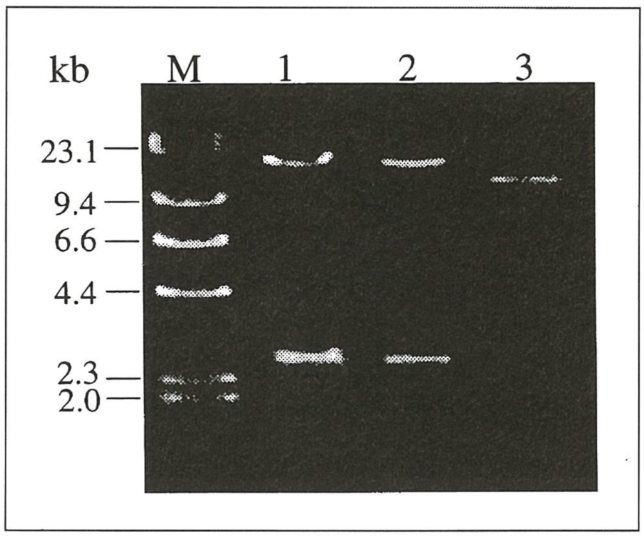


Fig. 4. Confirmation of the transformation of *A. tumefaciens* with recombinant plasmid harboring a chitinase gene under the control of PR1a promoter by restriction enzyme analysis. Lanes 1 and 2, recombinant plasmids isolated from *E. coli* and *A. tumefaciens*, respectively, were digested with *Bam*HI/*Hin*dIII to generate a 2.4-kb PR1a promoter fragment; lane 3, circular recombinant plasmid; lane M, *l**Hin*dIII DNA size markers.

CLN1621-360-7-0 are presented here. During the trial, only a few plants wilted partially and returned to normal later. The treatments (different inoculum densities) had no effect on the date of flowering, fruit-set ratio, fruit number, total fruit weight, and plant height (Table 14). However, the internal Rs population in the stem base samples at the end of the trial increased with the increase in the initial inoculum density. Therefore, a resistant tomato variety could tolerate a high amount of Rs in the plant without suffering a loss in productivity. Confirmation of this phenomenon in the field is necessary.

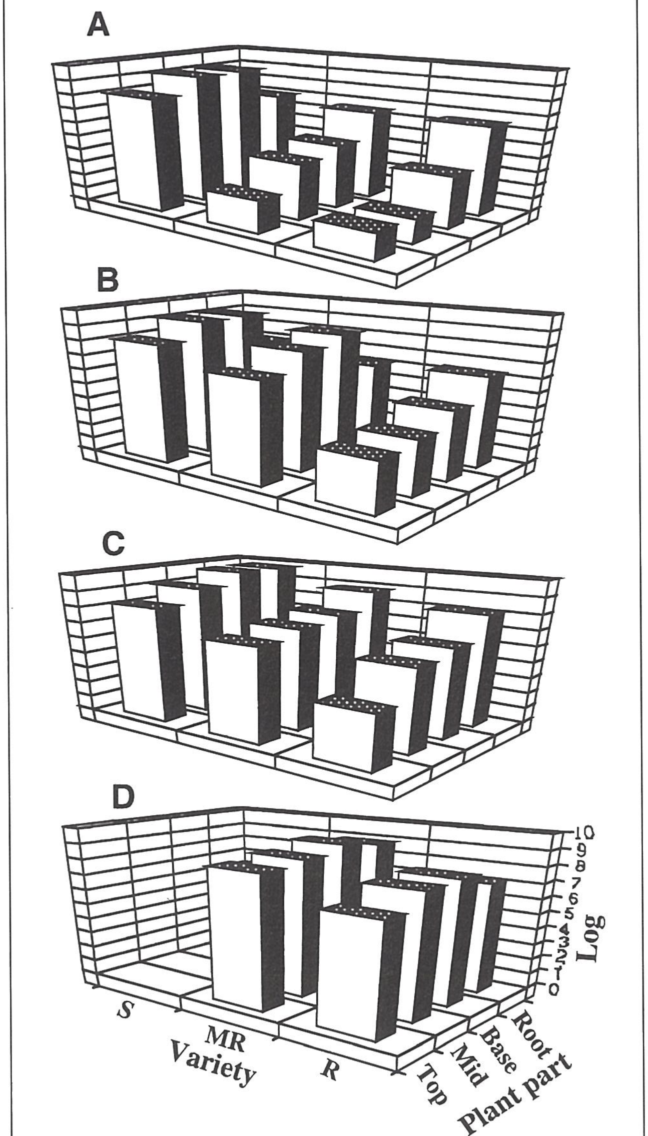


Fig. 5_{A-D}. Population of *R. solanacearum* present in root [log (cfu/g of fresh tissue)] and stem parts [stem(Base), midstem (Mid), and topstem (Top); log (cfu/cm)] of L390 (S), CL5915-93D4-1-D-3-0 (MR), and Hawaii 7997 (R) at three dats (A), 10 days (B), 17 (C), and 24 days (D) after transplanting. Labels of all axes are as indicated in fig. 6 D. S=susceptible, MR=moderately resistant; R=resistant.

Population structure of *Ralstonia solanacearum* from Taiwan production fields and a disease nursery

Location specificity of resistance in tomato to BW has been demonstrated and is a bottleneck for resistance breeding. It has been hypothesized that variation among strains of Rs in genetics and aggressiveness might contribute largely to the location-specificity. Various studies have demonstrated the genetic and aggressiveness diversity among Rs strains. However, Rs strains used in these studies were collected randomly over a long period of time, from various host crops, or over a large geographical region. Therefore, the results can not be used to represent the strains attacking tomato recently in the field located in any particular region. For a better understanding of the location effect, we investigated, among other things, the population structure. We wanted to understand the genetic diversity, the degree of differentiation, and the selection forces of the pathogen population. The following is a case study on the Rs population present in tomato fields in Taiwan.

Strains of Rs were collected from tomato production fields in Taiwan from 1993 to 1996. From this collection, 45 strains were selected to represent the Taiwan production field population. PSS 4, which was collected in 1988 and is used for routine screening at AVRDC, was included in the production field population. For collecting strains in a disease nursery located in the central region, the susceptible tomato line, L390, was grown from August to October 1996. The disease nursery was divided into five equal subfields in which three plots of 30 tomato plants were transplanted. In one of the subfields, a varietal screening for BW resistance, consisting of three replications of 20 plants of 12 tomato entries, was also sampled. Five plants that showed complete wilting symptoms were collected randomly from each plot. Soil samples were also collected from the nursery before and 15 days after transplanting. All bacterial strains isolated from the soil and plants were tested for their pathogenicity by clipping-inoculation on susceptible line L390, identified by PCR using Rs-specific primer pair AU759/760, and identified into biovars.

Genetic polymorphism among strains in the production field population was analyzed by RAPD and by rep-PCR method. Genomic DNA from each strain was extracted. Three 10-mer OPERON primers were used for RAPD amplification (OPAD1, OPAG6, and OPAG14) following regular RAPD procedures. A 7.5-ml portion of the RAPD product was separated on a 1.5% agarose gel in 0.5X TBE buffer at 6.7 V/cm. The three primer sets for rep-PCR method were REP (REP1R-I, REP2-I), ERIC (ERIC1R, ERIC2) and BOX (BOXA1R). A 6-ml portion of the rep-PCR product was separated on a 2% agarose gel in 1X TAE buffer at 5 V/cm. The disease nursery population was only analyzed by RAPD method with the four OPERON oligomers (OPAD1, OPAG6, OPAG14, and OPAE1) following the protocol described above.

Comparison of fingerprints generated from each strain allowed identification of unique banding patterns. Each unique banding pattern generated by RAPD or rep-PCR alone or a combination of both methods was considered as haplotype. The presence or absence of bands at each position along a lane was converted to binary data (1 for presence and 0 for absence). A tree was generated based on dissimilarity coefficient by the unweighted pair group arithmetic average (UPGMA) and the robustness of the tree branches was tested with a bootstrap analysis. Clusters were determined by using average linkage method and the most reliable number of clusters was determined based on a consensus among three clustering criteria (cubic clustering criterion, pseudo-F, and pseudo-t^2) by SAS. Genetic diversity was estimated by Nei and Li's haplotypic diversity index H for the total population and each subpopulation at different hierarchical levels considered. Population differentiation was estimated using the coefficient of genetic differentiation G_{ST} as well as by the Fisher's exact test considering the distribution of clusters in each hierarchical level. The index of genetic differentiation was calculated as $G_{ST} = (H_T - H_S)/H_T$; with H_T being haplotypic diversity for the all population and H_S being the average of the haplotypic diversity of the subpopulations.

Production field population

The three RAPD primers revealed 34 haplotypes which can be grouped into 23 clusters according to cluster analysis. The three rep-PCR primers revealed 22 haplotypes grouped into four clusters. Comparison of the results obtained by both methods showed that strains

Table 14. Effect of latent infection by *R. solanacearum* on date of flowering (Fldate), fruit-set ratio (Frset), fruit weight (Frwt), fruit number per plant (Frno), total fruit weight per plant (Towt), and plant height (Ht) of CLN621-360-7-0, a tomato variety resistant to BW

Treatment[1]	Fldate (day)	Frset (%)	Frwt (g)	Frno	Towt (g)	Ht (cm)	Stbs[2] [log (cfu/cm)]
CK	16.1 b[3]	62.4	18.5 a	53.5 a	578.4 a	106.4 a	0.0 c
L	16.6 b	63.6	19.2 a	28.2 a	549.9 a	110.9 a	3.0 b
M	18.8 a	67.9	17.9 a	27.4 a	510.7 a	109.0 a	2.9 b
H	16.9 ab	59.3	17.5 a	30.1 a	516.3 a	101.6 a	7.8 a

[1] CK:check, L:10^3 cfu/g dry soil, M: 10^5 cfu/g dry soil, H: 10^7 cfu/g dry soil.
[2] Internal population of *R. solanacearum* measured at the end of trial.
[3] Means with the same letter are not significantly different (p=0.05) according to Duncan's multiple range test.

belonging to the same RAPD haplotype or cluster also belonged to the same rep-PCR haplotype or cluster. This good correspondence allowed us to combine RAPD and Rep-PCR data for further analyses. The combined data defined 34 haplotypes grouped in 13 clusters (Fig. 6).

Estimates of genetic diversity in the production field population were high in both haplotype and cluster levels (Table 15). The population was partitioned into two hierarchical levels, biovar and geographic origin, in order to determine their effect on population structure. Results indicated that the population was differentiated at biovar level when considering clusters [G_{ST} = 0.085, p(Fisher's exact test) = 10^{-7}], but not haplotypes (G_{ST} = 0.014). Differentiation among clusters at the biovar level was quite obvious since only two among the 13 clusters consisted of strains of both biovars 3 and 4 (Fig. 6). For geographical grouping, five regions were defined according to the main agro-ecological production areas in Taiwan. Similar to the biovar level, genetic differentiation was only pointed out at geographical level when considering clusters [G_{ST}

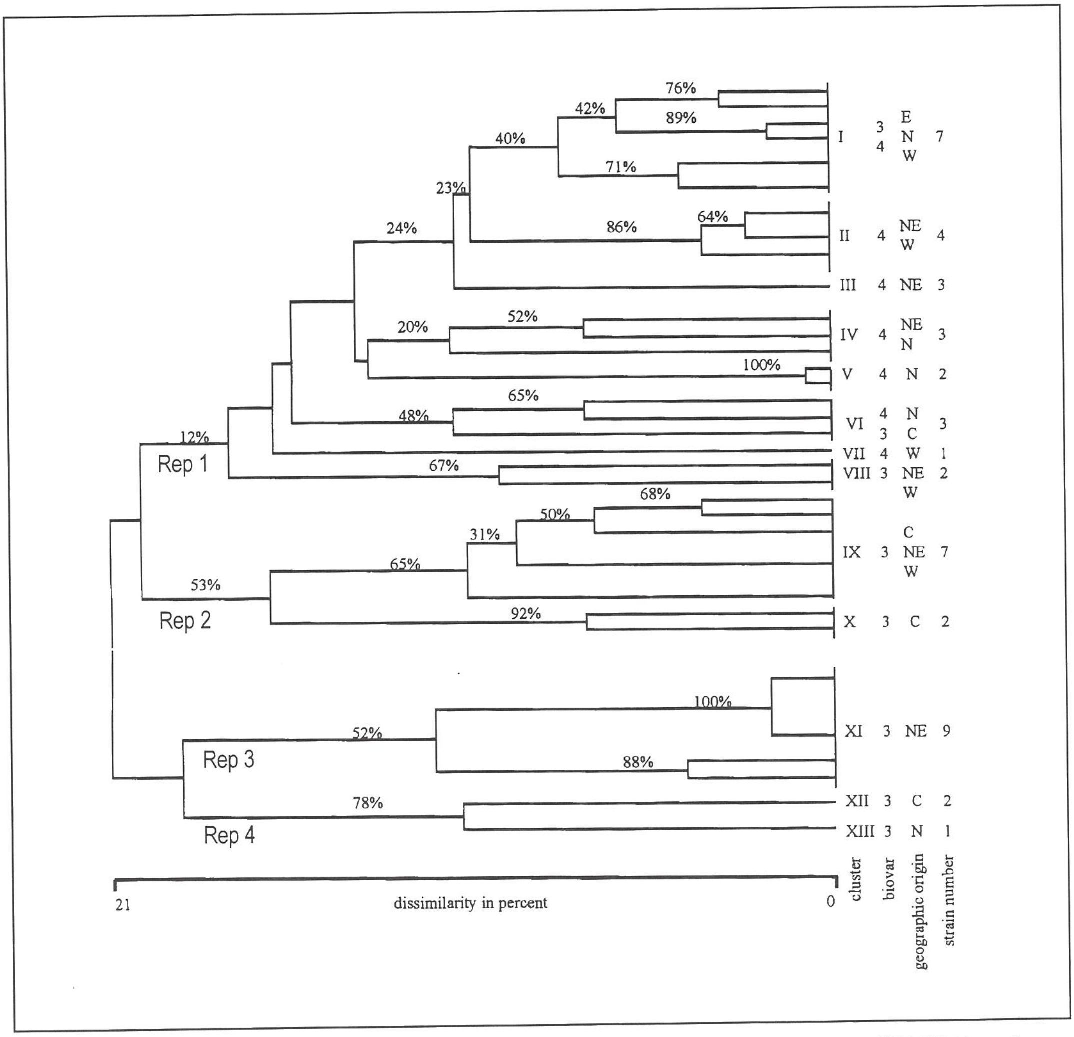


Fig. 6. Dendrogram derived the unweighted pair group method arithmetic mean (UPGMA) and rep-PCR showing dissimilarity relationships among *R. Solanacearum* strains collected from Taiwan tomato production field. RAPD/rep-PCR clusters (in Roman numerals), REP clusters (REP 1, 2, 3, and 4), biovar, geographic origin (W: west, C: central, N: north, NE: north-east), number of strains per cluster, and bootstrap values (values on the branches representing the percentage of times the group occurred out of 2000 iterations) are indicated.

= 0.266, p (Fisher exact test) = 10^{-7}], but not haplotypes (G_{ST} = 0.027). A similar result was obtained after discarding the small sample from the eastern region, and G_{ST} is equal to 0.086, [p = 3.5×10^{-7}] when considering cluster. Thus the production field population is differentiated at the biovar and geographic level. However, the fact that this genetic differentiation was pointed out only at the cluster level could mean that other factors could also act on the structuration of the production field population.

Disease nursery population.

L 390 population. The RAPD analysis of the disease nursery population defines 65 haplotypes with 20 and 46 from the soil and L390 respectively. Only a single haplotype encompasses both soil and plant strains. Cluster analysis allows grouping of disease nursery haplotypes into nine clusters. Among them, three clusters consist of 75% of the strains and 65% of the haplotypes of the population.

The genetic diversity of the disease nursery population was high at both the plant and soil level (Table 16). The high level of genetic diversity in this nursery population might have been due to the diverse cropping history of the field. No differentiation is evident between populations from soil and plant at haplotype (G_{ST} = 0.036) or cluster level (G_{ST} = -0.001). For the population from plant, a genetic differentiation at the subfield level is pointed out with both haplotype (G_{ST} = 0.082) and cluster [G_{ST} = 0.082, p = 5×10^{-9}]. Considering that the plant population originates from the soil and was recovered from a single host genotype, this differentiation at the microgeographical level could indicate that soil variability is a selection force acting on population structure.

Varietal screening population. Strains of Rs were recovered from only five tomato entries (L 390, L180, GA1565, CRA66, and Hawaii 7997) among the 12 in the trial (Table 17). This population consisted of 18 haplotypes grouped into three clusters. The genetic di-

Table 15. Genetic diversity in the production field population at different hierarchical levels

Level		Number of strains	Haplotype number	H[1]	Cluster number	H
Overall		46	34	0.981	13	0.906
Biovar	3	29	21	0.963	9	0.842
	4	17	14	0.971	6	0.816
Region	North	9	8	0.972	4	0.889
	North-east	18	9	0.889	6	0.725
	East	3	3	1.000	1	0.000
	West	10	9	0.978	5	0.844
	Central	6	5	0.933	4	0.867

[1] Nei and Li's index of genetic diversity, $H = [n/(n-1)][1 - \Sigma f_i^2]$, where f_i is the frequency of the i^{th} haplotype or cluster and n is the total number of haplotypes or clusters

Table 16. Genetic diversity in the disease nursery population at different hierarchical levels

Level		Number of strains	Haplotype number	H	Cluster number	H
Overall		87	65	0.99	9	0.78
Soil		25	20	0.97	8	0.78
Plant	All	62	46	0.98	7	0.78
	Subfield 1	13	7	0.73	4	0.60
	Subfield 2	13	12	0.99	4	0.69
	Subfield 3	14	10	0.92	4	0.71
	Subfield 4	12	10	0.97	5	0.79
	Subfield 5	10	9	0.98	4	0.80

versity was lower than the diversity of the overall disease nursery field at haplotype and cluster level. Comparison of populations from tomato entries pointed out a strong genetic differentiation of these populations at haplotype [G_{ST} = 0.276, p = 0.007] and cluster level [G_{ST} =0.322, p = 0.019]. The same conclusion was obtained after discarding the small size sample from Hawaii 7997. This significant genetic differentiation would mean that the host genotype acts on the structuration of the pathogen population. Given the different resistance level to BW of the tomato entries (highly susceptible, L 390; resistant, L180, CRA66, GA1565; and highly resistant, Hawaii 7997), it appears that the pathogen diversity decreased with the increase in host resistance, which could act as a selection pressure.

This is the first genetic analysis of an Rs population isolated from tomato and its field soil in Taiwan. The results showed that the pathogen population both in tomato production fields and a disease nursery is highly diverse genetically. The production field population is weakly differentiated at either the biovar or agro-ecological level. From the disease nursery population analysis we showed that microenvironment might act as a selection pressure on the pathogen population. We can conclude that several factors could act on the population differentiation. We can hypothesize, however, that none of them is predominant, which leads to maintenance of a high level of genetic diversity. The main tomato cultivars grown in Taiwan at present are moderately resistant (ASVEG #4 and #5) or susceptible (Farmers 301 and Santa) to BW. Thus, the selection pressure due to host genotype remains low in production fields. However, we showed that host genotypes with a different degree of resistance could be a strong differentiation factor on the pathogen population. This result needs to be confirmed in order to understand the consequences (in terms of the pathogen population structure) of releasing highly resistant cultivars.

Analysis of the interaction between strains of *Ralstonia solanacearum* and tomato varieties under different environments

Resistance to BW caused by Rs in tomato has been described as temperature-dependent, strain-specific, or location-specific. The complex interaction among pathogen, host, and environment of the tomato-Rs pathosystem has been the bottleneck for resistance breeding programs. In order to help understand this complex interaction, a preliminary study was designed to observe the interaction of representative strains differing in genotype and tomato varieties differing in resistance levels under different environments. The results will be applied in designing a system for evaluating aggressiveness of the pathogen.

Six strains (PSS4, PSS181, PSS186, PSS192, PSS197, and PSS212) of Rs isolated from tomato representing different genotypic groups were selected from the Taiwan production field population. Eight tomato varieties, L390, Fla 7421, Rodade, GA219, CRA66, L180, BF-Okitsu 101, and Hawaii 7996, differing in their resistance to BW, were used in this study. The experiment was performed in two environments: a greenhouse at 27°C and in an AVRDC field. The field

Table 17. Genetic diversity in the population at different hierarchical levels

Level		Number of strains	Haplotype number	H	Cluster number	H
Overall		43	18	0.893	3	0.682
Cultivar	L390	15	10	0.943	3	0.647
	L180	13	6	0.872	3	0.692
	GA1565	5	3	0.700	2	0.400
	CRA66	7	3	0.714	2	0.571
	Hawaii 7997	3	1	0.000	1	0.000

experiment was repeated twice in June (summer) and October (fall) 1997. Plants (one-month-old seedlings) were inoculated by drenching with 30 ml of bacterial suspension at 10^8 cfu/ml. For field trials they were transplanted two days after inoculation. All trials followed a split-plot design with strains as the main factor and varieties as the minor factor. There were two replications and 20 plants per plot.

Percent wilting was recorded every two days until the disease severity became stable. The final wilting frequency was analyzed by variance analysis after transformation (arcsin of squared root). The mean separation was done by DMRT.

Comparison of results from the field and greenhouse trials pointed out a significant environmental effect on the final wilting frequency. The mean wilting frequencies were 0.328, 0.554, and 0.430 for the first and the second field experiments, and the greenhouse experiment, respectively. The mean temperatures during the two field trials were almost the same (26.1°C and 25.4°C for the first and the second experiment, respectively). However, the first field experiment was subject to a tropical depression leading to partial field flooding and a temperature decrease from the 3rd to the 12th day, which was the period for wilting in most strain-variety combinations. Thus, the difference between the two field trials could be explained by weather. Temperature might have also contributed to the differences between field and greenhouse trials. The main difference, however, could have been in the tomato physiology and root system due to differences in growing conditions.

All strains and all entries except Hawaii 7996 showed a significant difference in their final wilting in the different environments. Strain and tomato entry ranking, however, remain mostly the same over trials (tables 18 and 19). Correlation analysis showed that final wilting frequencies were correlated among trials with a Pearson's correlation coefficient of 0.86 between the two field experiments, 0.72 between the first field and the greenhouse experiments, and 0.81 between the second field and the greenhouse experiments.

From final wilting frequency analysis over strains, three aggressiveness groups were found (Table 18): highly aggressive (PSS181), aggressive (PSS4, PSS192, PSS197), and moderately aggressive (PSS212, PSS186). The same analysis over tomato entries pointed out four resistance groups (Table 19): highly susceptible (L390, Fla 7421), moderately resistant (Rodade, GA219, CRA66), resistant (L180, BF-Okitsu 101), and highly resistant (Hawaii 7996). This ranking is in agreement with the worldwide BW resistance screening coordinated by AVRDC.

Use of tomato entries differing in their resistance

Table 18. Final wilting frequency over eight tomato varieties of six strains of *R. solanacearum* in three trials under different environments

Strain	Field Summer	Field Fall	Greenhouse	Mean
PSS181	0.722a[1]	0.917a	0.766a	0.804a
PSS4	0.383b	0.673b	0.664b	0.587b
PSS192	0.310bc	0.612b	0.550c	0.497c
PSS197	0.212cd	0.447c	0.535c	0.413d
PSS212	0.190d	0.337cd	0.120d	0.195e
PSS186	0.196d	0.271d	0.068d	0.152e

[1] final wilting frequency; mean separation were done using the Duncan's multiple range test on transformed data (arcsin of squared root). Numbers followed by the same letter in each column are not significantly different at the 5% level.

Table 19. Final wilting frequency over six *R. solanacearum* strains of eight tomato varieties in three trials under different environments

Variety	Field Summer	Field Fall	Greenhouse	Mean
L390	0.933a[1]	1.00a	0.909a	0.958a
Fla7421	0.943a	0.993a	0.831b	0.927a
Rodade	0.327b	0.597b	0.422c	0.444b
GA219	0.139cd	0.539bc	0.407cd	0.370c
CRA66	0.173c	0.544bc	0.404cd	0.357c
L180	0.175c	0.414c	0.216e	0.255d
Bf-Okitsu101	0.072d	0.093d	0.306de	0.164e
Hawaii 7996	0.015e	0.012e	0.022f	0.017f

[1] see Table 18.

levels allowed us to separate Rs strains according to their aggressiveness. This study confirmed that the interaction of Rs × tomato is environment dependent. No specific interaction of Rs × tomato × environment was shown.

Host resistance to late blight of tomato

Late blight caused by *Phytophthora infestans* is the most damaging foliar and fruit disease of tomato in tropical and subtropical highlands. None of the reportedly resistant varieties hold up against LB in the Asian highlands. With the identification of L3683, L3684, L3707, and L3708 as resistance sources against Asian LB, AVRDC initiated a project to introgress resistance from L3684 and L3708 into advanced tomato lines. This study was undertaken (1) to repeatedly test the resistant accessions for their resistance and durability in widely different geographic locations, (2) to identify additional resistance sources, and (3) to assist the breeders with introgression of resistance into advanced tomato lines.

Geographic testing of the resistant lines was done by supplying NARS in various countries with seed sets, including resistant and susceptible lines, to be planted in replicated trials in areas where LB epidemics occur regularly. The LB reactions of the lines were scored on a 0-6 scale, where 0 = no symptoms and 6 = 91-100% leaf area affected. To identify new sources of resistance progeny from individual plant selections made over the past more than six years, 89 *Lycopersicon pimpinellifolium* and 49 *L. hirsutum* accessions obtained from TGRC at the University of California were inoculated in the laboratory – 30- to 35-day-old seedlings were spray inoculated with a suspension of 2.5×10^4 sporangia per ml after a 2-hour incubation period to initiate zoospore release. Inoculated plants were maintained in the dark at 20°C and 100% RH to maintain leaf wetness for the first 24 hours. Thereafter, the leaves were allowed to dry and the plants were maintained at 20°C and 60-95% RH with a 14-hour light (70 $\mu Elm^{-2}ls^{-1}$) period per day. Disease severity was estimated on a scale of 0 to 6 at 10 DAI. The same laboratory protocol was used to assess reactions of individual plants in breeding populations.

Geographic testing of resistance

Seeds were distributed for testing during 1997 to Bhutan, Costa Rica, Ethiopia, Guatemala, Indonesia, Kenya, Malawi, Nepal, Taiwan, Tanzania, USA, and Zimbabwe. Thus far, we have received reports from Malawi, Nepal, Taiwan, Tanzania, and USA. In all locations reporting, the *L. pimpinellifolium* lines L3707 and L3708 showed the highest levels of resistance. The *L. hirsutum* lines L3683 and L3684 showed intermediate levels of resistance through most or all of the season. In Pokhara, Nepal, and Puli, Taiwan, lines L3707 and L3708 developed severe symptoms toward the end of the crop, but lines L3683 and L3684 showed no change in their resistance levels (Figs. 8 and 9). Isolate *Pi*-42 of *P. infestans* obtained from L3708 at Puli was also shown to overcome the resistance in L3707 and L3708, but not that of L3683 and L3684 in the laboratory. These results suggest the occurrence of a new race, tomato race 2 (T2) of *P. infestans*, at two locations, that overcomes the *L. pimpinellifolium* sources of resistance, but not the *L. hirsutum* sources being tested.

Screening wild tomato accessions for additional resistance sources

The AVRDC Mycology Unit has over the past six years identified numerous tomato accessions as potential sources of LB resistance. During 1997, progeny from 40 individual plant selections from these accessions were evaluated for their reactions to isolate *Pi*-16 of *P. infestans*, and two highly resistant selections were identified. One selection, designated L4885-1C-96Pis1, is an *L. pimpinellifolium,* and the other, designated LA 1459-3R-96Pis1, is an *L. esculentum* var. cerasiforme with DSR's of 1.7 and 3.1, respectively, on a scale of 0-6 in which a DSR of 6 = 91-100% blighted foliage.

In addition, 89 *L. pimpinellifolium* and 49 *L. hirsutum* accessions obtained from the TGRC at the University of California were evaluated for their reactions to isolates Pi-16 (race T1) and *Pi*-42 (race T2) of *P. infestans*. Five *L. pimpinellifolium* accessions (DSRs 1.5-2.5) and 21 *L. hirsutum* accessions (DSRs 1.1-2.5) were identified as new LB resistance sources. None of the *L. pimpinellifolium* accessions were resistant to isolate Pi-42, whereas all of the *L. hirsutum* accessions that were resistant to *Pi*-16 were also resistant to *Pi*-42.

Introgression of resistance into desirable tomato types

One objective of this activity was to introgress LB resistance from the *L. pimpinellifolium* accession, L3708, into indeterminate tomato types for tropical highland production. In this regard, three generation advances starting with a BC_3F_1 selection, CLN2037 BC_3F_1, were made during 1997, culminating in 14 CLN2037 BC_3F_4 lines that are homozygous for resistance to LB. During September 1997, 11 of these LB-resistant BC_3F_4 lines were sown for field observations to make individual plant selections for good fruit qualities and generation advance. Another objective of this activity was to introgress LB resistance from L3708 into lines adapted to the highlands of southern Africa. In 1996, LB-resistant selections from four crosses (CLN2036, CLN2037, CLN2040, and CLN2048) were crossed with three lines from the AVRDC-African Regional Program that carry resistance to root-knot, fusarium wilt races 1 and 2, and TMV. In December 1996, LB-resistant plants were selected from 22 of these crosses and taken to the field for generation advance. Four F_2 populations (CLN2256-2, CLN2260-3, CLN2264-4, and CLN2264-5) were inoculated on 5 September 1997 with fusarium wilt race 2 to eliminate susceptible plants and the survivors were inoculated on 17 October 1997 with isolate *Pi*-16 of *P. infestans*. Plants with high levels of resistance to fusarium wilt race 2 and LB were taken to the field for generation advance.

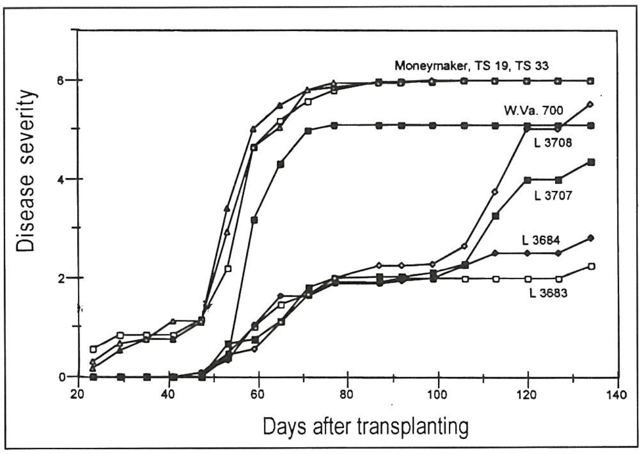


Fig. 7. Late blight development from natural inoculum in accessions in the field at Pokhara, Thailand, winter 1996-97

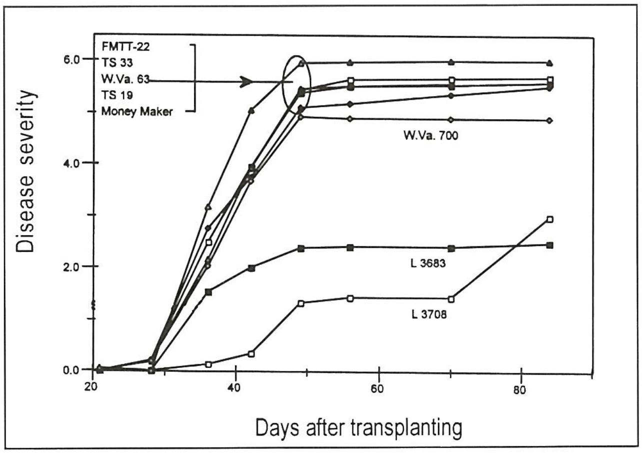


Fig. 8. Late blight development from natural inoculum in tomato lines in the field at Puli, Taiwan, spring 1997

Legume Improvement

The legume improvement project conducts research on two commodities: mungbean (*Vigna radiata*) and soybean (*Glycine max*), including grain and vegetable soybean. The goal is to develop high-yielding lines with resistance to disease and pests, early uniform maturity, resistance to shattering, improved seed quality, and adaptation to the tropics and subtropics.

One soybean line from AVRDC was released in Vietnam as a new variety. In the Philippines, two AVRDC lines were released as new grain soybean varieties, and three of the Center's lines were released as vegetable soybean varieties. The graded pod yield went to 16.3 t/ha in the spring season.

Based on work done in 1997, it appears that length of pod and sugar content have a strong correlation. The genotype component of variance for sugar content is substantial compared to the season or genotype × season interaction component of variance.

The Center continued to collaborate with Korea to advance early generation materials during the off-season. Near-isogenic lines for triple-null lipoxygenase have been selected in AGS292, KS#2, and AGS 129. Triple null alleles for lipoxygenase showed no association with undesirable agronomic traits.

Promising insect-tolerant soybean genotypes have been selected and will be evaluated in various countries.

RAPD markers have been identified to discern mungbean-yellow-mosaic-virus-resistant recombinant inbred lines from susceptible ones.

Additional moderate resistance to maruca infestation in mungbean has been identified. Rice bean is less damaged by maruca than are mungbean and blackgram.

Genetic resources enhancement and varietal improvement

Genetic resources activities

Mungbean and soybean accessions that did not have enough seeds for long-term preservation were regenerated. Requests for germplasm were served. Registration, passport, distribution, and seed inventory databases were updated.

Thirty-five accessions were added to the mungbean and five to the soybean germplasm collection in 1997. The collection has 6357 *Vigna* accessions representing eight species: *Vigna radiata* ssp. *radiata, V. radiata* ssp. *sublobata, V. mungo* ssp. *mungo, V. mungo* ssp. *sylvestris, V. glabrescens, V. unguiculata* ssp. *sesquipedalis, and V. unguiculata* ssp. *unguiculata,* and *V. umbellata*. The *Glycine* collection totals 14,068 accessions and includes 12 species: *G. clandestina, G. canescens, G. formosana, G. gracilis, G. falcata, G. javanica, G. latifolia, G. latrobeana, G. tabacina, G. tomentella, G. tomentosa, and G. soja.* Five hundred accessions of mungbean from 22 countries and 1500 accessions of soybeans were regenerated to provide enough seeds for the base collection.

A total of 796 seed packets of mungbean were distributed to four countries, 36 to AVRDC's Asian Regional Center in Thailand, and 2526 to headquarters scientists (Table 1). More than 2000 accessions were screened for resistance to maruca podborer. External distribution of soybean amounted to 6559 seed packets sent to 27 countries. The regional programs and headquarters scientists received 187 seed packets.

Table 1. Recipients of mungbean and soybean germplasm from AVRDC, 1997

Recipient	No. of samples: mungbean	soybean
External	796	6559
Taiwan	677	1291
Japan	88	5
Vietnam	24	205
Thailand	24	4
Korea		4214
Lao PDR		249
Cambodia		167
Ghana		86
Australia		56
Malaysia		47
USA		37
Bhutan		24
Others[1]		174
ARC	36	20
ARP		20
Headquarters	2526	147
Entomology	2520	147
Analytical Lab	3	
Soil Science	3	
Total	3358	6746

[1] Bangladesh, Belize, Congo, Costa Rica, Germany, Guam, India, Indonesia, Papua New Guinea, Philippines, Sri Lanka, Togo, Zaire, and Zimbabwe.

Breeding appropriate vegetable soybean

Three yield trials in autumn 1996 and 13 trials in spring 1997 were conducted. From the autumn 1996 advanced yield trials, two lines with large pod and seed size were selected: GC 91023-189-2-1, which yielded 6.88 t/ha graded pod yield and 79.39 g/100 seeds; and GC 89008-9-1-2-1, which yielded 5.78 t/ha and 83.5 g/100 seeds. Both matured in 69 days. From intermediate yield trials, entries having a 100-seed weight of more than 80 g, compared to 72 g for the check, were selected.

Combined analyses of 1996 spring, summer, and autumn data from the advanced yield trials showed no significant difference in graded pod yield between seasons. Unlike 1994 and 1995, the sugar content in 1996 was higher in the spring season than in the other two seasons (Table 2). It might be important to relate the temperature and sugar content.

A total of 38 crosses were made in 1997, principally aimed at further improvement of pod and seed size of vegetable soybean. Some Indian varieties were crossed to combine bacterial pustule and soybean rust resistance. From advanced and intermediate yield trials in autumn 1996 and spring 1997, a number of entries with 100-seed weights higher than 80 g were selected (Tables 3 and 4). The highest graded pod yield recorded was 16.25 t/ha in 82 days (Table 4).

When the three-season data from the 1996 advanced yield trials were analyzed for correlation between sugar content and pod size, as well as seed size, it was apparent that as the pod length increased the sugar content decreased. It was consistent in all seasons. However, neither 100-seed weight nor pod width showed any consistent relationship with sugar content. Therefore, in selecting for larger pod size, the results suggest that it is better to avoid very long pods. Results from the three-season data also suggest that the genotypic component of variance for sugar content is quite large; therefore, it should be possible to select for high sugar genotype (Table 5).

AVRDC soybean evaluation trial

A total of 15 AVRDC soybean evaluation trials (ASETs), 40 AVRDC glycine selections (AGS), 198 selected pedigrees, and 14 accessions were distributed to 27 cooperators in 20 countries. Interest in receiving and evaluating AVRDC soybean materials remains high, as in past years. Eight cooperators from five countries returned the results of their evaluations.

In Cambodia, the trials were conducted by the International Rice Research Institute in two seasons. In the wet season, AGS 314 was the earliest to mature, in 86 days, and yielded 1.7 t/ha, while CO 1 matured in 94 days and yielded 2.33 t/ha. In the dry season, AGS 129, a narrow-leafed variety, matured in 87 days and yielded 0.86 t/ha.

In Ecuador, GC 86017-170-1N produced 4.4 t/ha in 97 days, with almost no lodging.

The results from trials by Sakthi Soyas in India showed that AGS 66, GC 89049-1-1, GC 89050-6-1, and GC 87032-9-1 were promising, with yield up to 4 t/ha in about 90 days.

In Maharashtra, India, AGS 16 gave a yield of 2.94 t/ha in 92 days.

Table 2. Influence of season on graded pod yield and other traits in advanced yield trial (AYT), 1996

Season	Yield (t/ha) graded pod	Yield (t/ha) total pod	100-seed weight (g)	Pod length (cm)	Pod width (cm)	Dry matter	Protein	Fat	Sugar
96 SP	6.55 a	12.56 a	69.1 a	5.58 a	1.39 a	30.0 c	43.5 b	19.1 c	11.9 a
96 SU	6.55 a	11.79 b	64.3 b	5.10 b	1.27 b	31.5 b	44.0 a	20.2 b	11.4 b
96 AU	6.32 a	9.60 c	70.4 a	5.22 b	1.31 b	32.1 a	43.3 b	20.6 a	10.0 c

Table 3. Graded pod yield and 100-seed weight of selections from autumn season, 1996

Trial	Entry	Graded pod yield (t/ha)	100-seed weight (g)
AYT	GC 89008-9-1-2-1	5.78	83.5
	GC 91023-189-2-1	6.88	79.3
	KS #2 (ck)	6.68	57.0
IYT-1	GC 92019-B-2-13	9.9	74.5
	GC 92017-8	7.4	80.2
	GC 92018-261PS-7S-1	7.2	87.8
	KS #3 (ck)	9.5	62.2
IYT-2	GC 92005-72-2-4-2	11.05	75.4
	GC 92005-28M-2L-2	8.85	87.1
	GC 92005-20S-4L-1	7.15	85.7
	KS #3 (ck)	9.3	66.1

AYT = advanced yield trial; IYT = intermediate yield trial

The ROC mission in Sumatra, Indonesia, found that GC 88029-1-7-1 yielded 2.82 t/ha in 96 days when grown as an intercrop with sugarcane. The cooperator reported that the soil in the experimental area was low in pH, P_2O_5, and Ca. The entry will be evaluated again to confirm the results.

Vietnam made another selection from AGS 147 (a narrow-leafed entry) and released it to farmers as G 87-1.

In the Philippines, the National Crop Research and Development Center (NCRDC), Los Baños, selected GC 50215-2-18-17 and GC 00062 and had them officially approved and released as PSB-Sy4 and PSB-Sy5, respectively. They have a yield potential of more than 2 t/ha in the wet season and about 2 t/ha in the dry season.

Table 6 lists soybean varieties released to date.

AVRDC vegetable soybean evaluation trial

Interest in evaluating AVRDC vegetable soybeans continues to be steady. In 1997, 26 cooperators from 18 countries received 16 ASETs, 165 AGS lines, 40 pedigrees, and 3 accessions for evaluation. Results of six trials from three countries were received.

AGS 333 gave a graded pod yield of 7.8 t/ha in 83 days in Vietnam. Its dry seed weight was 32 g/100 seeds. AGS 334 yielded 6.81 t/ha in 76 days with a 100-seed weight of 28 g. In an evaluation conducted at Cantho, Vietnam, AGS 337 gave a graded pod yield of 8.31 t/ha in 79 days. The 100-seed weight was 62 g. AGS 329

Table 4. Graded pod yield, 100-seed weight and sugar content of selections from spring trials, 1997

Trial	Entry	Graded pod yield (t/ha)	100-seed weight (g)	Sugar content (%)
AYT	GC 92001-1-P-25-1	10.15*	73.5	11.90
	GC 92019-B-2-13	9.25*	76.9	9.90
	KS #5 (ck)	8.23	82.7	11.40
IYT-1T*	GC 91032-LP-22-1	16.25	72.9	8.56
	GC 91032-8P-11-1	12.85	81.7	10.06
	KS #5 (ck)	9.60	61.9	11.70
IYT-2T*	GC 92005-77-2-1	14.75	89.4	11.62
	GC 92005-7-1	11.05	98.3	9.53
	KS #5	8.70	86.0	10.99
IYT-1	GC 92017-183P-1-2	11.4	92.7	11.52
	GC 92025-149-1-1	11.0	82.3	9.02
	KS #5 (ck)	9.7	84.9	10.99
IYT-2	GC 92015-1-1	11.65	83.5	9.32
	KS #5 (ck)	9.95	85.6	10.74
IYT-3	GC 92014-P-12-1	11.65	81.5	9.44
	GC 93034-11-1-1	11.35	78.2	10.64
	KS #5 (ck)	7.6	85.6	10.96

AYT = advanced yield trial
IYT = intermediate yield trial
*IYT-1T, IYT-2T were part of a Council of Agriculture Project, Taiwan.

Table 5. Estimate of components of variance (%) for quality traits of AYTVS in three crop seasons, 1996

Component of variance	Protein	Fat	Sugar	Starch	Fiber	Color	Hardness	Dry matter
Var R (S)	0.0	0.0	3.01	1.78	0.0	0.60	0.0	0.0
Var G	59.32	38.08	60.50	37.92	15.65	20.33	22.08	11.76
Var G x S	24.18	43.35	12.01	25.31	54.16	40.15	62.47	52.01
Var Error	16.50	18.57	24.48	34.99	30.19	38.92	15.45	36.23

matured in 73 days and gave a green pod yield of 7.3 t/ha with a 100-seed weight of 65 g.

In Korea, the total pod yield of AGS 331 was 7.0 t/ha in 110 days, with a 100-seed weight of 80.3 g.

In Bihar, India, AGS 337 gave an impressive yield of 18 t/ha (graded pod) in 70 days, with a 100-seed weight of 50 g. In Bangalore, India, AGS 343 yielded 11.83 t/ha (total pod) in 66 days.

Table 6. AVRDC grain soybean released by cooperators as of 1997

Local name	AVRDC ID #	Year	Country	Remarks
	G 2120 (M7) 69-1	1993	Bangladesh	HY, EM, LSU, G
Darcol	AGS 29	1981	Honduras	EM, UM, HY, CLS
KM 1	G 2120	1980	India	RF, HY
G 2120	G 2120	1980	Indonesia	HY, CC, SC, ST, G, LSV
Wilisb	G 2120	1983	Indonesia	EM, HY, (R)c
Kerincib	G 2120	1985	Indonesia	HY, (R), BF
Tidar	G 2120-M	1987	Indonesia	HY, EM, RF, LSV, G, ST
Krakatau	AGS 66	1992	Indonesia	R, CVMV
Taiwan 30050	AGS 17	1982	Malaysia	HY, MH
BPI Sy4	AGS 73	1985	Philippines	HY, EM, UM, LSV, BP, R, L, S, WA
La Carlotta Soy 1 (PSBSY-1)	Clark 63 x AGS 129 (LGSY 01-24)	1990	Philippines	(BP, R), EM, UM, L, (S) acceptable to Nestle
BPI-Sy 6 (Saguisag)	AGS 19	1990	Philippines	NL, HY, resistant to virus
PSB-Sy 4	GC 50215-2-18-17	1997	Philippines	HY
PSB-Sy 5	GC 00062	1997	Philippines	HY
Kaohsiung No. 9	AGS 12	1982	Taiwan	HY, NP, SSR, SQ
Kaohsiung No. 10	AGS 129	1985	Taiwan	HY, NL, BP, SSP
Tainan No. 1	AGS 66	1986	Taiwan	HY, S, MH, EM, SP, DM, BP, L, BS
Tainan No. 2	AGS 341	1993	Taiwan	NL, MH, HY, DM, (B), suited to spring and summer planting
Sukothai No. 1	AGS 9	1986	Thailand	NL, HY, NP, (R, DM, PSS)
Dowling	G 58a	1978	USA	R, HY
AK-03	G 2261a	1988	Vietnam	HY, EM
G 87-5	AGS 129	1991	Vietnam	HY, NL, BP, EM, R
AK-05	G 2261	1993	Vietnam	R, BP, HY, suited to spring & winter planting
HL 92	AGS 327	1993	Vietnam	EM, RMM, SQ, R, YMT, HY
G 87-1	AGS 147	1997	Vietnam	HY, NL, BP, EM, R
	GC 30229-8 (AGS 19)	1983	Zimbabwe	NL, EM
Nyalab	GC 30229-8	1992	Zimbabwe	HY, EM, Det
Seti Bhatta	KS 419 x KS 525	-	Nepal	HY, adapted to intercropping with maize
Total	28		12	

[a] Selected at AVRDC, but not an AVRDC-improved line.
[b] Cross between AVRDC line and local cultivar.
[b] Parentheses indicate moderate levels of resistance.

BF = resistant to beanfly
BP = resistant to bacterial pustule
BS = suited to bean sprouting
CC = suited to crude cultivation
CLS = resistant to cercospora leaf spot
CVMV = tolerant to CVMV
DM = resistant to downy mildew
EM = early-maturing
G = good germination
HY = high-yielding
L = nonlodging
LSV = long seed viability
MH = suitable for mechanical harvesting
NL = narrow leaflet
PSS = resistant to purple seed stain
R = rust-tolerant
RCI = suitable for intercropping with rice or corn
RF = suited to cultivation in rice fallow
S = nonshattering
SC = suited to intercropping with sugarcane
ST = preferred for making tempeh
SP = suited to summer planting
SQ = good seed quality for storage
SSP = suited to spring and summer planting
UM = uniformly maturing
WA = wide adaptability

The National Seed Board in the Philippines has officially approved three AVRDC lines as new varieties. AGS 191, AGS 190, and AGS 186 were released as PSB-VS 1, PSB-VS 2, and PSB-VS3, respectively. The NCRDC is extending the varieties to farmers in Batangas.

Table 7 is a list of vegetable soybean varieties released from AVRDC lines to date.

Seed multiplication of elite lines and Korean breeding lines

Eight promising entries and 83 promising selections from the previous year's advanced yield trials were multiplied. A total of 15 ASETs and 25 AVRDC vegetable soybean evaluation trials (AVSETs) were produced for distribution.

A total of 27 cross combinations of Korean F_3 generation entries were advanced to F_5. F_6 generation entries were multiplied in the spring. A total of 41 kg of seeds of 47 lines was air mailed to Korea on May 30, 1997.

In addition, two populations of soybean genetic map materials consisting of 86 and 95 seeds were planted and advanced for two generations in the greenhouse. In the autumn we had 56 and 91 plants in the greenhouse from the two populations, respectively. They will be harvested and shipped in January 1998.

Evaluation of *lxlx* allele in elite lines

An intermediate yield trial was conducted using BC_3F_5 near-isogenic lines (NILs) of lipoxygenase-null AGS 292, KS #2 (18 selections), and AGS 129 (18 selections). There were no significant differences either in graded pod yield or in most other traits between NILs and the parents. The KS #2 NILs were three days earlier maturing than KS #2. From BC_5F_2, a total of 34 triple nulls and 150 with null for two lipoxygenase alleles (Table 8) were selected for KS #2 and AGS 292. The observed number of plants did not fit well with the expected ratio of 64:1 presence:absence of lipoxygenase and it was probably due to the linkage between lx_1 and lx_3.

Developing insect-resistant lines using Brazilian lines

Pure lines from F_7 generations of crosses between insect-resistant lines IAC-100 or IAC 78-2318 and AGS 129 or 269, AGS 314 and OCB were evaluated in an intermediate yield trial (without insecticide application). The results are given in Table 9. Yields ranging from 3.34 t/ha to 5.11 t/ha were obtained with the selected pedigrees. Since the yields of the check varieties were not drastically reduced, one might assume that the in-

Table 7. AVRDC vegetable soybean released by cooperators as of 1997

Local name	AVRDC ID #	Year	Country	Remarks
MKS 1	AGS 190	1995	Malaysia	HY
Rawal-1	AGS 190	1994	Pakistan	HY
PSB-VS 1	AGS 191	1997	Philippines	HY
PSB-VS 2	AGS 190	1997	Philippines	HY
PSB-VS 3	AGS 186	1997	Philippines	HY
	AGS 190	1992	Sri Lanka	HY, suitable for soymilk and ice cream and soynuts, less beany flavor
Kaohsiung No. 1	AGS 292	1987	Taiwan	HY, MH, DM, EM
Kaohsiung No. 2	Ryokkoh x KS 8	1991	Taiwan	HY, MH
Kaohsiung No. 3	PI 157424 x KS 8	1991	Taiwan	HY, MH
KPS 292	AGS 292	1992	Thailand	HY
CM 1	AGS 190	1995	Thailand	HY, suitable for domestic consumption
GC 83005-9	GC 83005-9	1995	Bangladesh	HY, suitable for homestead cultivation
Total	12		7	

DM = resistant to downy mildewe; EM = early maturing; HY = high yielding; MH = suitable for mechanical harvesting sect infestation was not serious. On the other hand, the insects' failure to inflict damage on even the susceptible entries might be due to the predominance of insect-tolerant entries in the field. Several different pests were observed in the field and they did cause some defoliation. Mites were observed.

Table 8. BC_5F_2 seeds with different lipoxygenase-alleles after screening in summer 1997

Combination	Recurrent parent	*Lx*-triple null	$lx_1lx_1lx_2lx_2$	lx_nlx_n*
GC 96019	AGS 292	13	99	
GC 96020	AGS 292	7	18	
GC 96021	AGS 292	0	4	
GC 96023	AGS 129	0	0	
GC 96024	AGS 129	1	0	12
GC 96025		5	17	4
GC 96026		8	12	5
Subtotal	AGS 292	20	121	0
	AGS 129	14	29	21
Total		34	150	21

* Seeds with lx_1lx_1 or lx_2lx_2 or lx_3lx_3 only.

Selection of soybean for green manure

In the spring season, grain soybeans can be better than crotalaria or sesbaria as a green manure crop. Among six grain soybean varieties compared with sesbania and crotalaria in the spring season, G 2120 gave 43.5 t/ha in 74 days, while AGS 314, a mutant of G 2120, gave 30.1 t/ha in 61 days. In 61 days, crotalaria and sesbania gave fresh yield of 24.8 and 23.2 t/ha respectively (Table 10).

The total amount of green manure from each of the six soybean varieties ranged from 25.8 to 43.5 t/ha (Table 10). The total amount of N, P, and K were sub-

Table 9. Performance of insect-tolerant selections in intermediate yield trial, spring, 1997

Parents	Selection No.	Yield (t/ha)	Days to maturity	100-seed weight	Downy mildew reaction	Powdery mildew reaction
AGS 129 x IAC 78-2318	GC 90001-1-7-3	4.73	102	14.2	MS	
AGS 129 x IAC 78-2318	GC 90001-1-41-5	4.56	102	13.6	MR	
AGS 129 x IAC 78-2318	GC 90001-1-1-1-1	4.43	102	14.0	MR	
AGS 129	Check	4.78	95	17.5	HS	
IC 78-2318	Check	2.61	111	12.0	HR	
CV		7.79	2.58	4.37		
LSD (0.05)		0.69	5.42	1.23		
AGS 314 x IAC-100	GC 90012-18-25-3	3.78	110	9.9	-	-
	GC 90012-18-13-11	3.34	110	9.7	-	-
IAC-100	Check	4.24	110	15.2	-	-
AGS 314	Check	3.62	95	6.9	-	-
CV		18.02	1.31	5.62		
LS (0.05)		1.02	3.03	1.14		
269 x IAC 78-2318	GC 90004-12-20-2	5.11	99	15.9	-	-
	GC 90004-10-42-2	4.52	102	17.9	-	-
269	Check	4.39	95	19.3	-	-
IAC 78-2318	Check	3.29	111	11.5	-	-
CV		11.62	2.73	5.17		
LSD (0.05)		1.02	5.7	1.74		
IAC-100 x OCB	GC 90013-23-6-1	4.57	95	18.6	MR	
	GC 90013-21-35-2	4.55	111	20.7	-	
	GC 90013-21-37-6	3.75	96	18.1	-	
IAC-100	Check	4.33	111	15.3	-	-
OCB	Check	3.34	88	23.2	MR	
CV		14.45	2.44	6.06		
LSD (0.05)		1.06	5.46	2.23		

Note: No insecticides applied; - : no diseases; MS: moderately susceptible; HS: highly susceptible; MR: moderately resistant; HR: highly resistant.

stantially higher in the soybean variety Tropical compared to crotalaria and sesbania (Table 11).

The dry matter yield of residue from the six vegetable soybeans evaluated ranged from 6.0 to 6.6 t/ha compared to 4.9 and 5.0 t/ha for crotalaria and sesbania, respectively. In 80 to 87 days, selected entries of vegetable soybean can generate a dry matter yield of 5.0 to 5.9 t/ha. The N, P, and K from vegetable soybean residue is comparable to crotalaria and sesbania (Table 12). In addition, farmers can get a return of NT$109,000 to NT$164,000/ha as additional income (US$1:NT$33) from vegetable soybean.

Table 10. Performance of grain soybeans as a green manure, spring 1997

Entry	Yield (t/ha)		Days to harvest
	fresh	dry	
G 2120	43.5	7.4	74
Tropical	42.6	9.5	80
Green soybean	38.5	7.1	74
AGS 314	30.1	5.8	61
Improved Pelican	29.4	5.8	61
Bossier Late	25.8	6.1	69
Crotalaria	24.8	4.9	61
Sesbania	23.2	5	61
Means	32.2	6.4	67.5
CV	21.2	25.3	
LSD (0.05)	12	2.8	

Table 11. N, P, K content (kg/ha) of grain soybeans as green manure, spring 1997

Entry	N	P	K
G 2120	195.0	18.7	209.3
Tropical	278.4	24.8	266.3
Green soybean	200.4	17.8	201.2
AGS 314	200.6	17.3	149.0
Improved Pelican	203.5	16.8	160.0
Bossier Late	191.5	20.3	172.0
Crotalaria	134.1	15.4	108.3
Sesbania	129.9	13.9	126.5
Mean	191.7	18.1	174.0
CV	26.0	29.3	28.4
LSD (0.05)	87.3	9.3	86.6

Establishment and improvement of transformation systems for mungbean and vegetable soybean

Current biotechnology provides a new approach to varietal improvement of many agronomically important crops. Introducing genes for desirable traits into plants has become routine in several crops, but not in soybean and mungbean. To establish dependable transformation systems for varietal improvement, regeneration of soybean and mungbean has been induced through shoot morphogenesis pathway. Based on the developed regeneration systems, several methods of transformation, including Agrobacterium infection and microprojectile bombardment, have been tried.

Due to the nature of shoot morphogenesis, however, transformants were mostly chimeric, and homogeneous offsprings were produced by chance. In 1997, efforts were made at AVRDC to induce soybean regeneration through somatic embryogenesis pathway, which allows for more efficient selection and produces homogeneous transformants.

Nine soybean varieties were used and some of them were induced to produce embryos to the cotyledonary stage. In addition, optimal bombarding conditions for mungbean were determined and used to transform mungbean cotyledons. GUS staining indicated that some of the regenerated seeds contained the GUS gene.

Nine soybean varieties, Century, Fyattee, Jack, Mandarin, Masshokutou, Williams 82, AGS 292,

Table 12. N, P, K contents (kg/ha) of residue of vegetable soybean selections, spring 1997

Entry	Residue		
	N	P	K
GC 91023-189-3	164.5	18.0	150.0
KS #3	170.1	16.0	123.3
GC 89012-5	147.6	15.3	129.3
GC 89008-9-1-3-1	154.7	15.8	133.1
GC 87009-71-1-8	146.0	13.9	146.8
GC 87021-13-B-5	119.1	12.5	111.8
Mean	141.3	14.6	127.9
CV	9.7	7.3	4.9
LSD (0.05)	23.6	1.84	10.8

Kaohsiung No. 2, and Kaohsiung No. 5, were tested. Three mm apo-axis pieces were cut from 3- to 6-mm-long immature cotyledons and cultured on embryo induction medium (MS basal medium with B5 vitamins, different concentrations of 2,4-D, and 3 or 6% of sucrose). After one month, the concentration of 2,4-D was reduced to induce development of embryogenic calli. Embryogenic calli were cultured in FNL medium (MS basal medium + B5 vitamins + 2,4-D 5 mg/l + 5 mM asparagine) to establish suspension culture for transformation and selection, and subsequently transferred to MSM6AC medium (MS medium + 6% maltose + 0.5 g/l active charcoal) to induce histodifferentiation. Embryos grown to the cotyledonary stage were transferred to MSM6 medium (MSM6AC medium without active charcoal) for maturation and then MSO medium (MS medium + B5 vitamins) for growth of seedlings.

Mature seeds of mungbean variety VC 1973A were soaked overnight. Cotyledons were cut and centered on agar plates for bombardment. Conditions for bombardment were: 6 mg gold particles (1.0 mm in diameter) mixed with 100 mg plasmid DNA of pBI121, at pressures of 1350 or 1550 psi at a distance of 6 cm. Bombarded cotyledons were cultured on MBB5 medium (MS basal medium + B5 vitamins + BA 5 mg/l) for 2-3 days before being transferred to medium containing kanamycin (50 mg/l) for selection. Regenerated seedlings were transplanted to the greenhouse and seeds were collected for GUS staining assay.

A number of cotyledons produced somatic em-

Table 13. Induction of somatic embryogenesis among different soybean varieties

Variety	Co. size (mm)	MBS$_3$					MBS$_6$				
		D_0	D_5	D_{10}	D_{20}	D_{40}	D_0	D_5	D_{10}	D_{20}	D_{40}
AGS 292	3-5	0/14	22/34 (115)		18/28 (54)	4/27 (7)	0/14	2/14 (4)	15/28 (50)	0/14	0/14
Century	3-5	0/12	4/12 (22)	7/11 (61)	3/13 (13)	7/12 (16)	0/12	3/12 (3)	5/12 (7)	8/12 (30)	3/12 (11)
Fyatte	3-5					62/118					23/103
Jack	3-6					46/62 (271)					31/65 (137)
KS II	3-5	0/9		3/8 (19)	0/8	4/9 (18)	0/7	0/8	3/8 (16)	1/11	0/8
KS V	3-4						0/74	0/76	11/76	33/77	21/61
	4-5						0/62	0/76	4/65	5/64	6/76
	5-6						0/60	0/46	0/46	0/46	1/46
	6-8						0/22	0/22	0/22	0/22	0/22
Mandarin	3-5				3/11	0/11				1/11	0/11
Massh.	3-6	0/11	4/11 (8)	2/11 (2)	0/11	0/11	0/11	0/9	1/11 (1)	0/11	0/11
William	3-6	0/13	6/14	12/14	12/14	10/14	0/14	0/14	5/14	3/14	4/14

MBS$_3$/ MBS$_6$: MS basal salt + B5 vitamin compounds + 3% / 6% sucrose.
$D_{0,5,10,20,40}$: 2,4-D $_{0,5,10,20,40}$ mg/l
-/-: ratios of cotyledons produced somatic embryos
( ): No. of induced somatic embryos.

Table 14. GUS assay of 24 putative transgenic lines

	1	3	4	5	6	7	9	10	11	12	14	16	17	18	19	20	21	22	23	24	25	26	27	28
Seed	8	10	57	56	14	12	6	10	30	4	53	10	64	18	76	41	15	67	69	88	72	77	78	69
GUS	2	3	32	1	7	5	0	1	0	0	0	0	2	0	54	9	5	18	21	16	4	2	9	0
GUS%	25	30	56	1	50	42	0	10	0	0	0	0	3	0	71	22	33	27	31	18	6	3	12	0

GUS: Cotyledons of seeds showing GUS activity.
GUS%: Percentage of seeds with cotyledons showing GUS activity.

bryos and a number of induced embryos were recorded (Table 13). Generally, media with 3% sucrose showed more efficient embryo induction. However, the concentration of 2,4-D needed to induce embryos varied between varieties. Embryogenic suspension cultures of varieties Jack, Fyattee, and Kaohsiung No. 5 were established and cotyledonary-stage embryos of Jack were observed. Induction of seedling growth from cotyledonary-stage embryos was not successful. Factors in need of investigation might include age of globular-stage embryos for induction of histodifferentiation, as well as maturation status of cotyledonary-stage embryos.

A total of 28 putative transgenic lines were obtained from 180 bombarded cotyledons of mungbean VC 1973A, but four of them (lines 2, 8, 13, and 15) failed to produce seeds. Intensity and frequency of GUS blue spots varied among lines (Table 14). Lines 4, 6, 7, and 19 showed high frequency and intensity of GUS activity. Lines 9, 11, 12, 14, 16, 18, and 28 showed no GUS activity at all. The rest of the lines only showed weak GUS activity, either low in frequency or weak in intensity. The results indicate that most of the putative transformants were chimeric, because most lines contained seeds without GUS activity. Variance of GUS activity of inter- and intra-lines might have been the result of different copy number and genomic integration sites of the GUS gene. Seeds showing no GUS activity might have escaped selection or have contained the GUS gene without expression. Further Southern analysis is necessary to verify the introduction of the GUS gene into these putative transgenic seeds.

Development of RAPD markers for MYMV resistance in mungbean

Varietal development of mungbean for resistance to mungbean yellow mosaic virus (MYMV), one of the most serious diseases in South Asia, is an important objective of AVRDC. Using recombinant inbred lines (RILs), this study sought random amplified polymorphic DNA (RAPD) markers linked with MYMV resistance. Finding markers to facilitate AVRDC's MYMV resistance breeding efforts is especially important because the disease does not occur in Southeast and East Asia.

Genomic DNA of 42 MYMV-resistant and 25 susceptible RILs, as well as their original parents, NM92 (the source of MYMV resistance) and TC1966, was extracted and tested by polymerase chain reaction (PCR). A total of 823 10-mer random primers from Operon Co. and the University of British Columbia were used.

PCR was performed in 25 µl reaction with 0.2 mM respective primers, 0.02 ng genomic DNA, 2.5 µl 10× buffer, 3 mM $MgCl_{2,}$ 0.2 mM dNTPs, and 0.625 unit Taq DNA polymerase. RAPD reactions were performed in 25 µl volume containing 2.5 µl 10× buffer, 3 mM $MgCl_2$, 0.1 mM dNTPs, 0.2 mM primer, 0.625 unit Taq DNA polymerase, and 0.02 ng genomic DNA. Amplification was performed in Ericomp and/or Thermolyne Thermal Cycler for three cycles (1 min at 94°C, 1 min at 36°C, and 2 min at 72°C), followed by 40 cycles (30 sec at 94°C, 30 sec at 36°C, and 1 min at 72°C), and further extension at 72°C for 10 min. The amplification condition was three cycles at 94°C for 1 min, 36 °C for 1

Table 15. Potential RAPD markers for MYMV resistance in mungbean

Primer	RAPD markers(kb)	Resistant F_7 RIL line		Susceptible F_7 RIL	
		No. tested	No. (%) with RAPD	No. tested	No. (%) with RAPD
UBC 682	0.65	42	35 (83%)	25	7 (28%)
Operon M6	0.80	39	34 (87%)	25	2 (8%)
Operon M7	0.70	41	37 (90%)	25	0 (0%)
Operon T8	0.82	42	36 (86%)	25	8 (32%)
Operon T15	0.41	42	39 (93%)	25	0 (0%)

min, and 72°C for 2 min, followed by 40 cycles at 94°C for 30 sec, 36°C for 30 sec, and 72°C for 1 min, and further extended at 72°C for 10 min.

Among the 823 primers tested, 172 revealed polymorphism between NM92 and TC1966. These 172 primers were then tested against resistant and susceptible RILs. Five of the 172 primers, UBC682, Operon M6, M7, T8, and T15, created polymorphisms which have strong linkage with MYMV resistance or susceptibility (Table 15). These amplified DNA products could be potential RAPD markers for MYMV resistance. Two of the RAPD markers, generated by primer M7 and T15, cosegregated with resistant RILs at 90 and 93%, respectively. These markers are hardly detected among susceptible RILs.

MYMV resistance had been reported as a recessive trait, possibly monogenic, in NM92. Based on this, the F_7 generation should have reached more than 98% homozygosity. The high cosegregating ratio of these five RAPD markers with MYMV resistance calls for further molecular marker analysis. The F_8 generation of RILs have been generated and will be used to test the validity of the identified five RAPD markers in the discrimination of MYMV-resistant RILs from susceptible ones.

Table 16. Useful restriction enzymes in parental assay of 24 cDNA clones

Clone name	Useful restriction enzymes			
Pal1100	*Bst*NI	*Eco*RV		
Arcx1	*Eco*RI	*Hin*dIII	*Dra*I	*Bst*NI
Arcx2	*Hin*dIII	*Dra*I	*Bst*NI	*Nde*I
Arcx11	*Hin*dIII	*Dra*I	*Bst*NI	*Nde*I
Arc1100	*Bst*NI	*Hae*III	*Eco*RV	*Eco*RI
PI-500	*Bst*NI			
PI-300	*Hin*dIII	*Bst*NI	*Eco*RV	
SSH12	*Eco*RI	*Hin*dIII		
SSH17	*Hae*III	*Bst*NI		
SSH64	*Bst*NI	*Eco*RV	*Hin*dIII	*Hae*III
SSH72	*Eco*RI			
CF4	*Eco*RI	*Hin*dIII		
CF14	*Dra*I			
CF69	*Nde*I	*Hin*dIII		
gA2	NP[z]			
GAI	*Nde*I			
GB6	*Eco*RV			
GL3	*Nde*I	*Eco*RV	*Bst*NI	
GL4	NP			
GL11	*Eco*RV	*Nde*I		
5GB8-1	*Nde*I	*Bst*NI		
5GB8-21	NP			
5GB8-25	*Eco*RI			
CF71	*Hin*dIII			

[z] NP: no polymorphic enzyme was found

Development of molecular markers for bruchid resistance in mungbean

Bruchid resistance is an important mungbean varietal development objective at AVRDC. To understand bruchid resistance at the molecular level, various techniques (i.e., mRNA differential display, non-radioisotopic RNA fingerprinting, cDNA subtractive hybridization, and CapFinder method) were tested with the near-isogenic line VC6089A with bruchid resistance and its recurrent parent VC1973A from the Institute of Botany, Academia Sinica. Twenty-four cDNA clones were thus identified. The purpose of this experiment was to screen these cDNA clones with a mungbean population of known bruchid reaction for their linkage with bruchid resistance.

Twenty-eight individuals from $F_3BC_2S_2$ of the cross between VC3890A and TC1966 were used. Each was highly bruchid resistant or susceptible. Genomic DNA was extracted on a single plant basis. Ten restriction enzymes (*Eco*RI, *Eco*RV, *Hin*dIII, *Hae*III, *Dra*I, *Bst*NI, *Hin*fI, *Nde*I, *Pst*I, and *Kpn*I) were used in the RFLP parental assay of 24 cDNA clones to identify enzymes capable of revealing polymorphism between resistant and susceptible parents (i.e., VC3890A and TC1966). The polymorphic enzymes identified were then used to digest genomic DNA of $F_3BC_2S_2$ for RFLP analysis with the above-mentioned 24 cDNA clones.

Restriction enzymes which revealed polymorphism between VC3890A and TC1966 were identified from 21 out of 24 cDNA clones (Table 16). No polymorphism was detected by gA2, GL4, and 5GB8-21 cDNA clones with the tested enzymes; this could be due to false positive results of mRNA differential assay or high similarity of these alleles between parents. Three probes, Arcx1, Arcx2, and Arcx11, were cloned from TC1966 with primers designed based on the documented nucleotide sequence of the arcelin gene which has been reported to be correlated with bruchid resistance in other legumes. The parental assay of these three arcelin-related probes suggested Arcx 2 and Arcx 11 are identical, while Arcx1 is highly similar to Arcx 2 and 11.

Five clones, Pal1100, Arcx1, SSH64, CF4, and CF71, were detected as heterozygous or homozygous to resistant parent TC1966 for the bruchid-resistant progenies, but homozygous to susceptible parent VC3890A for the susceptible progenies (Table 17). This suggests their possible linkage with bruchid resistance and deserves verification. Nine probes, which could not be scored properly due to poor resolution of X-ray film, will also be tested. The banding patterns

Table 17. RFLP analysis with 21 cDNA clones for resistant and susceptible progenies.

Clone name	Resistant	Susceptible	Remarks
Pal1100	2[z]	3	Deserves further testing
Arcx1	2/3	3	Deserves further testing
Arcx2	3	3	
Arcx11	3	3	
Arc1100	3	3	
PI-500	-[y]	-	
PI-300	-	-	
SSH12	3	3	
SSH17	-	-	
SSH64	3/2	3	Deserves further testing
SSH72	-	-	
CF4	2	3	Deserves further testing
CF14	-	-	
CF69	-	-	
GAI	-	-	
GB6	3	3	
GL3	3	3	
GL11	3	3	
5GB8-1	3	3	
5GB8-25	-	-	
CF71	½	3	Deserves further testing

[z] 1- Homozygous to resistant parent TC1966, 2 - heterozygous, 3 - homozygous to susceptible parent VC3890A.

[y] Poor RFLP resolution.

of the other seven probes were homozygous to the susceptible VC3890A in both resistant and susceptible trial progenies, therefore would not be responsible for the bruchid resistance.

Maruca podborer resistance in mungbean

Maruca pod borer, *Maruca testulalis* Guyer, is a destructive pest of most economically important *Vigna* species of legumes, such as mungbean, cowpea, and yardlong bean, throughout tropical Asia-Pacific and Africa. The insect lays its eggs on foliage and inflorescences. Newly hatched larvae feed on flowers and/or bore inside young pods. Before they are full grown, larvae leave pods and pupate in soil. As a result of larval feeding, flowers drop and pods do not develop. Larval feeding on green seeds inside the pod results in direct loss in seed yield. Because of its concealed larval and pupal stages, this insect is difficult to control by conventional measures, such as insecticide sprays, mechanical or cultural measures, and there are very few reported effective natural enemies. AVRDC is, therefore, screening its mungbean germplasm for resistance to this pest with the purpose of breeding maruca-podborer-resistant mungbean cultivars.

In summer 1997, AVRDC conducted three host-plant resistance screening tests. In the first test we screened 2500 accessions from our germplasm collection; in the second test we rescreened 26 entries to confirm their possible resistance to maruca; and in the third test we compared the preference of maruca for three of its recorded hosts: mungbean, blackgram, and rice bean.

A parcel of land was plowed and worked into 0.75-m wide ridges and furrows. They were in turn divided into 4-m long single plots. Seeds of each of the *Vigna* accessions were sown in single rows on the top of individual 4-m long plots. Every 13th row was sown to *Sesbania indica*. The leaves of this green manure crop are severely attacked by maruca, which provides a source of infestation to the mungbean planted for maruca resistance screening. The crop was grown utilizing customary cultural practices, including weeding, top-dressed fertilizer application, irrigation, and application of fungicide to control plant diseases. No insecticide was used, however, to control any insect pest.

When the green pods of most accessions started filling, we observed each plant for maruca larval feeding in pods, or in the absence of pods, in flowers. The percentage of damaged plants was calculated. The data for the 2500 accessions were subjected to a statistical analysis based on mean percent damaged plants and standard deviation (SD) of the mean of all 2500 entries. The accessions that had percent damage of less than mean - 2 SD were considered highly resistant (HR); those between mean - 1 SD and mean - 2 SD, moderately resistant (MR); between mean and mean - 1 SD, were considered to have low resistance (LR); between mean and mean + 2 SD, were considered susceptible (S); and more than mean + 2 SD, were considered highly susceptible (HS). For confirmation, we analyzed the podborer damage data by ANOVA and means were compared by DMRT. No special statistical test was used to study the preference of maruca for mungbean, blackgram, and rice bean.

In the first test with 2500 mungbean accessions, maruca infestation ranged from 0 (no damage) to 77.8% of plants damaged. The distribution of all entries in various resistance rating categories is summarized in Fig. 1. Mean damage was 23.03% and SD was 12.71%. There were 424 MR accessions, 948 LR, 1013 S, and 115 HS. No accession was HR, although 22 accessions were damage free. This is because of very high variation in damage amounting to over 50% SD. Although in most accessions the damage was assessed by observing pest-infested pods, in some late-maturing accessions where pods had not yet developed, we relied on the presence of maruca larvae feeding in flowers. We assumed that accessions with flower damage would be equally damaged in the pods. This assumption will be tested when we plant the 22 damage-free accessions with 5-6 highly susceptible accessions in a multireplicate screening to be planted twice in summer 1998.

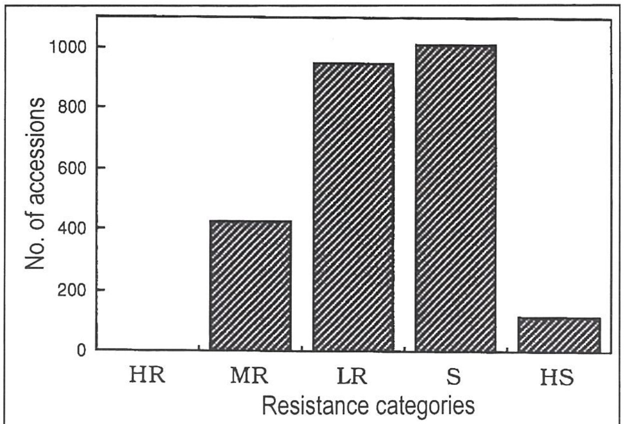


Fig. 1. Distribution of *Vigna* germplasm in various maruca-damage resistance rating categories

Table 18. Bean podborer damage to various accessions in second germplasm screening

Accession	No. of plants plants	Damaged plants	Damage (%)[a]
V2795	190	119	63.59 a
V3744	164	61	35.92 cde
V3852	159	47	29.26 d-g
V3927	132	58	44.66 bcd
V3968	237	8	3.43 i
V4041	236	7	2.98 i
V4044	210	8	4.33 i
V4121	179	52	28.94 d-g
V4149	272	5	1.80 i
V4202	221	15	8.06 hi
V4253	255	5	2.11 i
V4337	155	39	24.75 e-h
V4353	228	6	2.61 i
V4503	221	26	12.95 ghi
V4504	174	74	22.90 b-e
V4518	216	32	16.78 fghi
V4519	183	12	7.51 hi
V4545	258	8	3.08 i
V4697	245	0	0.00 i
V4990	177	92	51.97 abc
V5300	157	38	31.84 def
V5817	187	19	12.21 ghi
V5919	257	7	2.28 i
V5921	169	68	39.25 b-e
VC1973A	111	61	55.38 ab
TC1966	27	0	0.00 i

All data are means of 3 replicates.
[a] Mean separation by DMRT

In the confirmation of resistance test, maruca podborer infestation started initially on sesbania. (On sesbania, the pest larvae fold several leaflets around themselves and feed hidden.) Later, infestation spread to mungbean where the podborer larvae fed on flowers or inside green pods. Plants with mature pods had damage to pods. Plants without pods were found to have flower damage. We assumed that accessions with damaged flowers would also have damaged pods. The results of the screening are summarized in Table 18. Accessions TC1966, a *Vigna sublobata* entry, and V4697, a mungbean entry, were undamaged by podborer. It must be pointed out that both accessions are later maturing and had only flowers when we made our observations. Whereas very few plants of TC1966 survived through heavy rains and high temperatures, V4697 had a large number of healthy plants at observation time. The performance of TC1966, which was based on an average of nine plants per replicate, will need further verification. This accession rarely grows well in the field in Taiwan's hot and humid summer months when the podborer population is high.

Podborer damage in several other accessions, such as V3968, V4041, V4044, V4149, V4253, V4545, and V5919, was very low and on par with V4697 and TC1966. Some of them had pods, others had only flowers at observation time. During next season, these least-damaged nine accessions will be planted and evaluated separately for flower damage and pod damage in yet another multireplicate test in order to select the most reliable resistant accession for bean podborer resistance breeding.

Maruca damage to 20 mungbean, 20 blackgram, and 20 rice bean accessions tested varied from 7.85 to 33.64% in mungbean, 4.23 to 53.24% in blackgram, and 0 to 25.92% in rice bean. The order of magnitude of damage in all three species showed wide variation. In general, rice bean accessions were the least damaged. When we compared mean damage for each species, the damage to rice bean was significantly less than to mungbean and blackgram, both of which had similar levels of damage. Two rice bean accessions, TV2495 and TV2553, were free of podborer infestation.

It must be pointed out that in each species, the maturity of individual accessions varied. Some of the accessions were judged by damage to pods while others were judged by damage to flowers. In flowers, podborer larvae feed on corolla, calyx, stamens, and ovaries. We assumed that insect damage to ovaries is similar to the damage that would be caused to pods. This might not always be the case.

Sustainable Use of Natural Resources and Inputs

Among the nutrients that farmers apply to vegetables, N is by far the most important with respect to yield. Farmers tend, therefore, to apply large quanitities, despite the fact that crops seldom recover more than 40% of what is applied, with most of the residual N lost from the soil by leaching, runoff, or volatilization. In 1997, most of the project's research resources were concentrated on methods to improve N management, both to reduce the cost of N and to increase the fraction recovered. Three avenues were explored: controlled-release fertilizer applications designed to release N at rates that match potential uptake by crops; methods that improve the recovery of conventional N fertilizer; and a method for predicting crop N uptake requirements, as well as N availabilities from the soil, applied wastes, and inorganic N fertilizers.

Recoveries of controlled-release fertilizer N applied to some 1997 dry-season experiments approached 100% and the N taken up was efficiently used. In wet-season experiments that should have favored slow release of nitrate-N, however, the efficiency of controlled release nitrate-N differed little from that of ammonium sulfate. In an experiment to evaluate alternative practices for conventional N fertilizer applied to red pepper, the apparent efficiency of inorganic soil N initially available to 15 cm exceeded that of broadcast ammonium sulfate N. This finding suggested that the residual inorganic N in the surface 15 cm was only a fraction of the soil N available to the crop. The soil organic N content was too small and stable for mineralization to account for the N taken up. Therefore, large quantities probably came from fixed ammonium N or from N retained below the plow layer. Similarly, quantities of soil N taken up by Chinese cabbage and tomato were larger than expected. Uptake of soil N by the three crops ranged from 70 to 120 kg N/ha. Because the control yields in these experiments were high, yield responses to broadcast or banded N were comparatively small. To adjust the N fertilizer rate so that it is near optimal, and therefore efficient, the inorganic N in the soil profile must be accurately quantified.

Methods were developed to adjust the inorganic N fertilizer rates to account for the N contributions from crop residues and organic wastes, and for expected N recovery rates. The method is based on a mass balance, with estimations required for each component of the balance developed from a synthesis of research conducted at AVRDC and elsewhere.

AVRDC continued its quest for a small-scale hydroponics system that performs productively in the tropics. A new version that uses coated fertilizers and automated drip irrigation was developed and found promising when evaluated with fresh market tomatoes and cherry tomatoes. Yields equivalent to 41 t/ha of the former and 30 t/ha of the latter were obtained from the best treatments assessing combinations of water and fertilizer.

Application of coated compound fertilizers to solanaceous fruit vegetables in the tropics

Greater awareness about environmental issues is forcing farmers to adopt more efficient and environmentally sound technologies to minimize chemical residues, such as pesticides and nitrate, that find their way to surrounding environments. AVRDC scientists have confirmed that in the tropics at most 40% of nitrogen fertilizer applied to solanaceous crops is utilized, and the rest is leached out of fields. Recently, several fertilizer companies have succeeded in developing coated fertilizers which release nutrients a precise rates according to soil temperature and water tension. Due to their slow-release action, even direct contact between these fertilizers and crop roots results in only minimal damage. The goal of this project was to design a labor-saving and environment-friendly fertilization technology for solanaceous vegetable production in the tropics.

Three types of coated compound fertilizers with different dissolution-periods, 70, 100, and 140 days, were applied to tomato and chili pepper plants at three rates of application, i.e., 110, 147 and 220 kg/ha in N, using two fertilization methods. In the first method, the total amount of coated fertilizer necessary for the plants entire growth period was added to seedling media. In the second method, the fertilizer was applied in the field, by spotting, banding, or broadcasting. Hereafter, the first method, second method, and the AVRDC recommended fertilizer application will be referred to as SMA, FA, and AR, respectively. In all the treatments, except for AR, coated compound fertilizers were used.

Seedlings which received 100-day and 140-day coated compound fertilizers in their media did not show growth retardation due to the so-called salt effect, and produced about 1.5 times as much biomass as those plants that did not receive the coated fertilizer. However, application of 70-day type substantially retarded seedling growth, and plants eventually died due to high salt concentration in the media.

SMA and AR produced significantly higher fruit yields of tomato than did FA (Table 1). These results lead us to two important conclusions. (1) When coated fertilizer is applied to seedling medium, half the amount of fertilizer (110 kg/ha) can produce tomato fruit yield comparable to full application using conventional fertilizer (220 kg/ha). (2) For high tomato yield, it is primarily important to achieve initial vigorous plant growth. FA produced less fruit yield than did SMA and AR, because (1) in the SMA method, fertilizer was applied one month earlier than in the FA method, so the SMA seedlings were substantially bigger when they were transplanted to the field; and (2) although basal fertilizers were applied at the same time using the FA and AR methods, the coated fertilizer in the former started to dissolve much slower than the straight fertilizer in the latter, resulting in initial growth retardation.

Chili pepper yields are summarized in Table 1. Unlike tomato, there were no significant differences among the treatments or among the groups. The chili pepper was harvested one month later than tomato, consequently, enough nitrogen might have been released from the coated fertilizer for the FA plants to catch up with the SMA and AR plants in terms of fruit yield.

Nitrogen budgeting per plant is summarized in Table 2. N balance can be expressed in the following equation: (N uptake + N left in soil) = (N added + N unknown) X + B. Here, N unknown is N sources other than fertilizer added, X is absorption coefficient, B is a constant relating to soil N, etc. To simplify the equation, N unknown is, at first, calculated by subtracting N added from the sum of N uptake and N left in soil. There was a significant difference between SMA and FA (Table 2). N unknown for SMA was seven-times higher than for FA. The N unknown was most likely from the compost used as seedling medium. SMA seedlings were raised in 650 ml of compost while FA seedlings were raised in 180 ml of compost. Suppose N unknown does not change among the treatments within the same group, and takes a constant value, hence can be replaced by a mean value (6.88 and 0.99 for SMA and FA, respectively). Thus, the relationship between them would be reduced to a linear equation with only one independent variable, $Y = AX + B$. The constants, A and B were calculated by a least-square method and the best fit equation was obtained as $Y = 0.85X + 0.99$.

Residuals against the predicted Y became statistically significant between SMA-FA group and AR, and their values are 0.350, 0.071, and -4.271, respectively. This indicates that the coated fertilizers give rise to very tiny leaching loss of nitrogen compared to the conventional fertilizers, such as ammonium sulfate and urea when applied to a tomato field. This is true in particular when coated fertilizers are applied in a seedling medium. Table 1 clearly shows that half an amount of coated fertilizer can produce, at worst, a comparable

Table 1. Yield of tomato and chili pepper under different fertilization methods

Fertilization method[b]	N applied (kg/ha)	Yield: Tomato (t/ha)	Yield: Chili pepper[a] (t/ha)
SMA	110	103.3 a	31.2 a
SMA	147	79.8 b	32.5 a
FA	147	80.5 b	31.2 a
AVRDC	220	102.0 a	30.1 a

[a] SMA: seedling media application of coated compound fertilizer
FA: field application of coated compound fertilizer
AVRDC: AVRDC recommended fertilization of straight fertilizer

Table 2. N budget in different fertilizer application methods

Crop	Fertilization method[a]	N balance (g/plant)	N unknown (g/plant)	Residuals[b] (g/plant)
Tomato	SMA	-1.85 b	6.88 a	0.35 a
	FA	0.25 b	0.99 b	0.07 a
	AVRDC	3.41 a		- 4.27 b
Chili pepper	SMA	- 6.95 b	10.33 a	1.89 a
	FA	- 4.62 b	5.34 b	- 1.65 ab
	AVRDC	- 1.38 a		- 2.71 b

[a] SMA: seedling media application of coated compound fertilizer
FA: field application of coated compound fertilizer
AVRDC: AVRDC recommended fertilization on tomato and chili pepper

yield achieved using a full amount of conventional fertilizer.

Coated fertilizer was found to be as much as twice as efficient as conventional fertilizer in terms of utilization rate when applied to solanaceous fruit vegetables in a dry season. In other words, apart from minimizing leaching loss of eutrophied nutrients out of vegetable fields, coated fertilizers might, to a great extent, reduce the total production cost of vegetables.

AVRDC water-saving hydroponics

There is great demand for safe and nutritious vegetables in peri-urban areas. Simple, less intensive cultivation technologies are urgently needed to meet this demand. AVRDC's non-circulating hydroponic system might be an answer.

A 30 cm × 200 cm × 20 cm container was constructed out of polystyrene (Fig. 1). A trough of nylon netting was suspended from two aluminum pipes spaced 10 cm apart and fitted along the inside top length of the box. This trough would hold the growth medium, about 400 cc of peat moss per plant.

Macronutrients were applied by coated compound fertilizer (CCF) ($N:P_2O_5:K_2O$=14:12:14, Chisso-Asahi Co. Ltd.) and dolomite powder (Ca 30%, Mg 22%, Fe 1.1%, B 0.2%). Similarly, micronutrients were added in the form of slow-releasing coated fertilizer (Mn 10.6%, B 4.0%, Zn 4.1%, Cu 2.7%, Minerass E Frit, Ferro Enamal Ltd.). Application rate for the coated fertilizer was determined from a best-fit equation for N absorption by hydroponically grown tomatoes. About 9.9 g N is absorbed per plant in 100 days so that the application rate of the CCF was set at 70 g/plant (N content of CCF is 14 %). In the "Basal" treatment, all 70 g of CCF was applied as a basal fertilizer in the middle layer of the medium, while in the "Basal + Top" treatment, 30 g of CCF was applied as basal and 40 g was added in two top-dress applications of 20 g each, with a one-month interval. Dolomite was applied separately at a rate of 15 g/plant as a basal and was also top-dressed at 40 days after transplanting (DAT). Forty milligrams of micronutrient fertilizer was applied once as a basal application. Water was supplied by drip irrigation. A total of 210 ml of water was supplied to each plant per day in the first two weeks. Water supply was increased by about 40 ml and 100 ml for the "limited" and the "normal" watering plots, respectively, at five weeks after transplanting (WAT). Finally, a total of 410 ml and 340 ml of water was added to each plant per day in the "normal" and the "limited" plots, respectively, at 7 WAT and afterward. These levels were kept until the termination of the experiment.

Three-week-old seedlings of two tomato varieties, a summer tomato line, CL5915-206, and a cherry tomato, CHT154, were transplanted on 21 July 1997, to the peat moss medium in the hydroponic container in an AVRDC greenhouse.

The microclimates outside and inside the container were as follows: Maximum air temperature in the greenhouse and inside the container were 41 and 32°C, respectively. The temperature of the peat moss media went up to 31°C by around 1630 hours and the water which accumulated at the bottom of the container (1 to 2 cm deep) rose to as high as 40°C by around 1400 hours.

The first harvest of the cherry tomato variety was conducted at 70 DAT. There was no significant difference in the yield and yield components between the water treatments (Table 3). In the fertilization method, however, Basal + Top produced about 20 % higher yield than Basal only. The interaction between the water treatments and the fertilization was significant. This indicates that tomato growth is strongly affected in this hy-

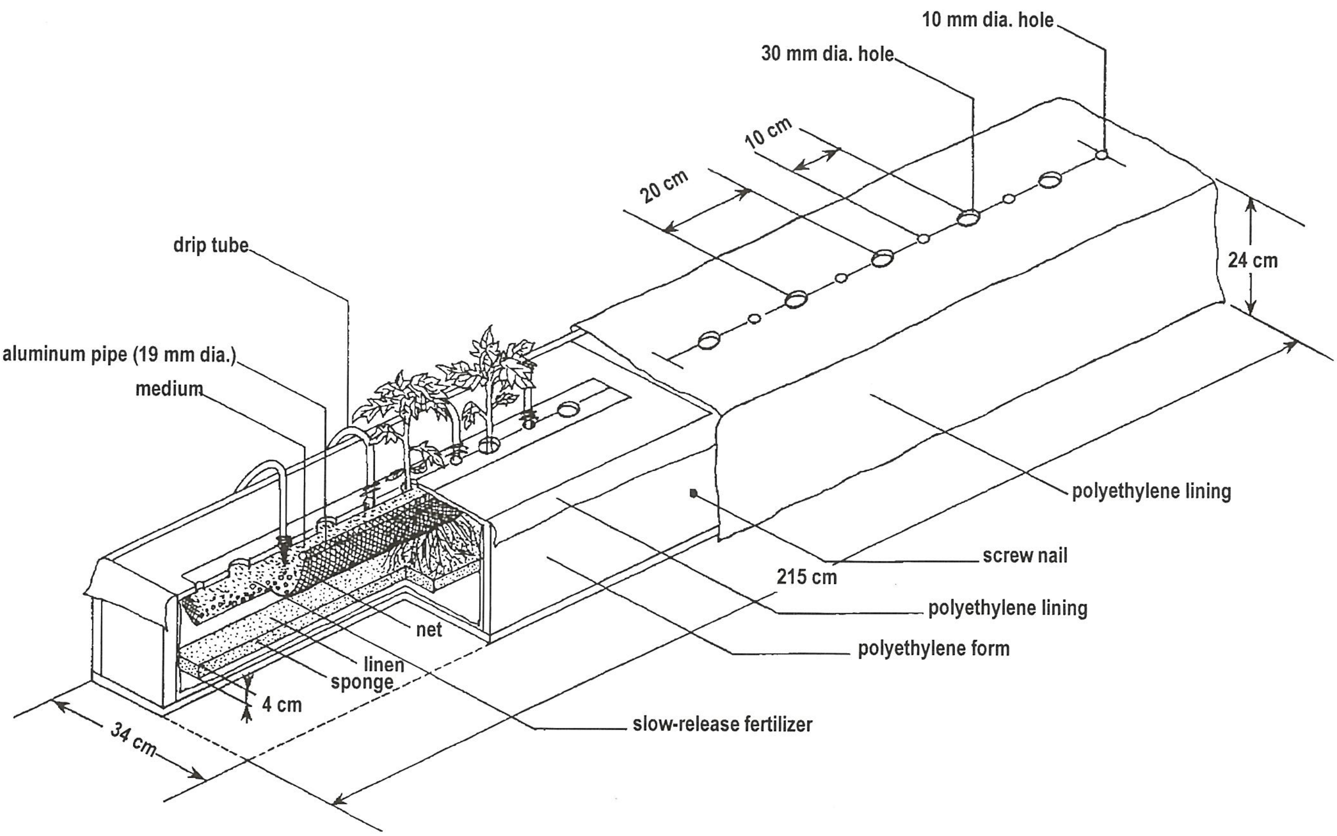


Fig. 1. System construction for water-saving hydroponics

droponic system when water supply is limited, whether all (70 g) or only a portion (30 g) of the coated fertilizer is applied as a basal treatment. When water was limited, the Basal + Top treatment produced higher yield, and the Basal plot produced lower yield. No difference was observed, however, when water was supplied at the Normal level.

The first harvest of summer tomato was conducted at 70 DAT. Unlike the cherry tomato, there was a significant difference in fruit yield between water treatments, but not between fertilization methods (Table 4). The Basal only plot with the Normal water supply produced the highest yield, while the Basal only plot with Limited water supply produced the lowest yield. The interaction between water treatment and fertilization method was also significant.

Fruit acidity and soluble solids (Brix) were compared. No significant difference could be observed in these indices between water treatments, whereas only the Brix became statistically significant between the fertilization methods. It is noteworthy that the Brix values of the cherry tomato exceed 8.5 in all the treatments. The Brix of this line grown in the field seldom exceeds seven.

Blossom end rot (BER), usually a problem in noncirculating hydroponic production of summer tomatoes, was negligible in the Normal plot. Yield was 1.5 times higher than targeted for at 70 DAT. The summer trial yielded between 60 and 70 t/ha in four months. Thus, this environment friendly, water- and labor-saving hydroponic system could help overcome the problems associated with high temperatures in summer tomato production to achieve high yield and high quality.

Management to increase recovery and utilization efficiency of inorganic N by vegetables

N efficiency can be increased by matching the availability pattern of fertilizer N with the uptake patterns of crops. Particularly in the wet season, nitrate

Table 3. Effect of water supply and fertilization on yield and quality of cherry tomato

Treatment	Total fruit number (X 1000/ha)	Average fruit wt. (g)	Total yield[a] (t/ha)	Acidity (% citric acid)	Soluble solid [b] (Brix)
Main-plot: Water supply					
Normal	4,755 a	5.95 a	27.3 a	0.35 a	8.8 a
Limited	4,293 a	5.73 a	26.1 a	0.33 a	8.9 a
Sub-plot: Fertilization					
Basal	4,280 a	5.48 a	23.5 b	0.33 a	8.6 b
Basal+Top	4,768 a	6.20 a	29.8 a	0.35 a	9.1 a

[a] Plant population is calculated as 71,429 plants per ha.
[b] Mean separation within column by DMRT at $p = 0.05$.

Table 4. Effect of water supply and fertilization on yield and quality of fresh market tomato

Treatment	Total fruit number (X 1000/ha)	Average fruit wt. (g)	Total yield[a] (t/ha)	Acidity (% citric acid)	Soluble solid[b] (Brix)
Main-plot: Water supply					
Normal	634 a	61.6 a	41.0 a	0.25 b	5.6 b
Limited	518 a	58.0 a	29.0 b	0.33 a	6.6 a
Sub-plot: Fertilization					
Basal	586 a	61.3 a	36.1 a	0.29 a	6.0 a
Basal+Top	566 a	58.3 a	34.0 a	0.29 a	6.1 a

[a] Plant population is calculated as 71,429 plants per ha.
[b] Mean separation within column by DMRT at $p = 0.05$.

leaching or denitrification promoted by excess soil water contribute to inefficiency.

Nitrogen deficiencies during early growth are more detrimental to species such as Chinese cabbage than to others, such as red peppers. Compared to red pepper, Chinese cabbage has little opportunity to compensate for an early deficit. Moreover, N remaining in the soil from the previous crop affects early growth of the following crop. Regardless of the compensatory nature of the species, the quantity of inorganic N in the soil at planting should be considered when N rates are decided.

Three dry season (DS) experiments compared early N management (form, rate, placement, starter solution). In field experiments on Chinese cabbage and tomato, initial soil inorganic N was <10 mg/kg, but it ranged from 20 to 60 mg/kg in a red pepper experiment. Other than the pre-plant N treatments, management practices (including N topdressings) for these experiments were those commonly followed at AVRDC.

In all experiments, it was evident that the soil supplied N in quantities that exceeded the initial inorganic N (IIN) plus that which could be mineralized from organic matter during crop growth. Estimates of the quantities of N obtained from the soil by red pepper, Chinese cabbage, and tomato, were 90, 70, and 120 kg N/ha, respectively. For all crops in these experiments, it was evident that the soil supplied N in quantities that exceeded the IIN plus that which could be mineralized from organic matter during crop growth.

Only Chinese cabbage exhibited benefits from starter N. The beneficial effects of starter N (4.4 kg N/ha applied in solution to the transplanted seedlings) and banded basal N on Chinese cabbage are evident in Fig. 2. The starter and banded effects were largely additive (i.e., starter N did not substitute for banded basal N). Regardless of application method, large quantities of inorganic N were detected in the soil at harvest and the concentrations increased with N rate.

Early in the tomato experiment, viruses infected many plants (Fig. 3). The percentage of rogued plants was greatest in the direction of the prevailing wind (from the north). The effect of plant density, used in an analysis of covariance on fruit yield, is apparent in Fig. 4. Starter N had no effect, and preplant broadcast and banded N had only minor effects on tomato yields (Fig. 5).

Red pepper yields were significantly related to IIN. The dashed portion of the yield response function in Fig. 6 reveals that red pepper took up a large quantity of IIN. The response to IIN was three-fold the response to broadcast N (Fig. 7), though responses were expected to be equal.

Three wet season (WS) experiments compared controlled release fertilizers (CRF). Heavy rainfall and irrigation (purposely applied in excess) created conditions ideal for nitrate leaching and denitrification.

Ammonium sulfate (AS) was applied at rates up to 240, 200, and 240 kg N/ha in the first and second Chinese cabbage, and eggplant experiments, respectively. Two rates of two CRFs were applied in the first Chinese cabbage and in the eggplant experiments (Figs. 10 and 12). In the second Chinese cabbage experiment, combinations of formulations designed to release in synchrony with N uptake by Chinese cabbage were tested.

The intensity of rainfall + irrigation (R+I) during the first CRF experiment, indicated by the dates and quantities (mm/day) in Fig. 7, was representative of the intensities in the other WS experiments. Total R+I was 714, 538, and 1380 mm on the first and second Chinese cabbage and the eggplant experiments, respectively. Inorganic N release patterns of the five CRF formulations are shown in Fig. 9.

Cumulative N availabilities from CRF were predominantly linear functions of cumulative degree days. No CRF formulation was superior to AS as measured by yield response (Figs. 10 to 12). The yields of the four CRF treatments in the eggplant experiment fell almost exactly on the AS response curve (Fig. 12).

Responses to CRF-N were more variable in the Chinese cabbage experiments (Figs. 10 and 11), perhaps because a close synchrony between release and uptake is harder to achieve for a crop that is harvested after only 40 to 50 days. When band-applied to AVRDC soils, AS is probably an efficient wet-season fertilizer because the combination of banding and ammonium fixation protects N from rapid nitrification and therefore from leaching and denitrification.

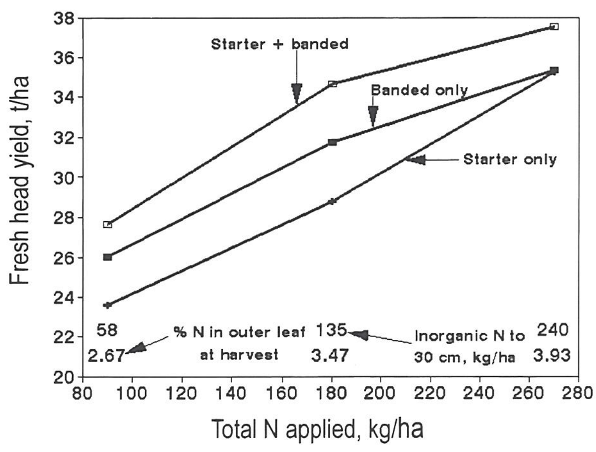


Fig. 2. Chinese cabbage head yield responses to N rates and methods of placement

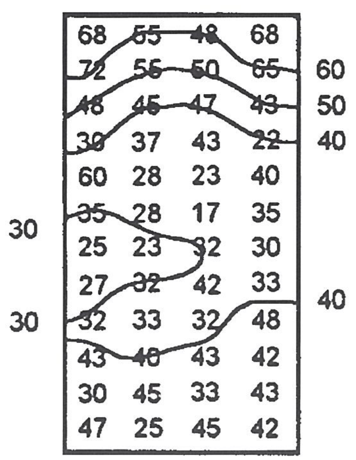


Fig. 3. Percentage of virus-infected tomato plants rogued per plot

An N balance equation to determine N fertilizer rates

Nutrient management efficiency can be improved by using balance equations of the form $M_{crop} = \Delta M_{org} \times e_{org} + \Delta M_{in} \times e_{in} + M_f \times e_f$, where M is a nutrient (kg/ha), and subscripts crop, org, in, and f refer to the crop requirement, the soil and waste organic nutrient supplies, soil inorganic and fertilizer inorganic nutrient supplies, respectively. The denominators are nutrient recovery rates. To use the equation to improve N management for a crop, N_{crop} must be estimated. Furthermore, the

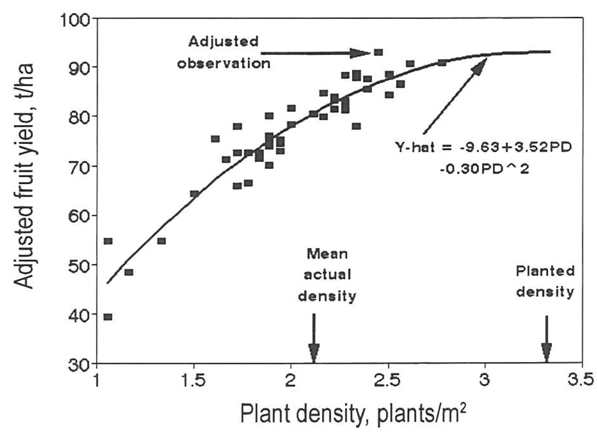


Fig. 4. Tomato yield versus plant density

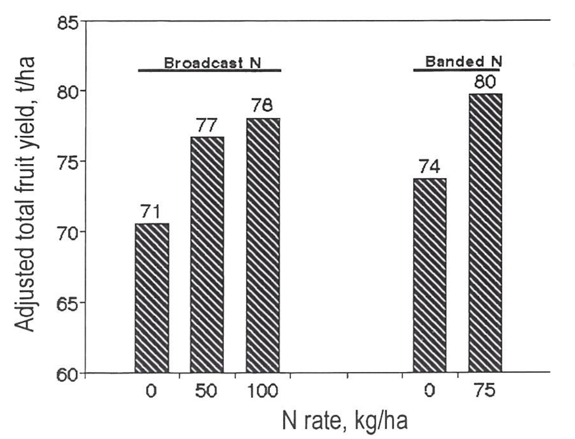


Fig. 5. Tomato yields (adjusted) from broadcast and banded N

time course of uptake identifies the growth stage of the crop at which the uptake rate of N is maximum. The estimated difference between $\Delta N_{org} \times e_{org} + \Delta N_{in} \times e_{in}$ and N_{crop} is the requirement from inorganic fertilizer ($N_f \times e_f$). To calculate the fertilizer rate (N_f), e_f must be estimated. The following sections were abstracted from draft sections of a manual on fertility management for vegetable crops.

To develop relationships between nutrient uptake and yields, data from AVRDC experiments and published reports were compiled. For each crop, functions were established to relate economic yields to total N uptake. To estimate e_f, a simple method appropriate for vegetables was developed.

Functions of economic yield (dry basis) versus N uptake by tomato, pepper, and eggplant, are shown in Fig. 13, and common cabbage, Chinese cabbage, and leaf vegetables are shown in Figs. 14 to 16, respectively. With the exception of the Chinese cabbage, the data

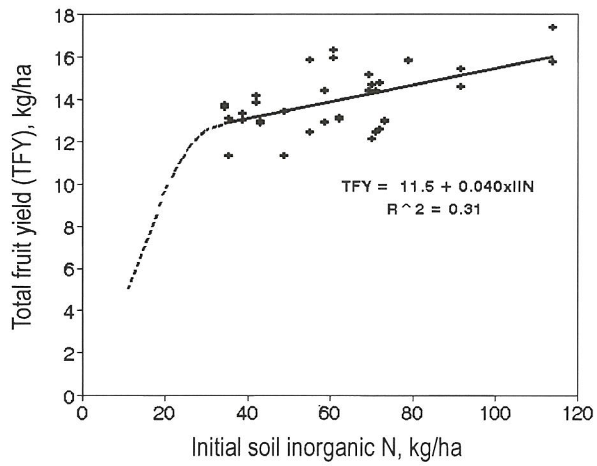


Fig. 6. Total fruit yield of red pepper versus initial soil inorganic N

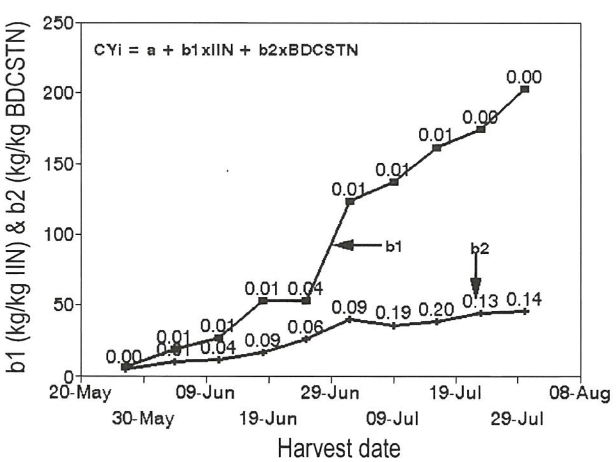


Fig. 7. Coefficients from regressing cumulative red pepper yields on initial soil inorganic and broadcast N

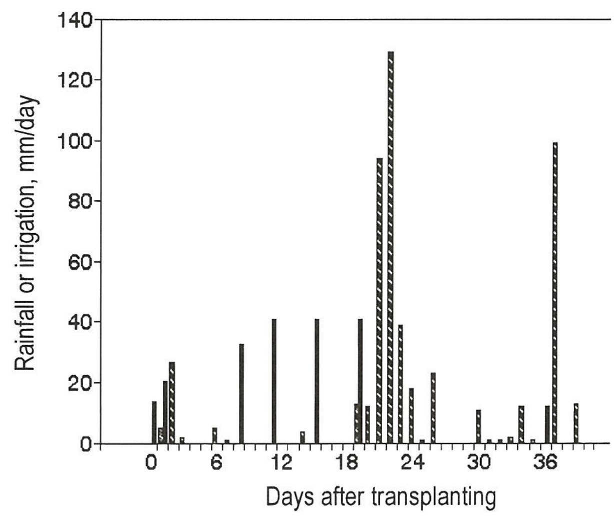


Fig. 8. Daily rainfall and irrigation on the first wet-season Chinese cabbage experiment

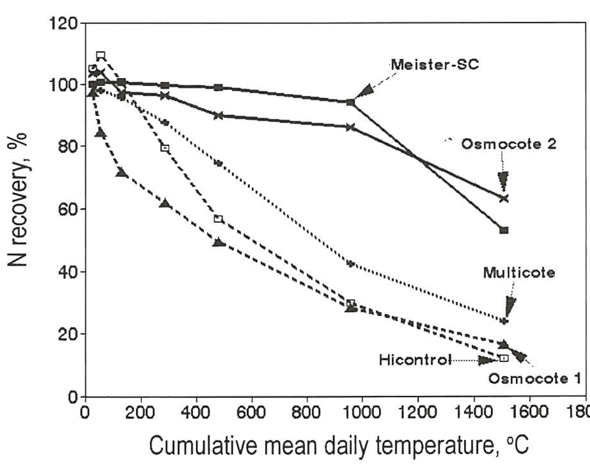


Fig. 9. Percentage of N remaining in CRF granules versus cumulative degree days, °C

represent wide environmental distributions. The bottom function (solid) shows average relations, the top function (dashed) shows the efficient frontier, and the middle function (dotted) shows a relation regarded as efficient but not risky.

The time course of N uptake for a high-yielding common cabbage crop is shown in Fig. 17. Roman numerals designate growth stages (GS). The daily N uptake rate during GS III was 4.2 kg/ha. Similar figures are presented for other species in the manual. P and K uptake parallel N uptake. The average ratio of P to N uptake is 1:0.15. The ratio for K exhibits large variation within a species. Nevertheless, a ratio of 1:1.2 appears to be appropriate for tomato and leafy vegetables, and 1:1 appears appropriate for other crops.

For vegetables, e_f generally decreases as N rate increases. The relation is linear over much of the N application range (Fig. 18). When exceptions to linearity occur, e_f remains constant over the initial segment of the response function, but subsequently decreases as N rate increases. The points that locate the e_f function in fig. 6 are apparent N recoveries. The calculated recov-

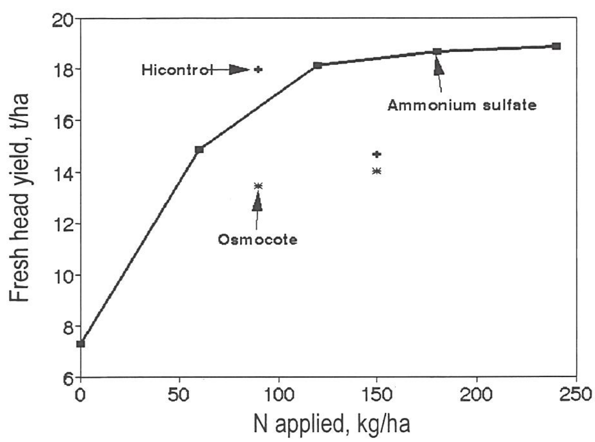


Fig. 10. Mean yields from the first wet-season Chinese cabbage experiment

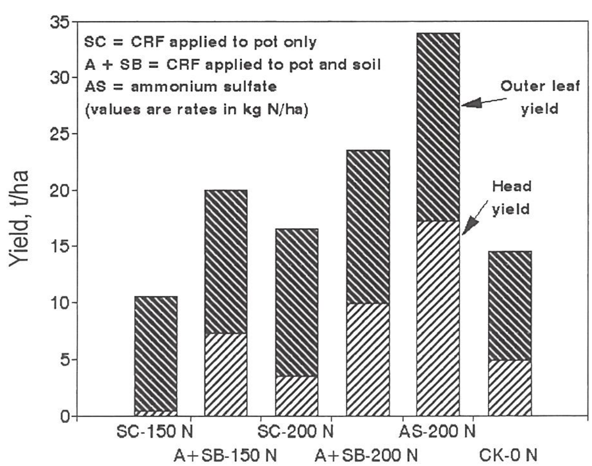


Fig. 11. Mean yields from the second wet-season Chinese cabbage experiment

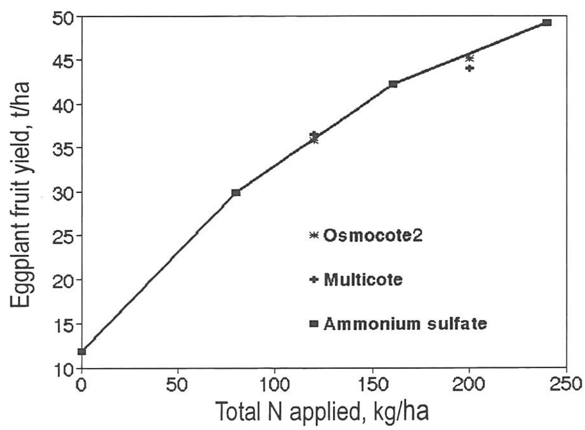


Fig. 12. Mean yields from the wet-season eggplant experiment

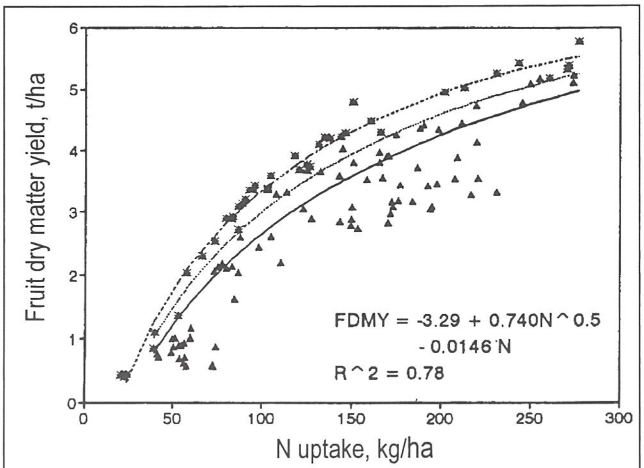


Fig. 13. Solanaceous fruit matter yield (dry) versus N uptake

eries are plotted and the function is drawn. For vegetables, e_f at high N rates are most relevant. The N uptake points for figures, such as those in Fig. 18, can be estimated from yield responses to fertilizer rates and yield-uptake functions (as in Figs. 13 to 16) as well as calculated directly from tissue N concentrations and dry weights of plant parts.

Functions of e_f versus N applied are dependent on soil properties, climatic factors, N source, and management practices (including irrigation and drainage practices). N rate versus e_f relations for the typical physical conditions and production practices which occur in a Resource Management Domain (RMD) are required for general use.

For example, the more skillful cabbage farmers in an RMD obtain yields of 70 t/ha. At 8% dry matter, N_{crop} is about 240 kg N/ha (from the equation in Fig. 14). The $\Delta N_{org}e_o$ for the RMD, entirely from soil OM, is estimated by other methods to be only 40 kg N/ha. When the preceding crop is maize, $\Delta N_{in}/e_i$ is 20 kg N/ha; when

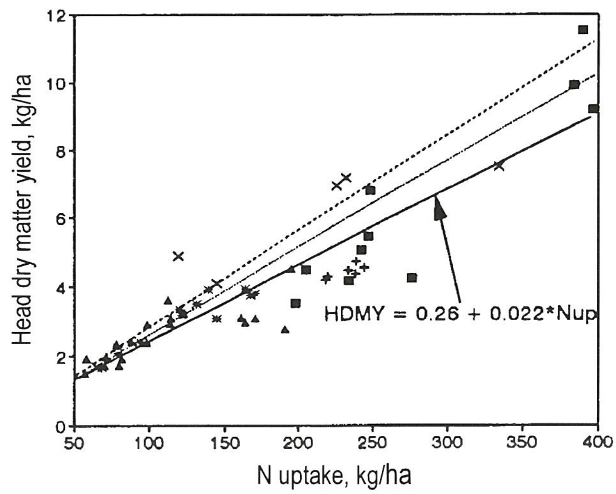


Fig. 14. Common cabbage head yield (dry) versus N uptake

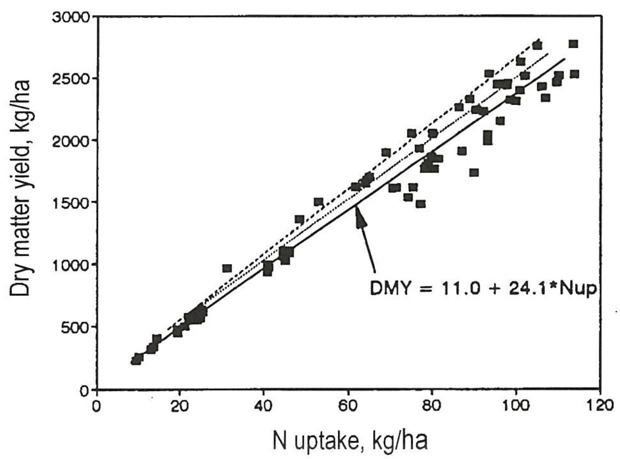


Fig. 16. Leaf vegetable yield (dry) versus N uptake (kangkong excluded)

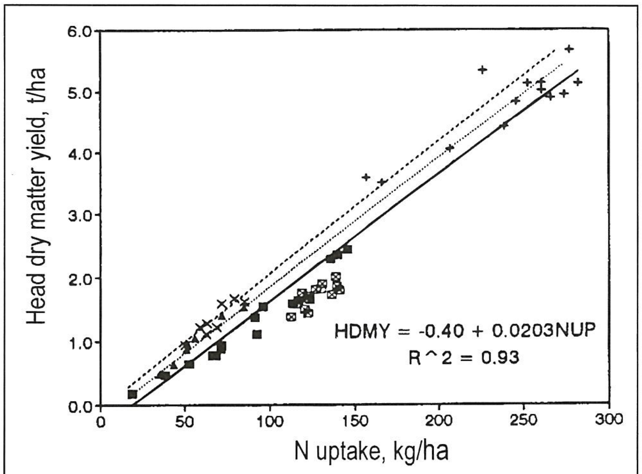


Fig. 15. Chinese cabbage head yield (dry) versus N uptake

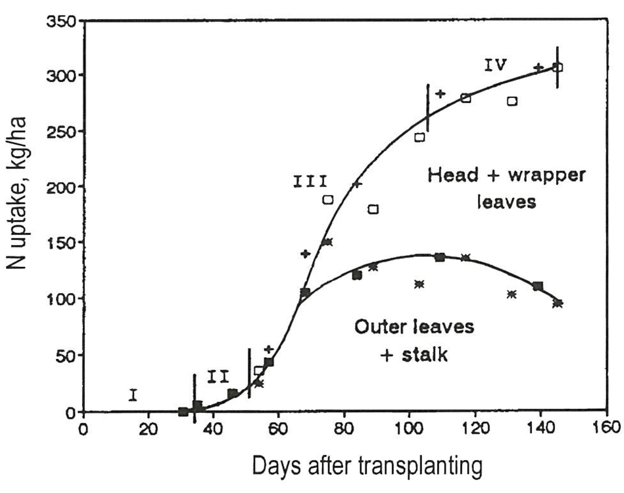


Fig. 17. Cumulative N uptake by common cabbage versus days after planting

the preceding crop is mungbean, it is 70 kg N/ha, both expressed as Nitrogen Fertilizer Equivalents (NFE). For N_{crop} = 240 kg N/ha, e_f is about 0.6 kg/kg. If the preceding crop is maize, the N_f requirement is 310 kg/ha; if the preceding crop is mungbean, it is 260 kg/ha. From Fig. 17, it is reasonable to expect that the most efficient recovery would be attained by N applications of 25 to 30% at planting with the balance sidedressed early in GS II, and the remainder about one-third of the way into GS III.

About 130 kg N/ha from the fertilizer + residual NFE would not be recovered. By resorting to tables and equations in the manual, the approximate quantity of N available for the following crop can be determined. The N harvest index for cabbage is about 58% and, therefore, about 100 kg N/ha taken up by the crop will be recycled in the crop residue if it is incorporated. The crop residue will decompose rapidly, releasing N in the process. The estimated quantities of residual N fertilizer and N recycled released from the residue can be used to adjust the N rate for the next crop.

Effect of raw and composted crop residues and animal wastes on N availability

Methods of estimating the M_{crop} and $M_f \times e_f$ terms of an N balance equation were described above. Methods to estimate $M_{org} \times e_o$ and $M_{in} \times e_i$ are summarized here for N. The methods are based on research conducted in recent years at AVRDC as well as on methods abstracted from literature, particularly from publications that describe the modeling of soil N processes.

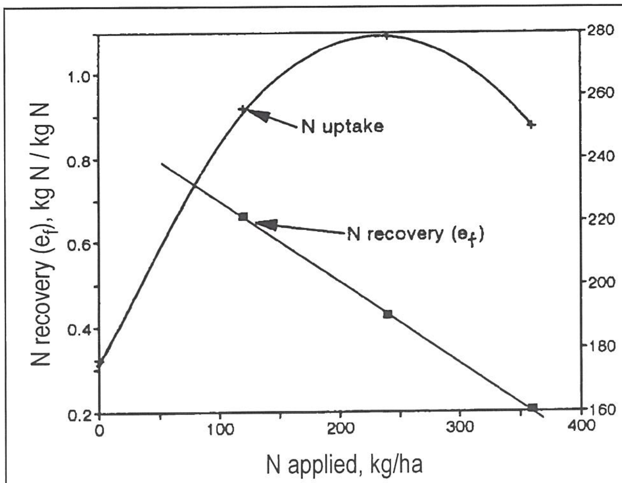


Fig. 18. N uptake by cabbage and e_f versus N applied

The $\Delta N_{in} \times e_i$ term in the balance described previously is probably the most difficult to quantify. The best (but usually impractical) procedure is to sample the soil to the expected depth of effective root growth, and extract N_{in} chemically. For the equation, 1 kg/ha of extracted N_{in} is approximately equivalent to 1 kg inorganic fertilizer N/ha. An alternative procedure is to estimate the quantity of unrecovered N from the previous crop (and the mineralization of soil or residual organic N if the preplant fallow period is lengthy), and use equations in the manual (accompanied by tables and figures) to determine if denitrification or leaching will have caused significant N loss. These calculations will indicate the size of ΔN_{in}, as well as suggest if strategies to reduce losses due to leaching or denitrification would be beneficial.

N_{org} represents several organic N sources, including the N in young and old soil organic fractions. Contributions can be estimated by equations (used for plotting Fig. 19) or from a table. Several tables summarize the typical nutrient contents of other N_{org} sources: crop residues, green manures, agricultural wastes, and, to a lesser extent, other wastes. Given the characteristics and history of each source and quantity to be applied (or that *has* been applied if residual contributions extend to several crops), N_{org} can be estimated. To estimate ΔN_{org} during the crop (and pre- and post-crop fallow periods), C and N mineralization are calculated as functions of C composition and CN ratio. Figure 20 contrasts N mineralization rates for materials with narrow CN ratios but differing C composition. A k-rate of 0.0001 d^{-1} represents a very slowly decomposable (highly humified) source of C. A k-rate of 0.05 d^{-1} represents an easily decomposable C source. N in vegetable crop residues and green manures, composed of readily decomposable C with a narrow CN ratio, mineralizes so rapidly that its release is concentrated well before the daily uptake requirement for most crops is maximum (Fig. 21). Figure 22 is representative of a rapidly decomposing material.

Mineralization from material with CN ratios in the range of 20 to 24 is so slow that daily rates are too small to be major sources of N for a crop even during GS III. When the CN ratio is wider than 24, N immobilization occurs, usually for a brief period. After the immobilization phase, however, N mineralizes slowly; moreover, some of the mineralized N is previously immobilized soil N or fertilizer N. A method to estimate the quantity of N fertilizer required to offset the yield depressing effect of N immobilization is described in the manual.

Mature composts have narrow CN ratios but con-

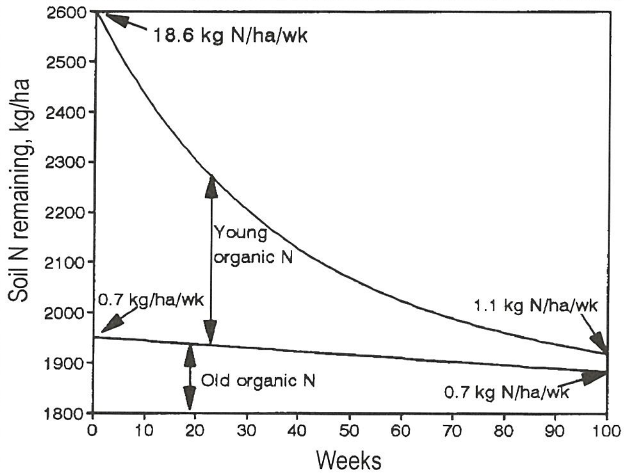


Fig. 19. Soil N remaining in young and old fractions and average weekly N mineralization rates

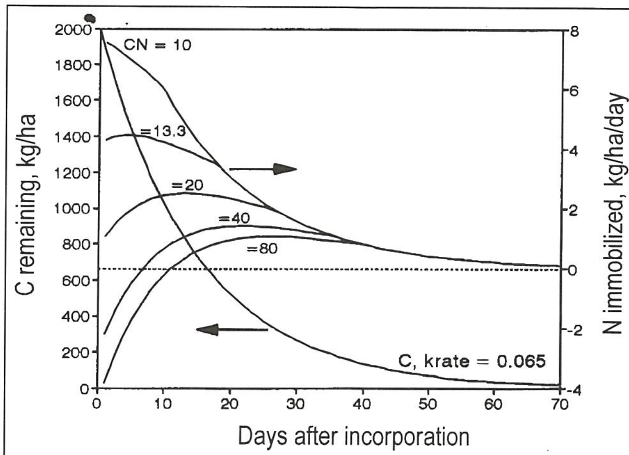


Fig. 21. Estimated C remaining and daily rates of N immobilization or mineralization from 2000 kg/ha application of easily decomposed C, with CN ratios from 10 to 80

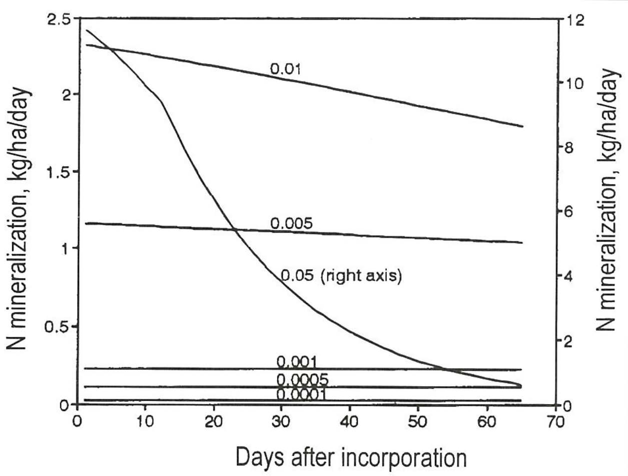


Fig. 20. Daily rates of N mineralization from 400 kg N/ha in materials with a wide range of k-rates for C but with an initial CN ratio = 10 for all

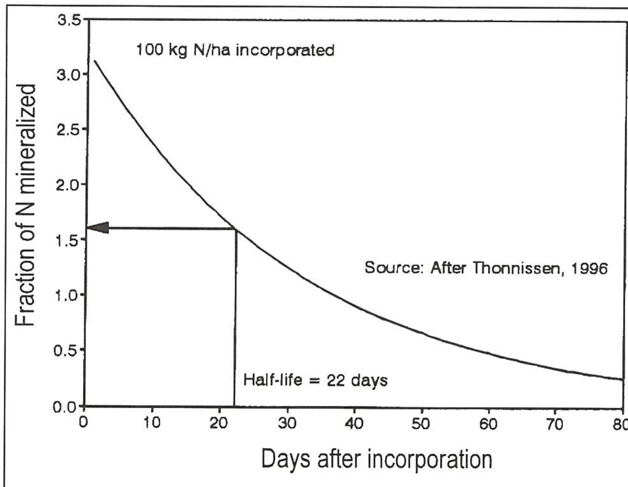


Fig. 22. Daily rates of N mineralization from a soil-incorporated green manure (60-day soybean)

tain very slowly decomposing forms of C. Although the daily N mineralization rate of each application is small (Fig. 20), the accumulated residuals increase the average daily rate (Fig. 23). But because mineralization proceeds regardless of the presence or absence of a crop, excessive accumulations of residual compost N should be avoided. Long idle periods between crops should be minimized. Computational methods are described in the manual as are methods for selecting k-rates for C for different sources.

N release rates from livestock manures range from rapid to slow, depending on animal species and other factors. The substantial inorganic N plus urea-N in fresh manure is available upon incorporation. The availabilities of N in old manures, however, are reduced because C undergoes partial humification during storage; moreover, some accumulated inorganic N is lost. The curves in Fig. 24 were derived from values published for the USA by assuming that the annual cumulative degree days in the tropics is 3650°C greater than in temperate USA and that the Q_{10} for mineralization is 2. The use of manure coefficients in the balance equation is described in the manual, as are methods to confirm coefficient validities for local sources and conditions.

N recovery from ΔN_{org} (i.e., e_o), is similar to e_f for an equivalent quantity of N_f, provided that seasonal availabilities are similar. To the extent that they are not, the e_o must be adjusted.

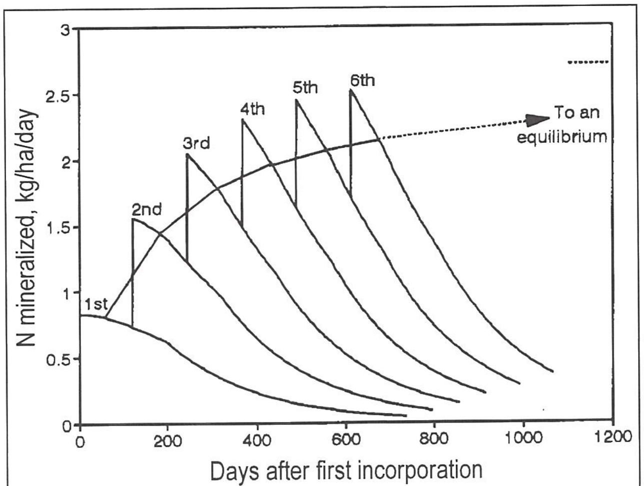


Fig. 23. Estimated daily N mineralization from mature compost incorporated at 123-day intervals, each application containing 333 kg N/ha

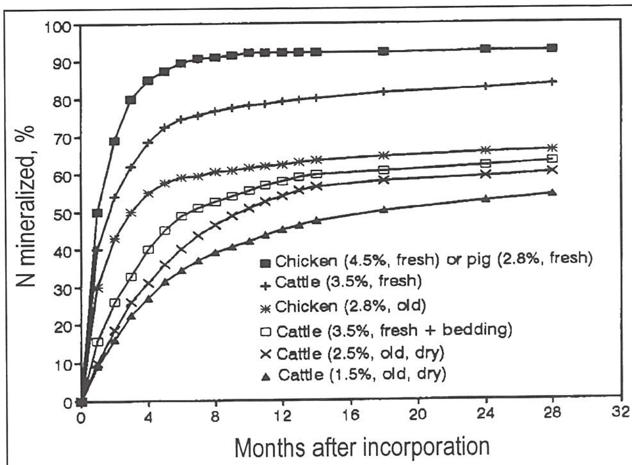


Fig. 24. Estimated cumulative mineralization percentages from animal wastes

Overcoming Seasonal Stresses of Production

The main constraints on summer vegetable production are high temperatures, flooding, and associated insect and disease problems. To address these constraints, appropriate management of crop, soil, and water should be practiced for more sustainable and economically viable vegetable production during hot and humid summer months. This project aims to develop integrated technologies to overcome these seasonal stresses. Innovative techniques, as well as traditional techniques, are assessed for their effectiveness.

In 1997, the susceptibility of tomato plants to flooding damage was assessed at different growth stages, and the value of grafting tomato scions on eggplant rootstock was evaluated. Younger plants were found to survive flooding better than plants flooded at at a later growth stage. And tomato plants grafted onto eggplant rootstock showed convincing survivability after flooding. As for cultural practices to minimize bacterial wilt (BW), the effect of soil amendments, including various organic materials, such as tea leaf and bulb onion powder, was tested.

Grafting to minimize BW damage was studied. Three kinds of grafting combinations were tested, i.e., tomato-tomato, tomato-eggplant, and eggplant-eggplant, using several entries of scions and rootstocks. The extent of resistance to BW was clarified for tomato and eggplant rootstocks, and the susceptibility to BW was also found significantly different between different scions grafted to the same rootstock entry.

Minimizing bacterial wilt damage by grafting

Bacterial wilt is a devastating disease of solanaceous vegetables in the humid tropics. Grafting onto resistant rootstocks has proven to be an effective and economically viable means to control the disease. This project screened promising rootstocks for resistance to BW, compatibility between scion and rootstock, and the off-season yield of tomato and eggplant.

Three kinds of grafting, i.e., tomato-tomato, tomato-eggplant, and eggplant-eggplant, were studied. Tomato varieties FMTT22 and Known You 301 (KY 301), and eggplant varieties Bride and Pingtung Long,

Table 1. Mortality and yield of tomato plants with different tomato rootstocks

Rootstocks	Mortality (%) Scions FMTT22	Mortality (%) Scions KY301	Mean of rootstocks[a]	Fruit yield (t/ha) Scions FMTT22	Fruit yield (t/ha) Scions KY301	Mean of rootstocks[a]
Hawaii 7996	1.5	25.5	13.5 a	86.7	39.5	63.2 a
BF Okitsu 101	0.0	56.5	28.3 b	90.7	19.5	55.2 a
BL 1004	1.4	77.5	39.5 b	79.5	22.1	50.9 ab
CRA 66	13.0	90.5	51.8 bc	76.3	8.5	42.4 b
BL 989	18.0	94.5	56.3 c	66.7	5.3	36.0 bc
L 180	26.0	93.5	59.8 c	52.5	14.9	33.9 c
Non-grafted	82.5	100.0	91.3 d	19.7	0.0	9.9 d
Mean of scions	20.4 a	76.9 b		67.5 a	15.7 b	

	Mortality: Scion	Mortality: Rootstock	Mortality: Scion X Rootstock	Fruit yield: Scion	Fruit yield: Rootstock	Fruit yield: Scion X Rootstock
Significant level[b]	***	***	***	***	***	**

[a] Mean separation within column by DMRT at p = 0.01

[b] ** and *** stand for the significant level of p = 0.01 and 0.001, respectively.

were selected to supply scions. Similarly, six varieties of tomato and eggplant were selected as rootstocks. A split plot design was adopted with two replications, with entries for scion as the main plot and entries for rootstock as the subplot. The experimental field was inoculated by mixing chopped, infected tomato seedlings into the soil.

For tomato-tomato grafting, the best rootstock was Hawaii 7996 in terms of survival rate and fruit yield. This was followed by BF Okitsu 101 and BL 1004. Other entries did not show enough resistance to BW (Table 1). When FMTT22 was used as scion on the above-mentioned three rootstocks, there was virtually no BW damage. Survival rate of KY 301, however, was 75% at most, even though it was grafted onto a highly resistant rootstock, Hawaii 7996. Differences in mortality strongly indicate that resistant rootstocks cannot prevent the bacterial pathogen from invading the rootstock tissue and moving to the grafted scion through the splice. For tomato-eggplant grafting, the best eggplant rootstock was EG 203, followed by EG 190, and EG 197. The other entries showed unsatisfactory resistance to BW (Table 2). Differences between scions were not significant with regards to mortality, but were significant with regards to yield (FMTT22 > KY301).

Table 2. Mortality and yield of tomato plants with different eggplant rootstocks

	Mortality (%)			Fruit yield (t / ha)		
	Scions		Mean of	Scions		Mean of
Rootstocks	FMTT22	KY301	rootstocks[a]	FMTT22	KY301	rootstocks[a]
EG 203	9.7	35.5	22.6 a	45.9	17.3	31.5 a
EG 190	47.9	50.7	49.3 b	38.4	15.5	26.9 ab
EG 197	50.0	56.4	53.2 b	35.7	13.1	24.5 b
TS 64	69.1	87.1	78.1 c	20.0	8.8	14.4 c
EG 220	80.1	98.3	92.7 c	14.1	2.9	8.5 cd
EG 202	100.0	100.0	100.0 c	5.3	0.5	2.9 d
Non-grafted	100.0	100.0	100.0 c	6.1	0.0	2.9 d
Mean of scions	66.2 a	75.4 a		23.7 a	8.3 b	
	Significant level[b]			Significant level[b]		
	Scion	Rootstock	Scion × Rootstock	Scion	Rootstock	Scion × Rootstock
	ns	***	ns	***	***	ns

[a] Mean separation within column by DMRT at p = 0.01.
[b] *** stand for the significant level of p = 0.001.

Table 3. Mortality and yield of eggplant plants with different eggplant rootstocks

	Mortality (%)			Fruit yield (t/ha)		
	Scions		Mean of	Scions		Mean of
Rootstocks	Bride	Pingtung L	rootstocks[a]	Bride	Pingtung L	rootstocks[a]
EG 203	6.5	4.9	5.7 a	88.0	69.5	78.8 a
EG 190	27.5	6.5	17.0 ab	86.0	68.5	77.3 a
TS 64	59.0	37.1	48.4 bc	65.5	60.0	62.8 a
EG 197	59.6	45.2	52.4 c	58.0	53.5	55.8 ab
EG 220	96.7	93.6	95.2 de	11.0	10.0	10.5 cd
EG 202	100.0	100.0	100.0 e	0.0	0.0	0.0 d
Non-Grafted	96.8	30.4	63.6 cd	6.5	67.5	37.0 bc
Mean of scions	63.8 b	45.4 a		45.0 a	47.0 a	
	Significant level[b]			Significant level[b]		
	Scion	Rootstock	Scion X Rootstock	Scion	Rootstock	Scion X Rootstock
	**	***	ns	ns	***	*

[a] Mean separation within column by DMRT at p = 0.01.
[b] *, ** and *** stand for the significant level of p = 0.05, 0.01 and 0.001, respectively.

Tomato fruit yield in tomato-eggplant grafts was lower than yields from tomato-tomato grafts.

For eggplant-eggplant grafts, the best rootstock was EG 203 in terms of survival rate and fruit yield. EG 190 was also resistant to BW. TS 64 and EG 197 were moderately tolerant, and other entries were susceptible to BW (Table 3). Grafting onto susceptible rootstocks increased mortality. Non-grafted Pintung Long showed 30% mortality; however, mortality was 100 % when it was grafted onto EG 202 rootstock, and 94 % onto EG 220 rootstock. In eggplant-eggplant grafts, differences between scions were significant with regard to mortality (Bride > Pintung Long); however, it was not significant with regard to yield.

The best eggplant rootstock was EG 203, followed by EG 190, for both tomato and eggplant grafting.

Management of Insect Pests and Plant Diseases

Insect pests and plant diseases are major economic constraints in vegetable production in the tropics and subtropics. In addition to using host-plant resistance, AVRDC is developing technologies which emphasize combined biological control, cultural control, the use of sex pheromones, and minimal use of chemical pesticides. This integrated approach to control pests and diseases is the keystone of AVRDC's integrated pest management (IPM) technology. Besides being sustainable, the approach significantly reduces production costs and makes available to consumers good quality vegetables. At the same time, it reduces the risk that chemicals pose to humans and the environment.

AVRDC's IPM research has focused mainly on the control of diamondback moth (DBM), *Plutella xylostella*, a destructive pest of crucifers in the cool-dry season. During the last few years, however, the control of associated insect pests in the hot-wet season has also been studied and technologies to combat the whole crucifer pest complex have been sought. In addition, research was initiated to combat armyworms, *Spodoptera exigua* and *S. litura*, and onion thrips, *Thrips tabaci*. The IMP technologies include, in most cases, the use of parasites, predators, sex pheromone, biological insecticide based on *Bacillus thuringiensis*, and minimum use of chemical pesticides.

AVRDC has emphasized the use of soil amendments which have shown promise in reducing populations of soil pathogens, antagonistic microorganisms combined with crop rotation practices, and the use of moderately resistant cultivars to control economically important plant diseases, such as bacterial wilt (BW) and fusarium wilt (FW). These diseases are major problems in solanaceous crops and other important crops in the tropics.

(Activities related to management of insect pests and plant diseases are described in several other sections of this book. In particular, see the sections dealing with crop improvement.)

Control of tomato bacterial wilt with endophytic antagonistic bacteria

Microorganisms used as plant disease biocontrol agents usually colonize plant surfaces when expressing their antagonism (epiphytic antagonists). Application of epiphytic antagonists has several disadvantages; among these, successful application in the greenhouse cannot be transferred directly to the field, and fermentation and formulation for mass-production are necessary for large-scale application. Recently in Japan it was demonstrated that effective control of soil-borne diseases can be achieved in the field by applying endophytic antagonistic bacteria (EAB) directly through cuttings. Only a small amount of EAB is required for this application and EAB can colonize well inside the plant and avoid competition with soil microorganisms. Biological control of tomato BW using avirulent *Ralstonia solanacearum* (Rs) mutants or epiphytic antagonists has been studied. However, no successful cases have been reported in field application. In this study, we have shown successful application of the Japanese model in isolating and screening potential EAB for controlling tomato BW caused by Rs.

Samples of nine soils were collected from Miaoli, Yulin, Taichung, Tainan, Kaohsiung, and Pingtung in Taiwan. Strain PS95 (race 1, biovar 3) of Rs was used to infect each soil, at about 10^7 cfu/g of air-dried soil. Hypocotyl-cuttings of 14-day-old tomato seedlings or 28-day-old seedlings of Farmers 301 (susceptible to BW) were planted in each infested soil. Stem tissue of

Table 1. Antagonistic effect of endophytic antagonistic bacteria on the growth of *R. solanacearum* and the development of bacterial wilt on tomato

Strain	NA/KB/PDA[a]	Disease index (%)[c]			
		Exp.1	Exp.2	Exp.3	Exp.4
K8-1	0.0/ 3.2/ 0.0[b]	45.3[d]CD[e]	57.3 CD	27.2 DE	37.9 DE
EA2-4	0.0/ 15.3/ 12.8	42.0 CD	47.7 D	33.3 CDE	58.8 BC
KA4-1	15.8/ 23.0/ 6.3	63.3 AB	66.5 BC	23.7 E	50.0 C
GL4-8	11.3/ 0.0/ 13.9	69.7 A	87.2 A	49.7 B	30.0 E
A12-5	10.1/ 18.8/ 18.7	37.3 D	66.1 BC	39.4 BCD	75.3 A
A10-5	5.8/ 16.3/ 12.8	61.7 AB	66.7 BC	46.7 BC	48.3 CD
J1-4	0.0/ 14.4/ 0.0	55.3 BC	72.3 B	70.7 A	58.7 BC
CK		74.0 A	85.9 A	54.0 B	68.0 AB

[a] Inhibition in the growth of *R. solanacearum* displayed on NA, King's (KB), and PDA media.
[b] Diameter (mm) of clear zone; means of four replications.
[c] Disease index recorded 28 days after inoculation following the Winstead & Kelman system. Temperature ranges (mean max./min.) of the four experiments were 30.5/21.6°C (Exp.1), 32.8/22.9°C (Exp.2), 28.4/19.4°C (Exp.3), and 28.0/28.0°C (Exp.4).
[d] Means of three replications; 10 plants per replication.
[e] Means followed by the same letter are not significantly different, DMRT p = 0.05.

Table 2. Comparison of different application methods for endophytic antagonistic bacteria on their control efficacy of bacterial wilt of tomato

Strain	Disease index (%)			
	Hypocotyl-cutting	Soil infestation	Seed bacterization[a]	Root-dipping
K8-1	44.3[b] C [c]	39.3 B	15.3 B	19.3 AB
EA2-4	48.3 BC	47.3 AB	19.3 B	22.3 AB
KA4-1	53.3 B	28.0 C	21.3 B	14.3 B
A10-5	52.0 B	45.3 AB	56.7 A	12.0 B
CK	77.3 A	56.3 A	52.3 A	27.7 A

[a] The initial coated concentrations (cfu/seed) with strains K8-1, EA2-4, KA4-1, and A10-5 were 1.35×10^7, 2.90×10^6, 6.30×10^5, and 1.96×10^6, respectively.
[b] Means of disease indices recorded 28 days after inoculation of three replications, with 10 plants per replication.
[c] Means followed by the same letter are not significantly different, DMRT p = 0.05.

the surviving plants was collected, surface-sterilized, and ground in order to isolate EAB. Bacterial strains with different colony morphology were purified and tested for their antagonistic effect against Rs on PDA, NA, and King's B media.

Hypocotyl cuttings of 14-day-old tomato seedlings of Farmers 301 were soaked in suspensions of each EAB (10^8 cfu/ml) for 30 minutes, rerooted in peat moss for 14 days, then transplanted to pots containing infested soil. AVRDC field soil (sandy loam; pH 6.3) was collected and infested with PS95 (10^7 cfu/g of air-dried soil) for the pot trials. Symptoms of BW were recorded every week. The trial was repeated four times to evaluate the stability of control of each EAB. To gain information necessary to modify the EAB application method, effect of plant age, soaking period, and concentration of EAB suspensions were studied using four selected EAB strains in pot trials. To select the suitable plant age, hypocotyl-cuttings were made from 7-, 10-, 13-, 16-, and 19-day-old tomato seedlings of Farmers 301 and treated with individual EAB strains. Cuttings of 14-day-old seedlings were soaked in suspensions of each EAB strain for 1, 6, 12, 18, and 24 hours to determine the most suitable soaking period. Suspensions of each EAB strain at concentrations of 10^{10}, 10^8, and 10^6 cfu/ml were prepared to compare their control effect.

Table 3. Effects of seed and root treatments with avirulent *Fusarium oxysporum* and fungal-antagonistic bacteria on fusarium wilt expression in field-grown tomatoes

Test 1, October 1996 to March 1997 at AVRDC

Biocontrol agent	Application method[b]	Disease incidence (%)[c, d] 17 wk after transplanting
A 1, avir. Fo	seed+drench	58 cd
A 1, avir. Fo	seed	66 a-d
A 2, avir. Fo	seed+drench	68 a-d
A 2, avir. Fo	seed	76 abc
B 1, avir. Fo	seed+drench	71 a-d
B 1, avir. Fo	seed	75 a-d
FP, antag. bacterium	seed+drench	70 a-d
FP, antag. bacterium	seed	59 bcd
DP 2, antag. bacterium	seed+drench	55 d
DP 2, antag. bacterium	seed	75 a-d
None (control)		83 a

Test 2, May to July 1997 at AVRDC

Biocontrol agent	Application method[b]	Disease incidence (%)[c, d] 5 wk	7 wk	9 wk	13 wk
A 1, avir. Fo	seed+drench	19 ab	33 ab	50 ab	67 abc
A 1, avir. Fo	seed	11 b	22 b	45 ab	72 abc
A 2, avir. Fo	seed+drench	28 a	47 a	61 a	80 a
A 2, avir. Fo	seed	22 ab	42 ab	61 a	77 abc
B 1, avir. Fo	seed+drench	22 ab	36 ab	44 ab	70 abc
B 1, avir. Fo	seed	22 ab	34 ab	40 ab	69 abc
FP, antag. bacterium	seed+drench	16 ab	25 ab	44 ab	72 abc
FP, antag. bacterium	seed	19 ab	38 ab	49 ab	71 abc
DP 2, antag. bacterium	seed+drench	27 a	41 ab	52 ab	69 abc
DP 2, antag. bacterium	seed	16 ab	39 ab	45 ab	60 abc
None (control)	21 ab	43 ab	63 a	79 ab	

a 100 g of soil infested with 104 CFU of *F. oxysporum* f.sp. *lycopersici* (isolate *Fol*-23, race 2) were placed in the bottom of each transplant hole.
b Seed were immersed in conidial (106 spores/ml) or bacterial (107-108 CFU/ml) suspensions in 1%carboxy methyl cellulose for 1 hr and then air dried before sowing; roots of seedlings were drenched with 5 ml/plant of conidial or bacterial suspensions in water 3 days prior to transplanting to the field.
c Disease severity based on the percentage of plants expressing fusarium wilt symptoms on the date of evaluation.
d Means separation, DMRT $p < 0.05$.

Three other methods for applying EAB were compared with the hypocotyl-cutting method; (1) root soaking in EAB suspensions (10^8 cfu/ml) for 12 hours before transplanting; (2) seed coating with EAB suspension in 1% methylcellulose for one hour followed by drying; (3) soil infesting with EAB suspension (10^8 cfu/ml) in a 10:1 ratio (w:v).

A total of 208 strains of potential EAB were isolated. Their effectiveness in controlling BW was evaluated in four repeated pot trials. Seven EAB strains were found to significantly reduce the incidence of BW (Table 1). However, K8-1, EA2-4, KA4-1, and A10-5 had stable control effect by reducing about 30% of the final wilting percentage compared to the control. BIOLOG system identified strain K8-1 to be of the *Bacillus* sp., KA4-1 and A10-5 to be of the *Pseudomonas* sp., but strain EA2-4 could not be identified. Capacity of each EAB strain to inhibit Rs growth in media and reducing BW incidence were not related (Table 1). This indicated that the expression of antagonism could be affected by other microorganisms, nutrient status, or temperature, etc. Therefore, evaluating antagonistic effect in media is not helpful in selecting good EAB and can be skipped in the future.

Effects of plant age, soaking period, and concentration of EAB suspensions were studied in order to modify the hypocotyl-cutting treatment. Treating hypocotyl cuttings of 10- or 13-day-old seedlings had the best control effect compared to treating 7-, 16-, or 19-day-old seedlings. Treating 10-day-old seedlings resulted in 12.7 to 33% less disease incidence, and using 13-day-old seedlings resulted in 17.7 to 31.0% less incidence. A 12-hour-soaking period in EAB suspensions had the best control effect. Soaking cuttings in EAB suspensions with a concentration of 10^8 cfu/ml had the best control effect, reducing final wilting by 15.5%. The modified hypocotyl-cutting treatment was compared with three other methods, and was found to give the best control (Table 2). The amount of reduction in final disease incidence was 27.9% by hypocotyl-cutting method, 17% by soil infestation, 24.2% by seed bacterization, and 10.8% by root dipping. The cutting method looks to be the best.

Although based on this study the best control effect is only about 30% reduction in final severity, EAB still have good potential when used in combination with other disease management practices. For example, treating susceptible scions with EAB and then grafting onto tolerant rootstock could have an additive effect in disease control. Further research is necessary to learn the control mechanism of EAB and to discover other factors affecting their control efficacy.

Biocontrol of tomato fusarium wilt

Avirulent *Fusarium oxysporum* (*Fo*) isolates - A1, A2, and B1, and fungal-antagonistic bacterial isolates - DP 2, a *Bacillus* sp., and FP, a flourescent pseudomonad, were tested for their effectiveness in suppressing tomato FW symptoms in the field. Each organism was tested as a seed coating treatment and as a combination seed coating + root drench treatment. Two similar field tests were conducted at different times, the first from October 1996 to March 1997 and the second from April to July 1997.

In the first field test, tomato plants that received the following treatments, (1) the DP 2 bacterium applied as a seed coating and root drench, (2) the A1 avirulent *Fo* isolate applied as a seed coating and root drench, and (3) the FP bacterium applied as a seed coating, expressed significantly ($P < 0.05$) less severe FW symptoms at 17 weeks after transplanting (WAT) compared to plants that received no biocontrol agent (Table 3).

In the second field test, disease severity ratings were made at 5, 7, 9, and 13 WAT. None of the biocontrol treatments resulted in a significant reduction in FW severity compared to the nontreated control on any of the evaluation dates (Table 3).

Although it appears that some of these microorganisms can provide some limited protection against FW, they are not consistant in their performance, and even at their best they do not provide adequate protection for their use to be considered as a viable FW management practice.

Studies with a diamondback moth parasite *Microplitis plutellae*

Diamondback moth (DBM), *Plutella xylostella* (L.), is a pest of crucifers worldwide. This pest is especially serious in tropical lowlands. The pest has no effective natural enemies in the tropics. Intensive use of chemical insecticides to combat this pest has resulted in DBM becoming resistant to most chemicals, exacerbating the pest control problem. *Microplitis plutellae* (Musebeck) is a larval parasite of DBM. Two years ago, AVRDC imported this parasite from New York State to control DBM in Taiwan and the rest of Asia. AVRDC multiplies this braconid for introduction in various countries, and also conducts some basic biological studies to judge the suitability of *M. plutellae* for introduction in different agroecological regions. In this experiment we studied the range of temperatures ideal for its multiplication. And, to enable us to multiply the parasite more economically, we studied the preference of *M. plutellae* for various larval instars of DBM.

Two pairs of *M. plutellae* adults were placed in an acrylic cylinder (15 cm in diameter, 30 cm long). A wad of cotton dipped in 10% honey solution was placed in the cylinder to feed the parasite adults. Both ends of the cylinder were covered with nylon netting. Three such cylinders containing the parasite pairs were placed at 10°C, 15°C, 20°C, 25°C, 30°C, and 35°C for two hours. Excised cabbage leaves, each having up to 100 second- or third-instar DBM larvae, were also placed at the above temperatures for two hours. The DBM larvae were then placed inside the acrylic cylinders for 24 hours, exposed to the parasite for oviposition. The larvae were then transferred to 25±2°C and maintained until all larvae became pupae. When necessary, fresh leaves were provided to sustain larval feeding. At this stage, the number of larvae being parasitized was determined by the presence of parasite pupae. *Microplitis plutellae* pupae are smaller and dark brown, whereas DBM pupae, covered with loose silken web, are larger, initially green, and turn light brown before adult emergence. The percent parasitism was calculated.

In the second laboratory experiment, 100 larvae each of first, second, third, or fourth instars of DBM were placed on individual cabbage leaves inside 15-cm diameter acrylic cylinders. Six pairs of *M. plutellae* adults were placed in similar but separate containers. Both DBM larvae and parasite adults were placed at 27°C for 1 hour. We then placed two pairs of *M. plutellae*

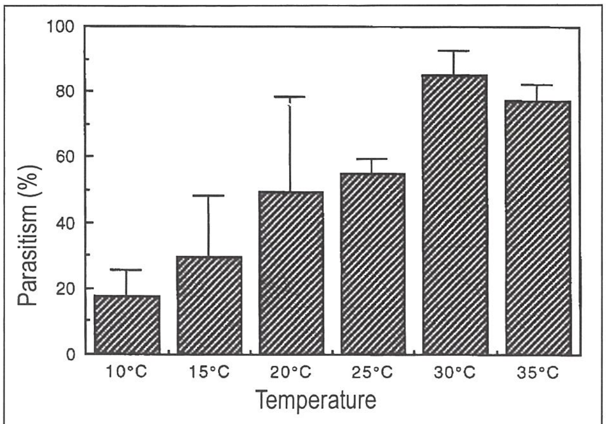


Fig. 1. Influence of temperature on parasitism of DBM larvae by *M. plutellae*

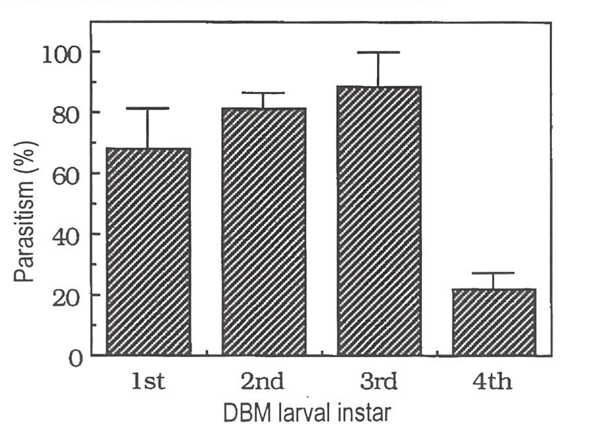


Fig. 2. Parasitism of various instar of diamondback moth larvae by *M. plutellae*

adults with 100 DBM larvae of a particular instar in each of three cylinders for 24 hours. The three cylinders represent three replicates of each treatment. After 24 hours, DBM larvae were separated from parasite adults and the larvae were reared until they all pupated. The number of DBM pupae and parasite pupae was recorded. Percent parasitism was calculated.

Parasitism increased gradually with increasing temperature from 10 to 30°C (Fig. 1). It declined slightly at 35°C, but was still over 75% of DBM larvae. A temperature range of 25 to 35°C appears to be suitable for survival and parasitism of this braconid. In tropical lowlands, where temperatures are normally 25°C and above, and where DBM is especially serious, *M. plutellae* should be suitable to control the pest. This was a welcome discovery, but very surprising because this parasite came from a distinctly temperate location, Upstate New York, where winters are very cold and summers are mild; the daily high rarely reaches above 30°C. Another braconid, *Cotesia plutellae* (Kurdjumov), is established in many lowland areas of Asia. *M. plutellae* could compete with *C. plutellae* and together they might more effectively control DBM.

Parasitism of second- and third-instar larvae was better than parasitism of first and fourth instars (Fig. 2). Although too small for *M. plutellae* adults to easily insert ovipositors for deposition of eggs, first-instar larvae were also parasitized in significant number. On the other hand, fourth instar larvae are old and can pupate before completion of *M. plutellae*'s larval period, which kills the parasite larvae. One need use only second- and third-instar larvae for rearing *M. plutellae*.

Socioeconomic Studies on Vegetables

During 1997, the socioeconomics project concentrated on the macro-level productivity implications of the introduction of modern mungbean varieties in Pakistan, quantification of yield and input-levels for the dry season vegetables grown with rice in the Philippines, the economics of asparagus cultivation in Thailand, and the implications for AVRDC research of varying demand and income elasticities and seasonal and annual fluctuations in various vegetables. From the previous year, the analysis of the impact of modern mungbean varieties in Pakistan was published as a technical guide, and vegetable situation reports for Sri Lanka, Malaysia, and Vietnam were completed.

Total factor productivity growth in post-Green Revolution agriculture of Pakistan

The main objective of this study was to quantify the trends in total factor productivity (TFP) and cost by cropping region in Pakistan's Punjab and Sind. This is the first attempt to estimate some parameters of sustainability by cropping region.

District-level data on all 35 crops, 6 byproducts, and 6 inputs used in the crop sector were collected for the period 1965-93. These outputs and inputs were valued at farm-gate prices. Based on the dominant cropping pattern in each district, the country was divided into eight cropping regions. Using the chain-linked Tornqvist-Theil indexing procedure, TFP was estimated by cropping region as an indication of sustainability.

TFP growth cloaks the effect of technological changes and resource degradation. As far as the rate of increase in productivity due to technological change is higher than the decrease in productivity due to resource degradation, the trend in TFP will be positive despite the occurrence of degradation. To separate the effect of resource degradation from technological change, the cost function was estimated using two variables which control: (1) cropping intensity defined as number of crops grown on a piece of land in a year, (2) proportion of modern variety wheat area compared total area. A negative regional trend coefficient indicates an improvement in resource productivity, and vice versa.

TFP estimates for all cropping regions in Punjab and Sind during 1965-93 are available. For our interest here, the growth in TFP for mungbean growing regions is compared with rice-wheat regions and overall Pakistan. Because modern varieties of mungbean were introduced in the mid 1980s, the results are reported only for 1980-93.

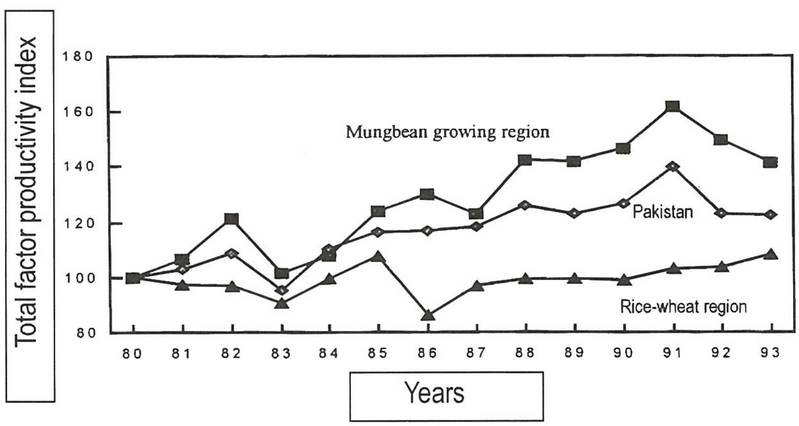
During this period, the rate of increase in TFP of the mungbean growing region was the highest when compared to the rate in other regions of the country. The crop sector productivity in the country as a whole increased at 2.2% per annum, while the rate of growth in crop sector productivity in the mungbean growing region was 3.3%. The lowest increase in productivity was in the rice-wheat region, which improved at an insignificant rate of 0.6% per annum (Fig. 1).

The trend in the cost of producing a unit of output in Pakistan was positive (0.12% per annum) during the study period (1965-93), indicating a sustainability problem in the crop sector. The overall trend was not significant in the Green Revolution period (GR), but became highly significant during the input intensification (INI) and post Green Revolution (PGR) periods. The mungbean growing region in Punjab had an increasing cost trend in the GRR and INI periods. Introduction of modern varieties of mungbean increased mungbean yield which induced area expansion from 70,000 ha in 1985 to 180,000 ha in 1995. And, since mungbean crop residue is mostly returned to the soil, soil fertility has improved. The result is improved productivity of wheat and reduced cost. This is reflected in a declining trend in the cost function for the region. Cost of production in the crop sector declined at a rate of 0.59% per annum in the region, compared to a significant increase in cost of production, 0.36% per annum, for the whole country. Costs also declined significantly in the cotton and mixed-crop regions of Sind. In Punjab, the mungbean growing region is the only region where cost had a declining trend during the PGR period (Table 1).

Characterization of vegetables (asparagus in this case) with field crops

The main objective of this activity was to characterize asparagus farmers, quantify input use, yields, farm management practices, and the economics of asparagus cultivation in Thailand.

Thirty-two asparagus growing farmers were randomly selected from 11 villages around Kamphaengsaen. A structured pre-tested questionnaire was used to obtain information on input use, farm management practices, and cultivation cost. Two research-



Growth rates (%) in TFP during 1980-93
Mugbean growing region = 3.3
Rice-wheat region = 0.6
Pakistan = 2.1

Fig. 1. Growth rate in total factor productivity in selective regions of Pakistan

ers each from Cambodia, Laos, and Vietnam conducted the survey as a part of their training.

Cultivation of asparagus in Kamphaengsaen district was started with the help of Know You seed Company of Taiwan in 1993. Before the seed company started its operation, multi-location demonstration plots on asparagus cultivation were set up by Kasetsart University, in collaboration with AVRDC, on the university's Kamphaengsaen campus. The seed company provided financial support to farmers to set up sprinkler irrigation systems, supplied seedlings, and ensured a market.

Farm size ranged from 0.08 to 5.1 ha and averaged 0.93 ha. Ninety-two percent of the sample area was farmer owned. All farm operators had at least a primary education. Average availability of labor in each farm family was 3.3 labor years. The land under asparagus was flat with little erosion and very good external drainage. More than 80% of the soils were medium or light textured. Asparagus, a perennial, is rarely mixed with other crops. As the market for asparagus is assured, only large farmers in the sample did not put all of their land under asparagus, mainly because of labor constraints.

Table 1. Trend in cost function by region, Pakistan, 1980-93

Region	
Punjab-maize	1.34
Punjab-mungbean	-0.59
Punjab-mix	1.08
Punjab-rice	2.35
Punjab-cotton	1.06
Sind-mix	-0.55
Sind-rice	-0.21[ns]
Sind-cotton	-0.70
Overall trend [a]	0.36

Land preparation and weeding is done by tractor with an average of two plowing passes, 1.35 harrowings, and 0.72 furrowings. Weeding is done manually during manual harvesting. Harvesting starts about two months after nursery transplanting, and continues for several months. The older plants are continuously replaced with younger shoots of the same plant. This is called "mother planting."

Asparagus cultivation is very labor intensive. In this study it was found to take 1742 labor-days/ha/annum, or about 7 labor-years, more than three-fourths of which in this study was provided by family labor. Harvesting, done simultaneously with grading and packing, was found to require 950 labor-days/ha/annum (Table 2). Large quantities of other inputs, such as fertilizer, pesticide, and irrigation were used. Average annual per-hectare fertilizer use was found to be 2373 kg, comprised of about equal amounts of nitrogen, phosphorus, and potash. Seventy-three irrigations (sprinkled) in one year were required, and 11.7 sprays of pesticide were made. Total per-hectare material and hired labor cost (excluding cost of family labor) was found to be 85,701 THB per annum (Table 3).

Average annual per-hectare yield of asparagus was found to amount to 15.8 t, producing a gross return of 241,288 THB (Table 3). Its cultivation could help even

Table 2. Labor use (labor day/ha) in different operations in asparagus cultivation in Kamphaengsaen, Thailand, 1997

Type of labor	Family		Hired		Total	
Land preparation and nursery planting	80.7	(6.1)	3.8	(0.9)	84.5	(4.9)
Mother planting	24.4	(1.8)	3.8	(0.9)	28.2	(1.6)
Fertilizer application	162.1	(12.2)	0.4	(0.1)	162.5	(9.3)
Interculture	217.5	(16.4)	33.1	(8.0)	250.6	(14.4)
Irrigation	193.1	(14.6)	0.0	(0.0)	193.1	(11.1)
Pesticide application (spray)	73.1	(5.5)	0.0	(0.0)	73.1	(4.2)
Harvesting + packing +grading	575.0	(43.4)	375.0	(90.1)	950.0	(54.5)
Total	1325.9	(100.0)	416.1	(100.0)	1742.0	(100.0)

The figures in parenthesis are percentages of the total labor use in a category.

out seasonality in vegetable availability, especially in the tropics. And it is a highly profitable venture under the conditions studied. After deducting all costs including family labor and land (i.e., return to management), net benefit was calculated to be 15,652 THB/ha. If family labor is not included in the cost, however, net benefit amounts to 155,587 THB/ha. The benefit-cost ratio is 1.81% (Table 3). Despite the crop's profitability, excessive input use in its cultivation might reduce long-term sustainability.

Asparagus is cultivated on about 3000 ha in Thailand. It is estimated that replacing rice with asparagus at the country level has generated an additional 19,500 jobs, 450 million THB in income (after paying input costs), and 6750 t of fertilizer demand. Additional demand for agricultural business services, such as marketing, are not included here, but could be substantial.

Characterization of vegetables with field crops

The main objective of this activity was to quantify the inputs and yields of dry-season vegetables grown in rice-based systems in northern Philippines, and compare them with those in the wet season. The activity was initiated in Illocos Norte in 1996 with the help of the socioeconomics department of Mariano Marcos State University (MMSU). The monitoring of input use and yields for all vegetable crops grown on the 150 sample farms continued throughout the dry season.

Looking at the area reallocation pattern from the wet to the dry season, farmers tend not to grow the same crop on the same parcel. For example, only one-fifth of the rice area went to rice, while 35% of the wet season rice area was shifted to vegetables. The share of mungbean, tobacco, and corn also increased in the dry season. Similarly, very little vegetable, mungbean, and corn area from the wet season was allocated to the same crop. This might be practiced to enhance soil fertility, or break the pathogen pattern. About two-thirds of the vegetable area, more than half of the mungbean area, and 85% of the corn area in the wet season was left fallow. This may be due to water or labor shortage as more labor intensive crops are grown in the dry season. Total vegetable area doubled during the dry season. The main new crop was garlic. If garlic is excluded, total

Table 3. Input quantities, costs, yield, and factor share in asparagus cultivation in Kamphaengsaen, Thailand, 1997

Inputs	Quantities	Values (THB/ha)	Factor share (%)
Seed (kg/ha)	1.0	1306	0.6
Fertilizer (kg of nutrient/ha)	2373.8	18650	8.4
Nitrogen	806.3	-	
Phosphorus	703.1	-	
Potash	864.4	-	
Material for mother planting	-	4111	1.9
Irrigation	73.2	11038	5.0
Pesticide	11.7	7780	3.5
Labor (labor days/annum/ha)	1742.0	179252	80.7
Family labor	1325.9	136435[a]	61.4
Hired labor	416.1	42817	19.3
Land rent		3500	
Total cost (family labor included)	-	225636	100.0
Total cost (family labor and land rent excluded)	-	85701	
Average yield in one year (t/ha)	15.8	-	-
Gross revenue		241288	
Net return in one year (including family labor and land as cost)		15652	
Net return in one year (excluding family labor)		155587	
Benefit-cost ratio (%) (on family resources and capital)		1.81	

[a] Family labor was evaluated at the prevailing average wage rate for all agriculture operations in the area.

area under the major vegetables remained almost the same as in the wet season.

Yields of vegetable crops in the dry season are generally higher than the national average, and vice versa for the wet season yields. Wide variation in vegetable yields was observed as reflected by the high coefficient of variation compared to that for rice. Although dry-season yields are higher than wet-season yields, the level of variation in yield is about the same in the two seasons. This suggests that perhaps management factors are more important with respect to yield variation than are climatic factors.

Watermelon and gourd are the highest yielding vegetables, followed by bottle gourd and sweet pepper in the wet season. Chili, tomato, long bean, and bitter gourd are the highest yielding vegetables in the dry season (Table 4).

Surprisingly, average nutrient application in vegetable production is not much higher than for rice, except in sweet pepper, onion, pechay, watermelon, and sweet potato in the wet season, and long bean and sweet potato in the dry season. Sweet pepper, which received the highest fertilizer application during the wet season, received only 213 kg/ha of nutrients in the dry season. Long bean was given the highest fertilizer dose during the dry season. Tobacco receives more fertilizer than do vegetables, except for long beans (Table 5).

On average, vegetables received 0-9 chemical sprays, but as many as 24 in the case of sweet pepper and 32 for tobacco. Most vegetables receive a higher

Table 4. Average yield of various crops in the wet and dry seasons in Illocos Norte, Philippines, 1996-97

Crop	Parcel number		Sample area(ha)		Yield (t/ha)		CV in yield (%)		National yield (t/ha)
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Vegetables	135	134	7.92	12.43	-	-	-	-	-
Eggplant	26	8	1.55	0.53	5.2	14.6	129	272	6.4
Sweet pepper	10	9	0.74	1.15	8.1	11.2	54	214	4.2
Tomato	15	9	0.68	0.54	5.1	23.8	118	242	8.5
Long bean	14	9	0.72	0.37	4.2	15.9	38	294	-
Squash	15	8	1.78	0.61	5.4	3.2	85	6	10.2
Cowpea	18	8	0.48	0.29	1.4	6.2	75	149	1.8
Garlic	-	69	-	8.14	-	2.4	-	93	-
Bottle gourd	7	5	0.29	0.10	10.0	5.0	129	194	7.0
Bitter gourd	7	1	0.69	0.27	5.1	13.8	101	0	4.1
Onion	5	-	0.30	-	2.9	-	47	-	4.7
Lady's finger	5	1	0.16	0.03	4.5	0.6	90	0	3.4
Patolla	1	1	0.03	0.05	1.0	2.0	0	0	2.9
Green pea	1	-	0.03	-	2.0	-	0	-	-
Taro	3	-	0.07	-	4.5	-	29	-	-
Pechay	4	-	0.12	-	3.7	-	58	-	5.5
Watermelon	1	-	0.21	-	66.7	-	0	-	-
Pigeon pea	1	-	0.03	-	2.0	-	0	-	1.9
Chili	-	3	-	0.31	-	26.7	-	44	-
Peanut	-	1	-	0.05	-	1.5	-	0	-
Radish	-	1	-	0.03	-	5.3	-	0	-
Jute	1	-	0.05	-	3.0	-	0	-	-
Potato leave	1	2	0.01	0.02	0.5	3.5	0	7	-
Other crops	152	134	29.09	17.90	-	-	-	-	-
Rice	132	17	27.34	6.23	3.9	3.4	6	3	2.8
Corn	4	35	0.51	4.21	1.7	3.6	5	8	2.0
Tobacco	-	36	-	3.37	-	9.2	-	26	-
Mungbean	16	46	1.24	4.09	1.2	0.7	191	1	0.7

- Implies that data is not available.

number of sprays than do cereal crops, such as rice and corn, but a lower number than does tobacco (Table 5).

The labor requirement for vegetable production is many times higher than for other crops, except tobacco. On average, vegetables employ 166 labor-days/ha, compared to 41 days for rice, and 58 days for corn. Chili production employs the highest amount of labor, followed by long bean, and tomato (Table 6). The share of female labor used on vegetables is about one third of the total labor, compared to only 16% for rice. Vegetable production in Ilocos Norte is mainly a family business and use of hired labor is minimal.

Seasonality and structural changes in the consumption pattern in different countries

To consider the important issues relating to AVRDC's selected vegetables, demand elasticity, income elasticity, extent of seasonality, and annual fluctuations in prices of these vegetables were reviewed from studies conducted by AVRDC in South, Southeast, and East Asia.

The review of literature on vegetable elasticities (Table 7) suggests that demand elasticity for all vegetables is around 0.60, which is much higher than the average income elasticity of 0.40. This indicates much more scope for increasing vegetable consumption by lowering prices than by increasing incomes. Moreover,

Table 5. Average fertilizer nutrient (kg/ha) and pesticide spray (number) applied to different crops in the wet and dry seasons, Ilocos Norte, Philippines, 1996-97

			Fertilizer nutrients (kg)									
	Observation (no.)		N		P		K		Total		Pesticide (spray)	
Crop	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Eggplant	26	8	116	182	49	44	36	44	200	269	3.1	4.0
Sweet pepper	10	9	836	114	380	36	378	63	1595	213	3.5	9.1
Tomato	15	9	165	96	57	39	57	67	279	202	3.7	4.4
Long bean	14	9	35	438	18	185	18	185	71	808	3.2	6.1
Squash	15	8	138	64	58	18	58	18	253	99	2.3	7.3
Cowpea	18	8	37	7	18	3	17	3	72	14	2.2	2.9
Garlic	-	69	-	158	-	48	-	44	-	249	-	2.5
White gourd	7	5	126	28	29	7	27	7	177	42	1.9	2.0
Bitter gourd	7	1	57	128	32	55	8	55	97	237	1.4	2.0
Onion	5	-	242	-	87	-	87	-	416	-	3.8	5.0
Lady's finger	5	1	126	42	22	42	23	42	194	126	2.2	3.0
Patolla	1	1	14	0	14	0	14	0	42	0	2.0	1.0
Green pea	1	-	0	-	0	-	0	-	0	-	0.0	0.0
Taro	3	-	6	-	6	-	6	-	19	-	0.0	0.0
Pechay	4	-	204	-	87	-	78	-	369	-	2.0	0.0
Watermelon	1	-	143	-	133	-	133	-	409	-	8.0	0.0
Pigeon pea	1	-	70	-	28	-	28	-	126	-	-	0.0
Chili	-	3	-	57	-	20	-	20	-	96	-	3.5
Peanut	-	1	-		-		-	-	-	-	-	0.0
Radish	-	1	-	0	-	0	-	0	-	0	-	2.0
Jute	1	-	92		0		0		92	-	1.0	0.0
Sweet potato	1	2	345	175	0	175	0	175	345	525	1.0	0.0
Rice	132	17	136	65	31	39	26	39	193	142	0.6	0.3
Corn	4	35	31	85	2	15	2	14	35	114	0.8	0.9
Tobacco	-	36	-	213	-	102	-	51	-	366	-	7.7
Mungbean	16	46	1	10	1	3	1	3	3	17	2.0	2.0

- implies data is not available

demand generated by increased income, if not matched by increased supply, can add pressure on prices or on foreign exchange resources.

The demand and income elasticities of tomato are relatively high and the crop has high annual variation in yield and seasonal fluctuation in prices. Therefore, research aimed at increasing overall production, extending production in the off season, and contributing to yield stability, is of interest to the Center.

On the other hand, chili has almost zero demand and income elasticity. Therefore, additional production by modern technologies has relatively little potential for increasing consumption. Additional production would almost certainly decrease prices proportionally. The seasonality in its prices is also low because of the availability of processed chili powder in the off-season. However, there is strong fluctuation in yield. Therefore, a chili research program should focus on stabilizing yield by developing technologies to enhance disease-resistance and stress-tolerance.

There might be little potential to generate additional demand by improving onion yields and lowering prices, as the demand elasticity is relatively low in South Asia. However, some potential does exist to expand onion consumption in Southeast Asia, as demand and income elasticities there are double those in South Asia. This is also reflected in relatively high annual per capita consumption of onion in South Asia (e.g., 4 kg in India) compared to South east Asia (e.g., 0.8 kg in the Philippines, and 0.4 kg in Indonesia). Onion yield is relatively stable in South Asia, but fluctuates in Southeast Asia. Therefore, stability in onion yield is an important research aim for Southeast Asia. As regional trade increases, perhaps the flow of onions from South Asia to Southeast Asia will increase.

Onion research should focus on extending availability in the off-season, as seasonality in prices is high. However, as onion can be stored for quite a long-time, more emphasis should be placed on improving storability than on extending production in the off-season.

Price elasticity of eggplant is relatively high in South Asia. However, as income elasticity is relatively low, its consumption cannot be pushed too far. It has

Table 6. Labor use (day/ha) on various crops grown in Ilocos Norte, Philippines, 1996-97

	Family			Hired			Grand total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Eggplant	71	29	100	3	0	3	74	29	103
Sweet pepper	54	14	68	69	11	80	123	25	148
Tomato	140	61	201	1	0	1	140	61	202
Long bean	138	94	232	172	0	72	310	94	404
Squash	67	4	70	3	0	3	70	4	74
Cowpea	86	58	143	0	0	0	86	58	143
Garlic	85	20	104	38	5	42	122	24	146
Bitter gourd	45	18	63	0	0	0	45	18	63
Bottle gourd	123	37	160	0	9	9	123	46	169
Lady's finger	75	61	136	0	0	0	75	61	136
Patolla	56	15	71	0	0	0	56	15	71
Chili	568	105	673	0	0	0	568	105	673
Radish	33	90	123	0	0	0	33	90	123
Sweet potato	64	8	71	0	0	0	64	8	71
Average for veg.	112	38	150	17	1	18	129	39	168
Rice	15	2	17	20	5	25	35	7	42
Corn	34	17	51	8	0	8	41	17	58
Tobacco	151	106	256	38	5	43	188	111	299
Mungbean	38	14	52	1	3	4	39	16	56

relatively low seasonality, but fluctuation in yield is quite high. Therefore, eggplant research should focus on stabilizing yield by increasing disease resistance and abiotic stress tolerance.

Chinese cabbage is an important vegetable in East Asia, but relatively unimportant in South Asia. Its price and income elasticities are moderate for South Asia, but very low for East Asia. No estimates on price elasticity are available for Southeast Asia, although income elasticities are quite high here. Therefore, almost no potential exists for expanding its consumption in East Asia, but low-cost technologies could increase its consumption in Southeast Asia, and moderate increases in consumption could be achieved in South Asia.

The price elasticity of demand for leafy vegetables reported in Table 7 is for urban areas in India. The same measure is quite low (0.2) in rural areas of India. The demand elasticity for the Philippines and Taiwan is quite high. Income elasticity is moderate. A moderate variation in annual yield and seasonality in prices exists. The main emphasis here should be on increasing its overall availability through increased peri-urban production.

Mungbean has high income and price elasticity in South Asia, indicating a high potential for increasing its consumption through increased production. Currently, however, a large gap exists between yields at research stations and yields in farmers' fields. Therefore, AVRDC should focus on adaptive research in order to tailor available technologies to farmers' needs in different ecoregions.

Research into grain soybean has high potential to achieve increases in the crop's consumption, as its demand and income elasticities (from use of the crop as livestock feed and edible oil) are expected to be around one. However, soybean is a highly traded commodity, and developing countries are under much pressure to open up there markets. Any technological innovation developed by AVRDC would be quickly picked up by the affluent and efficient producers in the West, in such countries as the USA and Brazil, and might give them a further edge over less efficient producers in Asia and Africa.

Vegetable soybean has a market in East Asia. As little can be achieved through additional research, AVRDC should continue to give low priority to this crop. Collaboration with NARS should be aimed at expanding vegetable soybean production.

Table 7. Demand and income elasticities, seasonality in prices, and fluctuations in yield of AVRDC vegetables in South Asia

Crop	Demand elasticity	Income elasticity	Price seasonality (%)	Yield fluctuation (%)
Tomato	0.60	0.40	200	15
Chili	0.09	0.10	34	11
Onion	0.30	0.35	150	4
Eggplant	0.50	0.20	41	12
Cabbage	0.41	0.39	114	22
Mungbean	0.69	0.24	10	5
Soybean	0.9	1.00	5	5
Leafy vegetables	0.60	0.35	50	8
Overall vegetables	0.60	0.40	143	15

Research Support

This project aims to develop methodologies for quality assessment of the Center's principal crops and improve their nutritional quality. Of note in 1997, the dietary value of mungbean was assessed and even enhanced, by way of recipes especially designed to release more available iron through advantageous combination and preparation of vegetables. The recipes were published in a book and will be used in a village-level study in southern India.

Mungbean as a better dietary iron source for South Asia

Mungbean is the third most important pulse crop of India after chickpea and pigeon pea. Nutritionally, compared to cereal grains, pulses are two- to three-times richer in protein and remain the least expensive source of food protein. Compared to other pulses commonly eaten in South Asia, mungbean is rich in dietary iron.

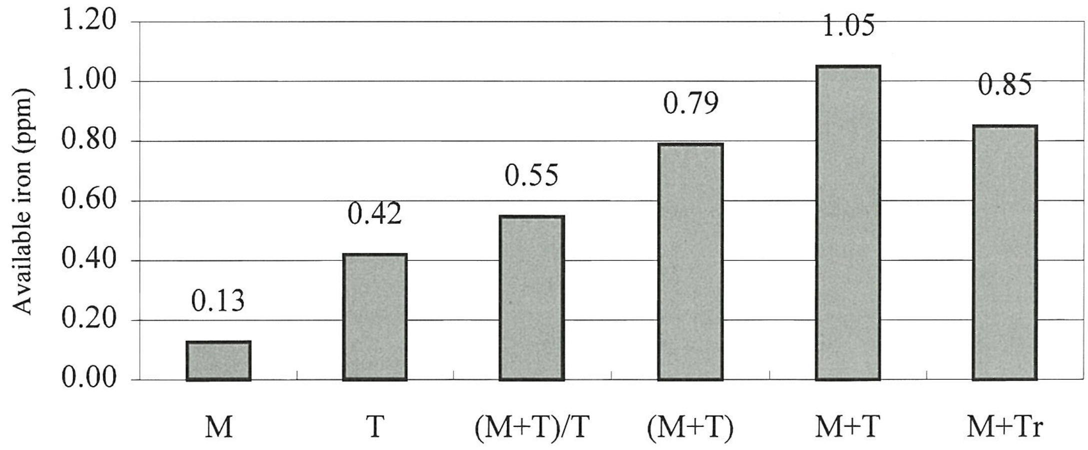
Iron deficiency anaemia is commonly found in both economically deprived and affluent populations. To correct this serious deficiency, increases in food dietary iron and the availability of that food are necessary. Food processing and iron chemistry are important factors affecting iron bioavailability. The chemistry of iron, particularly its valence, solubility and types of chelation, influence its absorption. Food processing methods can affect bioavailability; thus, processing method should be considered when trying to achieve the highest possible iron bioavailability.

Available iron is increased when mungbeans are cooked with select vegetables

In previous work, iron bioavailability of mungbean was proved to be enhanced through sprouting. Here we compared the enhancing effect of selected vegetables cooked with mungbean on mungbean's iron bioavailability. Figure 1 presents the effect of cabbage on the iron bioavailability of mungbean. Cooking mungbean with cabbage produced a two-fold increase

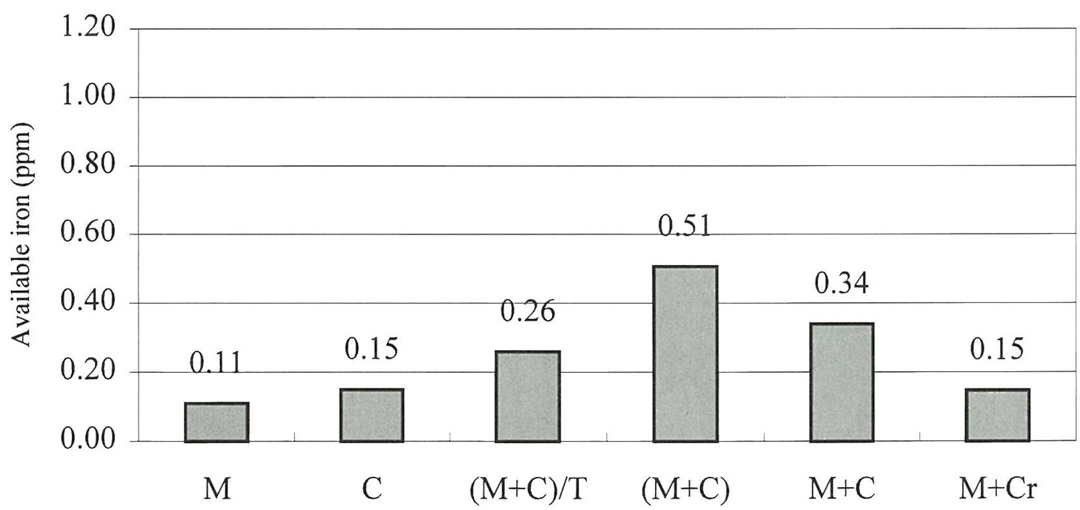
Table 1. Amount of total iron, available iron and bioavailability of iron in different mung bean Recipes.

Recipes	Total iron mg/100 g meal	Available iron µg/100 g meal	Bioavailability (%)
Mungbean masial	6.50	98.52	8.83
Mb d masial	5.55	84.23	10.88
DL koottu	8.54	56.31	5.63
Cab koottu	7.22	95.34	10.10
Amr koottu	9.39	67.68	6.95
Spn koottu	6.65	90.04	10.59
Tomato adai	2.43	45.41	9.71
Peasarattu	2.68	59.28	9.33
Tomato rice	3.76	100.43	11.28
Pongal (hot)	1.74	19.36	5.76
Pongal (sweet)	1.38	14.10	5.08
Pakoda	4.29	51.72	5.06
Bonda	6.63	59.68	4.00
Salad w/ sprouts	8.36	50.55	8.65
Salad w/ dhal	5.91	36.26	8.78



M: Cooked mungbean, T: Cooked tomato
(M+T)/T: Calculated Sum of M, 0.13 and T, 0.42
(M+T): M and T cooked together
M+T: M and T cooked saperately
M+Tr: Mixture of cooked M and raw T

Fig. 2. Enhancing effect of tomato on iron bioavailability of mungbean



M: Cooked mungbean, C: Cooked cabbage
(M+C)/T: Calculated sum of M, 0.11 and C, 0.15
(M+C): M and C cooked together
M+C: M and C cooked saperatedly
M+Cr: Mixture of cooked M and raw C

Fig. 2. Enhancing effect of cabbage on iron bioavailability of mungbean

in available iron, but when they were cooked separately, the increase was 1.3-fold in comparison with the calculated sum of each taken separately. When cooked mungbean was mixed with raw cabbage, available iron decreased to 60% of the calculated sum. Cooked tomato also produced an enhancing effect on cooked mungbean, as did raw tomato (Fig. 2). From these data, it was concluded that cooking with cabbage or tomato and mixing with raw tomato helps unlock the iron present in mungbean.

Evaluation of mungbean recipes for iron bioavailability

Fifteen recipes were designed using mungbean dhal (dehulled split) and dehulled mungbean (dehulled split with hulls retained) as principal ingredient in combination with select vegetables. To enhance the bioavailability of iron, recipes should include one or more ingredients rich in ascorbic acid. Table 1 presents the total iron, available iron, and the percentage of iron bioavailability of the prepared recipes.

Tomato mungbean dhal with rice was determined to be the best in terms of iron bioavailability (11.28%). Mungbean dhal masial (mungbean dhal, tomato, onion) ranked second (10.88%), and spinach koottu (mungbean dhal and spinach), and cabbage koottu (mungbean dhal and cabbage) ranked third and fourth with 10.6% and 10.1% iron bioavailability, respectively.

The bioavailability of mungbean masial, which uses whole mungbean, recorded bioavailability of 8.83%, compared to 10.88% for the same recipe made with mungbean dhal.

A salad made with soaked mungbean dhal or sprouts achieved the same percent iron bioavailability as mungbean (whole mungbean) masial. Recipes made only with rice and mungbean or mungbean powder were found to have low iron bioavailability. Recipes which included no enhancing ingredient had low iron bioavailability.

Human Resources Development

At AVRDC, emphasis is placed on research skills training to promote adaptive research and networking. The benefits are enjoyed by the Center and its national agricultural research system partners in the form of more productive and capable research team members.

Training

AVRDC headquarters trained 73 scholars from 25 countries in 1997 (Table 1). All undertook nondegree training and 41% underwent special research skills training. Women accounted for 47% of trainees. More than 58% were trained under the Crop Improvement Program and the rest were trained under the International Cooperation Program and the Production Systems Program.

In addition to AVRDC, eight other donors supported the Center's training program: Second Agricultural Extension Project, ADB-CLVNET, PROAGRO-PGS India Ltd., National Science Council, USAID Mungbean Project, Evergrow Seed Co., Nong Woo Seed Company, International Cooperation and Development Fund (formerly Committee of International Technical Cooperation/Taiwan).

Research fellowship. Research fellows worked in the following research areas: Study of seed dormancy in pepper lines, study of optimum harvest date in pepper and study of germination methods in pepper; and communication- and training-related materials production.

Research internship. Seven training scholars underwent training or conducted research at the Center. This is in line with the Center's goal of improving the research capacity of its partners and producing a critical mass of trained researchers in selected countries who will serve as collaborators of AVRDC.

Table 1. Distribution of training scholars by country and by category

Country	PF	RF	RS	RI	SPT	UST	Total
Cambodia					1		1
Cook Islands					1		1
Costa Rica					2		2
El Salvador					2		2
Guatemala					1		1
Guinea Bissau					1		1
Honduras					1		1
India	2	1					3
Indonesia					2		2
Japan			3				3
Korea				4	1		5
Laos					1		1
Liberia					1		1
Malawi					1		1
Netherlands			1				1
Paraguay					1		1
Philippines		1		1	1		3
Saudi Arabia					1		1
Senegal					1		1
Sri Lanka				2			2
Taiwan					4	27	31
Tanzania					1		1
Thailand				1	1		2
Tonga					1		1
Vietnam					4		4
Total	2	2	4	8	30	27	73

PF = Postdoctoral Fellow
RF = Research Fellow
RS = Research Scholar
RI = Research Intern
SPT = Special Purpose Trainee
UST = Undergraduate Student Trainee

Special research skills training. Twenty-one training scholars from Asia, the Pacific, South America, and Africa attended the special training course on Vegetable Cultivation and Seed Production held at headquarters in November. The course was designed to allow participants to learn scientific techniques and modern approaches in producing good quality vegetables and seeds.

Short-term training. Twenty-seven undergraduate students from seven academic institutions in Taiwan enrolled for the summer student training course. Two technicians from agricultural technical missions supported by the International Cooperation and Development Fund (formerly Committee of International Technical Cooperation/Taiwan) came to AVRDC for study and training.

Training materials. During the year, videos and 106 slide sets with scripts were distributed to 31 training scholars.

Communication and Information

The Center is a major publisher, collector, and distributor of information on tropical and subtropical vegetables. The Center's first priority is to ensure that its scientists, including scientists in its outreach offices, have access to information necessary for their research and training efforts; second, to help ensure a reliable source of information to the Center's NARS partners; and third, to serve as a worldwide information clearinghouse.

Information and documentation

Information collection

Some 226 book titles, 76 photocopies, and 368 titles of serial publications were acquired through exchange or as gifts from 228 institutes and organizations in 49 countries. Subscriptions to 109 journals were renewed for 1998.

Processing information

A total of 1001 book titles and crop documents, and 27 new serial titles were indexed and added to collections and databases which now hold 53,248 bibliographic records and 1644 journal records. Back issues of 300 journal titles were bound. The journal collection now totals 14,076 volumes.

Disseminating information

Selective dissemination of information (SDI) services added 14 new users from 10 countries, bringing the total number of users to 327 in 62 countries. Two issues of Library List (new acquisitions) were provided for internal and external users through the Center's web site.

Some 44 literature searches were provided from Tropical Vegetable Information Service (TVIS in-house database) and CD-ROM databases for internal and external users.

The library recorded 4101 book and crop document loans. A total of 1691 titles were photocopied and delivered to 85 users and 74 libraries in 17 countries. The library also helped disseminate news and information from the CGIAR information dissemination coordinator.

Interlibrary collaboration

Library staff participated in meetings and workshops around Taiwan. The Center is contributing 1662 journal records to the Sci-Tech Interlibrary Co-operation Association, Southern Taiwan Branch, for free access through National Chung Chen University's web site <http://www.lib.ccu.edu.tw/cindex.htm>.

Publications and communications

Communication materials production

The Office of Publications and Communications provides a wide range of communication support services to researchers and staff. The Center's print shop handled more than 170 printing requests in 1997, including production of bound brochures, programs, and substantial training materials. In all, 255,200 pages were printed in-house and 11 publications were printed at an outside print shop. The items ranged from newsletters and promotional literature to technical bulletins and major proceedings. The office also oversaw the reprinting of depleted stock. Some 20 research papers were edited on their way to refereed journals.

Production of audiovisual and display materials

OPC prepared several hundred art requests for publication and presentation, including detailed figures, maps, charts, certificates, and various diverse items ranging from invitations to posters to T-shirt designs. The unit's photographer took several thousand photographs in 1997. Many were for publication, many for slide presentation, others illustrated training materials, and still others were in support of administration. The Center's WWW site was revamped.

Circulation and dissemination of research

Some 2743 publications were distributed by OPC in 1997. About half were given away for free and half were sold for cost recovery (sales amounted to US$13,186). OPC developed an order-entry database for the start of 1997 which greatly speeded the filling of publications orders by automating much of the invoice preparation, record-keeping, and report generation. The Center's mailing list was given a thorough cleaning and up-dating in 1997. The list now includes 2687 entries (including 673 libraries) in 162 countries. It should be noted that the Technical Centre for Agricultural and Rural Cooperation ACP-EU kindly reimbursed postage for publications sent to most countries in Africa and the Caribbean.

Collaborative Research and Networks

The emphasis of the collaborative research and networks project is to encourage the NARS to take an active role in initiating subregional collaborative networks. AVRDC plays a catalytic role and helps forge partnerships. The aim is to enhance the research and development capabilities of the national programs.

Cambodia, Laos, and Vietnam Network (CLVNET)

The Cambodia, Laos, and Vietnam Vegetable Research Network (CLVNET) was formulated by the participating national agricultural research systems (NARS), AVRDC, and the Asian Development Bank (ADB) to promote increased production and utilization of vegetables. Specifically it aims to upgrade the NARS by providing improved germplasm and adaptive research technologies; strengthen the research capacity of NARS scientists in crop management practices, including integrated pest management technologies; and establish databases of vegetable information in the participating countries, including information on vegetable production, marketing, and production constraints.

Collection, exchange, and evaluation of germplasm

Training

In March, six researchers (two from each country) completed ARC's five-month training course on vegetable production and research. A second group of six scholars is undergoing the same course. The first group was trained specifically in adaptive trials whereas the second group is concentrating on seed production and multiplication.

Adaptive trials

A joint planning meeting was held on 16-17 March at AVRDC's Asian Regional Center (AVRDC-ARC), Kasetsart University, Kamphaengsaen campus. Technical Working Group Members of the subnetwork reported on the highlights of the year-one wet season field trials.

Cambodia

Vegetable soybean. Of ten varieties evaluated, AGS 335 had the highest total and marketable yields at 5.49 and 3.19 t/ha, respectively. AGS 292, used as check, had the lowest total yield at 1.6 t/ha.

Grain soybean. This trial failed because of early flooding which completely damaged the crop. Part of Kbal Koh station was still underwater in October during the visit or the monitoring team.

Yardlong bean. All seven yardlong bean entries were found well adapted to conditions at Kbal Koh. Among the entries, Tun 209 gave the highest marketable yield, 36.8 tons/ha. Although the introduced cultivars out-yielded the local check, their pods were of lower market value because Cambodians usually prefer light-green, long pods.

Eggplant. Six eggplant varieties from AVRDC and a local check were evaluated from 9 April to June 26. Entry 084 Teng Pao (check) had the highest yield, 22.6 t/ha. All introduced entries had lower marketable value as Cambodians prefer long and purple fruits. Additional material with preferred characteristics has been provided for the 1997-98 dry season trial.

Tomato. Of nine tomato entries tested in Kbal Koh (seven from AVRDC and two local checks), TMTKK1 (local check 1) and CLN 1621L gave the highest marketable yields, 59.7 t/ha and 59.1 t/ha, respectively. CLN

14660 and CLN 1621 T showed the lowest cracking and insect damage.

Chinese cabbage. Twelve varieties were tested, however, results could not be analyzed as the crop was seriously damaged by pests (diamondback moth [DBM] and flea beetles). The rate of insect damage from planting to harvest was 72-85%.

Water convolvulus. Both entries tested (one from AVRDC and one local) showed high yield potential, 28.8-29.8 t/ha, and suitable horticultural characteristics under Kbal Koh conditions. These entries will be further tested along with new varieties during the 1997-98 dry season.

Laos

Of the seven crops tested in Lao PDR, only four yielded results. Sweet pepper, Chinese cabbage, and tomato trials failed because of flooding and/or heavy pest and disease infestation.

Eggplant. Among four varieties tested, including the local check, EG 203 Surya gave the highest yield, 8.1 t/ha, although it was not significantly different from those of other varieties.

Yardlong bean. Variety 205 performed better than the others. It produced the highest yield, 2.3 t/ha, and its pod length of 31.4 cm is acceptable in the local market.

Grain soybean. Of 13 varieties tested in the wet season, UFV-2 gave the highest yield, 1.4 t/ha, followed by AGS 134 and AGS 129 at 1.3 t/ha and 1.2 t/ha, respectively. These three varieties have similar agronomic characteristics and were all better than the check.

Vegetable soybean. Vegetable soybeans were tested at four locations. In Pakcheng station in the wet season, AGS 348 produced the highest yield, 4.6 t/ha. In Hatxayfong district during the wet season, AGS 335 yielded highest at 8.4 t/ha, followed by AGS 347 at 6.2 t/ha. AGS 327, a local selection used as check, produced 5.5 t/ha. Of the 11 varieties tested at Hatdokkeo station, AGS 346 gave the highest yield, 6.9 t/ha. In Neunsung district, local check AG 327 gave the highest yield, 7.3 t/ha. This variety is now commercially grown by farmers. More adaptability trials will be conducted in 1998.

Vietnam

Chinese cabbage. Among 11 varieties tested in Hanoi, Hybrid 62 gave the highest yield, 40.7 t/ha, followed by 77M(3) -27-MLS 7BLK at 37.9 t/ha. Hybrid 83-20 gave the lowest yield at 14.3 t/ha.

Vegetable soybean. AGS 346 gave the highest total yield, 17.6 t/ha. The other varieties gave yields ranging from 13.2 to 13.6 t/ha.

Yardlong bean. A variety named White had the highest yield, 15.2 t/ha, during the wet season trial in Hanoi. This variety also had the highest average pod weight at 21.8 g. The local check, RIFAV 97-1, had both the lowest yield, 10.3 t/ha, and the lightest pod weight, 14.8 g.

Mungbean. Of five mungbean varieties tested in the summer in Hanoi, KPS 1 produced the highest yield at 2.2 t/ha.

Soybean. The grain yield of the varieties tested during the wet summer in Hanoi ranged from 175 to 890 kg/ha. UFV2 gave the highest yield. Yields were generally low because of excessive field moisture.

Tomato. Among the eight varieties tested at the Plant Genetic Center during the summer, FMTT 572 gave the highest yield, 60.2 t/ha, followed by FMTT 589 at 45.2 t/ha. The local check yielded 20.6 t/ha.

Integrated pest and disease management

Four researchers, two from Vietnam and one each from Cambodia and Laos, underwent a two-month training course on integrated pest management (IPM) of DBM from February to April at headquarters.

Cambodia

A laboratory and parasite rearing facilities were constructed. Parasites *Cotesia plutellae* and *Microplitis plutellae* were reared and released to farmers' fields. The project also provided Kbal Koh research station with an electric generator and water tower as it had no electricity nor running water.

Laos

The three DBM parasites, *Microplitis*, *Oomyzus,* and *Diadegma*, provided by AVRDC, are being multiplied in rearing houses. *Cotesia* cocoons were found to be too old for release in the field. New rearing units will be set up during the next dry season. Under present conditions, *Diadegma* cannot be reared; however, work is going on with other parasites.

A technical guide written in the Lao on IPM-DBM is being developed. It will be used for farmers' training and other extension work.

Vietnam

Laboratories for parasite rearing were refitted in Ho Chi Minh City and Hanoi. Both are now being used for rearing *Plutellae* and *Oomyzus sokolowskii*. At the Institute of Agricultural Sciences (IAS) in Ho Chi Minh City, 2457 *D. semiclausum*, 2563 *M. plutellae,* and 525. *0. sokolowskii* were raised. At the Research Institute for Fruits and Vegetables in Hanoi, 463 *O. sokolowskii* and 1831 *M. plutellae* were raised. These parasites were released to farmers' fields. Off-season cabbage was grown in a newly constructed nethouse for these experiments. Data are still being gathered.

Two survey teams, one in the north and another in the south, conducted DBM damage observations in selected districts. In Hoc Mon district of Ho Chi Minh City, the rate of DBM damage on early cabbage planting (August) was estimated at 34-41%. The damage on the main season cabbage planting (September) was higher at 52-64%. In Lultina district, Hanoi, the rate of DBM damage on early cabbage planting ranged from 18 to 24%, while the main season cabbage planting had higher damage, 28-35%.

A field survey in Donganh district, Hanoi, found less damage in the rice-rice-cabbage rotation compared to the rice-cabbage-cabbage rotation. Spraying 10-13 times with polytrin and Regent did not provide effective control of DBM in either Tuliem or Donganh districts.

Disease management - bacterial wilt in tomato

Cambodia

Preliminary observations made in April-June indicated that AVRDC tomatoes resist bacterial wilt (BW).

Laos

A new, easy-to-follow protocol was provided to the trained researcher. Experiments will be implemented soon.

Vietnam

The main activities for this subnetwork are being conducted at IAS. In 1997 they included a survey, strain identification, characterization and identification of resistance to the local BW strain. Surveys are now being initiated in the northern part of the country.

In Tuliem, Hanoi, the severity of BW damage to the very early tomato crop was 0.9% at 35 days after transplanting (DAT) and 6.3% at 56 DAT. In the early tomato crop, 0.5% damage was recorded at 35 DAT and 3.7% at 56 DAT. In Anhai, Hanoi, considerable damage was found in the early tomato crop. The French variety used by the farmers showed some tolerance compared to the varieties Green Poland and White. In Donganh, the rice-rice-tomato rotation had lower BW damage than the upland crop - upland crop - tomato rotation. The peak of damage occurred at the flowering stage.

Vegetable information survey and database management

Two researchers from each CLVNET country underwent a three-week training program at ARC in Kamphaengsaen under Dr. Mubarik Ali with the assistance of KU and ARC staff. These researchers were trained in diagnostic and monitoring survey sampling approaches and procedures, and spreadsheet and data entry. In addition, an actual diagnostic survey was conducted in the vegetable fields around Kamphaengsaen.

In Cambodia, four districts, Rian Svay, Mukkompol, Lvea Em, and Ksach Kandal, were selected for survey. Preliminary data indicated that onion and lettuce are the major vegetables being grown and that growers face constraints such as pests, high prices of inputs, and poor marketing. In Laos, survey and data collection were begun in the central areas of Vientiane, Khammuane, and Savannakhet.

Collaborative Network for Vegetable Research and Development for Central America (REDCAHOR)

REDCAHOR is a research and development network linking seven countries: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and the Domincan Republic. Regional workshops were held in 1997 which provided a regional forum for the free discussion of ideas, identification of problems, and prioritization of suggested regional responses to the identified constraints. The workshops focused on three areas of importance: (1) regional vegetable trials; (2) IPM; and (3) utilization of vegetable germplasm resources.

Regional vegetable trials

More than 50 professionals, including researchers from the public and private sectors from the seven countries, participated in a region-wide meeting to plan and organize vegetable adaptation trials in the REDCAHOR countries. The workshop held in Managua, Nicaragua, in November, will be followed by a meeting in Panama City, Panama, in May, 1998. The meeting in Nicaragua focused on development of a regional trials network, whereas the meeting in Panama will focus on implementation, e.g., distribution of seeds and analysis of results.

REDCAHOR is providing partial support for direct costs associated with the planting, care, evaluation and harvest costs associated with these trials within each country. Five different vegetable trials are scheduled for 1998: processing tomato, fresh market tomato, sweet pepper, summer onion, winter onion, summer squash, and winter squash. Each trial may be planted in as many as two locations within each country.

One limitation identified was the need for computer software for development and organization of regional trials.

Integrated pest management

Evaluation of germplasm for resistance to white-fly-transmitted Gemini virus in Lycopersicon, Capsicum, *and* Cucurbita

One hundred each of *Capsicum* and *Lycopersicon* accessions from AVRDC, CATIE, and Pairmani (Boliva) have been distributed to the REDCAHOR countries for identification of new sources of tolerance to white-fly-transmitted Gemini virus. The objective is to identify in each country one to three accessions with some degree of tolerance or resistance in comparison with local checks.

This is the first systematic, integrated evaluation of germplasm resources ever organized on a regional basis. REDCAHOR is providing partial support for direct costs associated with these trials within each country. REDCAHOR regional coordinators for this project are from IDIAP, Panama, and MAG, Costa Rica.

Biological control of Plutella *in* Brassica

Parasitic insects are being considered as a control for *Plutella* on *Brassica*. A researcher from Nicaragua, now studying at AVRDC headquarters, will work in cooperation with a researcher from ZAMORANO, Honduras, to evaluate the intermating of *D. semiclausum* and local *Diadegma* species.

The introduction of a new parasite into Central America might require additional data to demonstrate that it will not be injurious to local fauna; therefore, the experiments with ZAMORANO are critical to successful introduction of this parasite on a regional basis. We are being very cautious with the introduction of the parasites to Central America to avoid potential environmental or political misunderstandings.

REDCAHOR is providing partial support for direct costs associated with these experiments and evaluation of the parasites. Coordinators of this activity are from Universidad Nacional Agragia, Nicaragua, and ZAMORANO.

Collaborative Network for Vegetable Research and Development (CONVERDS)

CONVERDS training program for African researchers and extension specialists

Twelve people from 12 countries participated in a workshop/course on variety evaluation and seed production of vegetable crops from 29 September to 5 October 1997 (Table 1). The regular five-month vegetable production course was conducted from 1 July to 28 November 1997 (Table 2). Twenty-one participants from 10 countries successfully completed the course. More than 80 people attended a field day for researchers, extensionists, and farmers, 13 October 1997, at AVRDC-ARP.

In 1997, the curriculum of the five-month vegetable production course was revised as recommended during the BMZ/GTZ review in September 1996 of the CONVERDS training component. The revised curriculum now includes extension modules. The intention is to enhance the capacity of African researchers and extensionists, particularly in southern African countries, to conduct effective research and extension on vegetable crops.

Table 1. Participants in the workshop/course on variety evaluation and seed production of vegetable crops, by country, affiliation and degree

	Affiliation			Degree			
Country	Min	Agric	Univ	Dipl	BSc	MSc/PhD	Total
Angola	1		0	1	0	0	1
Botswana	1		0	1	0	0	1
Ethiopia	1		0	0	1	0	1
Kenya	1		0	0	1	0	1
Lesotho	1		0	1	0	0	1
Malawi	1		0	0	0	1	1
Mozambique	1		0	1	0	0	1
Sudan	0		1	0	0	1	1
Swaziland	1		0	0	0	1	1
Tanzania	1		0	0	1	0	1
Zambia	1		0	1	0	0	1
Zimbabwe	1		0	0	1	0	1
Total	11		1	5	4	3	12

Table 2. Breakdown of participants to 4th SADC regional vegetable production course by country, affiliation, and degree

	Affiliation			Degree			
Country	Min	Agric	Univ	Dipl	BSc	MSc/PhD	Total
Angola	1		0	0	1	0	1
Botswana	2		0	0	1	1	2
Kenya	3		0	0	2	1	3
Malawi	1		1	1	0	1	2
Mozambique	1		0	0	1	0	1
Namibia	2		0	0	2	0	2
Swaziland	2		0	1	1	0	2
Tanzania	4		1	0	5	0	5
Zambia	1		0	1	0	0	1
Zimbabwe	2		0	1	0	1	2
Total	19		2	4	13	4	21

Training involves a blend of practical activities and theoretical classroom lectures. Lecturers are invited from universities, NGOs, and international organizations in Tanzania, Kenya, other Southern African Development Council (SADC) countries. Lectures are also given by technical staff from AVRDC-ARP and headquarters.

The training is for diploma or degree holders recommended by their respective ministries of agriculture in the SADC region. Candidates are screened by the training staff of AVRDC Africa Regional Program. In a few cases, especially if backed by strong requests from the SADC NARS, and provided that the candidate has ample field experience, certificate holders are also accepted.

South Asian Vegetable Research Network (SAVERNET)

SAVERNET was established with a Memorandum of Understanding signed by the six South Asian countries, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, in November 1991. At the SAVERNET-I final workshop held in Kathmandu, Nepal, in 1996, it was proposed that members pursue a second phase. On

Table 3. List of crops and new varieties for exchange in SAVERNET-II

Crop	Variety	Offering country	Remarks
Bottle gourd	BARI LAU-1	Bangladesh	For homegarden
Broadleaf mustard	Kumal Redleaf	Nepal	
	Marpa Broadleaf	Nepal	Late bolters
Brinjal (eggplant)	Sarlahi Green	Nepal	Light green
Cauliflower	Progress	Bhutan	
Cucumber	Shabi Ghenchu	Bhutan	
	Kusle	Nepal	Early variety
Ceylon Spinach	Local	Sri Lanka	*Basella alba*
Dolichos purpureus	BARI Sheem-1	Bangladesh	Early
	BARI Sheem-2	Bangladesh	Medium early
Edible podded pea	BARI Motorshuti	Bangladesh	
Methi kasuri (fenugreek)	Kasuri Local	Pakistan	
Okra	Bluebell	Bhutan	
Onion	Shenshu Red	Bhutan	
Peas	Meteor	Pakistan	Early
	Greenfeast	Pakistan	Late
	Rondo	Pakistan	PM tolerant
Radish	Tasakisun	Bangladesh	White
	BARI Mula-1		
	BARI Mula-2	Bangladesh	Pink
	Tokinashi	Bhutan	White
	Korean-4	Pakistan	
Red amaranth	BARI Lal Sak	Bangladesh	
Spinach	Local	Pakistan	
Swiss chard	Fordhook Giant	Nepal	
Tomato	BARI-3	Bangladesh	Heat tolerant
	BARI-4	Bangladesh	-do-
	BARI-5	Bangladesh	Winter, high yield
	Nozimi	Bhutan	
	Helfruich	Bhutan	
	Moneymaker	Pakistan	Indeterminate

10 January 1997, ADB approved a three-year project prepared by the six countries and AVRDC.

A joint planning meeting was held on 4-9 May 1997 in Kandy, Sri Lanka. At the meeting, 51 delegates from the six member countries, three seed companies, the Asia Pacific Seed Association, AVRDC, and ADB discussed and developed a master work plan.

The agreed objectives of SAVERNET-II are:

(1) to evaluate superior varieties of tomato, eggplant, chili, and onion identified by SAVERNET and to develop and test technology packages for adoption by farmers in their fields; and

(2) to continue to consolidate research progress made in various fields during phase-I, including: seed production from cabbage identified to flower and set seed in subtropical regions; BW resistance in tomato and eggplant; resistance to leaf curl and other viruses in tomato and chili; IPM of fruit and shoot borer in eggplant and fruit worm in tomato; and off-season vegetable production of tomato and chili.

The private sector expressed keen interest in participating in SAVERNET activities as partner. They have agreed to share and exchange some of their germplasm for national testing. They would like to evaluate some of their materials for disease resistance. The steering committee is working out the formalities involved in including the private sector in the network.

The six countries agreed to exchange and evaluate 32 varieties of 17 different vegetable crops (Table 3). The BW group has sent all of the agreed upon eggplant and tomato varieties for BW screening.

A one-month training course in mass rearing of egg parasites for eggplant fruit and shoot borer control, *Trichogramma* sp., was conducted at the Pakistan Agricultural Research Council substation in Multan, in September-October, 1997. One participant each from Bangladesh, Nepal, Pakistan, and Sri Lanka attended the course. The Entomologist from Pakistan coordinated the training with backstopping from AVRDC's entomologist.

AVRDC—Asian Regional Center

The Asian Regional Center (AVRDC-ARC) is AVRDC's link to national partners in Asia. Established in 1992 in Thailand, the Center is well situated to gauge the needs and capabilities of the region and to address the immediate and long-term needs of partner national agricultural research systems (NARS).

The Center conducts applied and adaptive research on AVRDC crops and regionally important crops, conducts training and information dissemination activities, and coordinates subregional networks and collaborative programs such as the Cambodia, Laos, Vietnam Network (CLVNET), the Human Resource Development Program in the Mekong Region, and the AVRDC-ARC China Program.

The Swiss Agency for Development and Cooperation (SDC) Mekong Project and CLVNET complement the Center's mission of assisting NARS in the development of their national vegetable production program.

AVRDC-ARC research activities remain focused on AVRDC's major crops and important regional crops. AVRDC-ARC and the Thai Vegetable Research Center (TVRC) conducted joint studies on tomato, pepper, vegetable soybeans, cucurbits, mungbean, and soybean. Many studies on various vegetables important to the region were also carried out by the participants in the Center's training program. On-farm trials of promising lines of tomato, cherry tomato, vegetable soybean, and mungbean were also carried out in advance of official release. And some 13 collaborative projects were forged with Chinese scientists.

(For more information on AVRDC-ARC's considerable network research activities, see the previous section, Collaborative Research and Networks.)

Research activities and on-farm trials

Twenty-nine studies on tomato, pepper, vegetable soybean, cucurbits, mungbean, and soybean were conducted jointly by AVRDC-ARC and TVRC scientists from January to October 1997, in addition to the 39 experiments conducted by training scholars in the 15th Regional Training Course in Vegetable Production and Research (RTC). Research was also carried out by training scholars and AVRDC-ARC staff for CLVNET.

Researchers from Kasetsart University (KU) also conducted biotechnological research supported by AVRDC either through provision of genetic materials or logistical support. On-farm trials of promising lines of tomato, vegetable soybean, and mungbean were conducted by both AVRDC-ARC and KU researchers before final recommendation for official release. On-farm trials are being conducted for a new tomato variety and mungbean variety which will be released sometime in 1998.

As in previous years, research on AVRDC-ARC's major crop, mungbean (*Vigna radiata*), focused on the specific needs of the targeted countries of Asia, in addition to the following major requirements: high and stable yield, large seed, uniform maturity, nonshattering pods, wide adaptability, varied crop duration to fit in different crop rotations and cropping seasons, and resistance to diseases, particularly powdery mildew (PM), cercospora leaf spot (CLS), and mungbean yellow mosaic virus (MYMV). The 21st International Mungbean Nursery (IMN) was distributed to cooperators all over the world, while lines scheduled for multilocation testing in South Asia were multiplied at AVRDC-ARC for AVRDC headquarters.

Development of near-isogenic mungbean lines resistant to bruchids

Bruchids are important pests that infest mungbean seeds in storage. A number of resistant lines have been developed through the joint effort of KU and AVRDC-ARC. Isogenic lines derived from the cultivars Kamphaengsaen 1 and Chai Nat 60 were tested for resistance to both *Callosobruchus chinensis* and *C. maculatus* in the dry season 1996 and rainy season 1997. The isogenic lines are not different from the recurrent parents in agronomic characters except in number of seeds per pod and plant height of isogenic lines of CN 60, which were predominantly higher than the parent cultivar.

Effects of multiple leaflet gene on physiological and agronomic characters of mungbean

Near isogenic lines of mungbean were produced from backcrossing between KPS 1 and CN 36 with the multiple leaflet line, V 5926, until BC_7 and BC_9. The isogenic lines were evaluated against the two recurrent parents at AVRDC-ARC's research and training site at KU's Kamphaengsaen Campus, Nakhorn Pathom Province, in the rainy season 1994 and dry season 1995. The effect of the gene controlling multiple leaflets on physiological and agronomic characters was investigated. Seed yield, plant height, and number of pods per plant were higher in the trifoliate cultivars than in the near-isogenic lines, whereas number of seeds per pod and 1000-seed weight were not significantly different.

Physiologically, the photosynthetic rate was not significantly different. Light interception, and dry matter accumulation were higher in the trifoliate cultivars than those of the multifoliate lines. Leaf area index (LAI) at the vegetative stage was higher in the trifoliate cultivars, but lower at flowering and young pod stage, due to high number of leaflets per plant of the multifoliate lines. After the R2 stage, LAI of the multifoliate lines was lower, as the number of leaflets per plant was constant, while in the trifoliate lines the number of leaflets per plant was increasing. Significant correlation was found between seed yield and number of pods per plant, light interception, LAI, and dry matter accumulation, with a coefficient of determination (R^2) of 99.7 and 73.2% for the trifoliate and multiple leaflet cultivars, respectively.

Application of RFLP techniques for selection of mungbean lines resistant to bruchids

RFLP was applied in selecting mungbean lines resistant to bruchids from the cross between resistant isogenic line of variety KPS, carrying the resistant gene from the wild mungbean TC 1966, and the susceptible line NM 10-12. F_1 plants were allowed to self to produce F_2 seeds. DNA was extracted from F_2 plants and detected by RFLP technique using PR 26 marker. The results indicated three phenotypes with distinctive DNA bands as follows: (1) a homozygous bruchid-resistant plant with one band of 5000 base size, which is the same band as from the resistant isogenic line of KPS 1 and TC 1966; (2) a heterozygous bruchid-resistant plant with two bands of 5000 and 3000 base size, which are the bands of the resistant and susceptible lines, and (3) a homozygous bruchid-susceptible plant with one band of 3000 bases, which is the band of the susceptible line, NM 10-12 and KPS 1. Data from 48 F_2 plants revealed a band ratio of 1:2:1.

Breeding for bruchid and MYMV resistance in mungbean using molecular markers

This research project, completed in May 1997, combined the expertise and resources of AVRDC-ARC and the Commonwealth Scientific and Industrial Research Organisation, Division of Tropical Crops and Pasture, Australia, to build on previous research of these organizations, and that of Dr. Nevin Young of the University of Minnesota, to develop a saturated genetic map of mungbean and use RFLP/RAPD markers to select for desired characteristics in breeding populations. The results, conclusions, and assessments of this collaboration are summarized below:

a) The resistance gene(s) in TC 1966 and AC 41 is effective against *C. chinensis* but not against all cultures of *C. maculatus* used in this study.

b) The presence of a texture layer on seeds reduces oviposition. Also, fewer eggs are laid on small seeds.

c) Correct phenotyping of genotypes for bruchid resistance might require the removal of the texture layer before assay.

d) Further research is required to resolve differences in the reported resistance of lines V 1128, V 2709, and V 2802.

e) RAPD markers closely linked to the gene for resistance to *C. chinensis* have been identified and converted to SCAR markers to aid marker-assisted selection.

f) differences between linkage distances reported in the Australian and Minnesota map indicate the need for further research to clarify the utility of markers for selection in different populations.

Selection for soybean lines having high seed protein

Soybean seeds from 738 introduced varieties were analyzed for protein percentage and the five highest accessions were identified (G 7945, G 8355, G 8884, G 8891, and G 8976). They were hybridized to form single- and double-cross hybrids from which a pedigree selection was applied. The single-cross group was selected for four consecutive generations while the double-cross group was selected for three generations. Average yields of the selected single-cross and double-cross lines were higher than those of the recommended cultivars by 26 and 64% while protein percentages were higher by 9 and 8%, respectively. However, 100-seed weights of the selected lines were lower than those of the recommended cultivars. Five lines were finally selected as having protein ranging from 50.4 to 52.7% with seed yield of 1.81 to 3.33 t/ha.

Resistance of chili to anthracnose

A total of 286 isolates of *Collectotrichum capsici* and *C. gloesporioides* were collected from 66 CLVNET growing areas all over Thailand from November 1996 to October 1997. The morphology, pathogenicity on CLVNET fruits, as well as the DNA fingerprints of these isolates, will be studied. The aggressive isolates will be selected for resistance studies.

Effect of light intensity on growth and yield of sweet pepper

Sweet pepper cv. California Wonder was grown under 30, 50, 70, and 100% light intensity at AVRDC-ARC, Kamphaengsaen, from December 1994 to March 1995. At 70% light intensity, sweet pepper produced the highest yield (803.3 g/pl), whereas those at 30% light intensity had the lowest yield (184.7 g/pl). Yield was related to height, diameter of canopy, leaf area and accumulation of dry weight throughout the experiment.

At 70% light intensity, sweet pepper showed the highest crop growth rate, relative growth rate, net assimilation rate, LAI, and harvest index, while leaf area ratio and specific leaf area were highest under 30% light intensity. LAI, crop growth rate, and stem dry weight showed additive correlation to fruit dry weight.

Effect of shading and spacing on seed yield and quality of *Capsicum frutescens* cv. Tabasco

Chili (*Capsicum frutescens*) cv. Tabasco was grown with no shading, 25% shading (white nylon net), 40% shading (blue nylon net), and 60% shading (black salan) at spacings of 75 × 75, 75 × 60, 75 × 45, and 75 × 30 cm.

Shading had an effect on plant canopy, leaf area, plant dry weight, pollen viability, pollen germination, fruit set, fruit size, fruit weight, number of seeds per fruit, seed yield, and seed quality, but no effect on physiological maturity of the seed. Chili plants grown under 25% shading gave the highest pollen viability (84%), pollen germination (61%), fruit set (62%), seed yield, and seed quality. Chili plants grown under 40% shading gave the highest seeds per fruit (24 seeds) while 60% shading gave the lowest seed yield and seed quality. Spacing had no effect on seed yield or seed quality.

Anthracnose resistance gene tagging

Moderately resistant pepper variety 83-168 was identified and crossed with many susceptible varieties. A RIL population for future QTL analysis is being generated. The population, now at F_4 generation, will be carried until F_7. A resistant variety found at AVRDC headquarters will be crossed with the present pepper varieties to create segregating populations. Another culture is also being considered to create a double haploid population.

Pepper germplasm using DNA marker

A microsallite marker (GATA) is being used in identification of pepper varieties and for facilitating pepper germplasm evaluation. GATA has been found useful in grouping pepper species, and it might be useful in comparing accessions with similar phenotypes. The work is being done in partnership with TVRC.

Influence of nitrogen, phosphorus, and potassium fertilizers on seed yield and seed quality of bitter gourd

The influence of NPK fertilizers on seed yield and seed quality of bitter gourd (*Momordica charantia,* L.) were studied. Bitter gourd was grown and treated with a combination of three rates of nitrogen (0, 15, and 30 kg N/rai), three rates of phosphorus (0, 10, and 20 kg P_2O_5/rai) and two rates of potassium (0 and 10 kg K_20/rai). Factorial in RCBD with three replications was used. The results showed that N, P, and K fertilizers had no effect on the timing of first bloom or male and female flower, total number or fruits, weight per fruit, number of seeds per 7 m^2 (6 plants), number of seeds per fruit, total seed weight, and 100-seed weight. However, the high rates of N, P, and K gave highest germination (92.9%) and germination index (23.2) when applied in a combination of 30, 20, and 10 kg N, P_20_5, and K_2O/rai, respectively .

Effect of planting date and spacing on seed yield and seed quality of sweet basil

Sweet basil (*Ocimum basilicium* L.) was grown in December, January, and February, 1994 and 1996, with spacing of 30 × 50, 40 × 50, and 50 × 50 cm at KU's Kamphaengsaen campus. Planting dates affected plant width, height, number of primary branches, days to flowering, seed yield, and seed quality. The widest bush, early flowering and maximum number of primary branches, highest seed yield, and seed germination were obtained from the December crop. Spacing had no effect on vegetative growth and seed quality, but did affect seed yield in December when a spacing of 30 × 50 cm produced the highest seed yield of 283.70 kg/rai with eight harvests. However, only three harvests should be enough for commercial seed production to minimize cost of production.

Germplasm multiplication and exchange

Nine sets of IMN, two sets of MYMV IMN, and 25 sets of mungbean breeding lines and accessions were provided to 36 research agencies and individuals worldwide in 1997. (The regular IMN sets also contained some MYMV-resistant materials.) For other vegetable crops, including vegetable soybean, AVRDC-ARC has distributed a total of 25 kg of material.

A total of 66 accessions of angled luffa, 81 accessions of smooth luffa, 60 accessions of melon, 81 accessions of wax gourd, and 226 accessions of tomato were multiplied and evaluated jointly by KU and AVRDC-ARC. Characterization of these materials is underway.

The exchange of materials between AVRDC-ARC and its national partners, especially China and the countries in the Mekong Region, has been strengthened through the vegetable networks which AVRDC-ARC coordinates. A number of these materials change hands through the training scholars who bring in seeds from their countries and carry materials home. Several AVRDC breeding lines were released through this form of exchange.

Through the network, a sizable number of genetic materials is expected to be collected and evaluated jointly by AVRDC-ARC staff and the national partners. Collecting expeditions in Laos, Cambodia, and Myanmar will be launched in 1998. Collections in Vietnam and China are ongoing.

Training

AVRDC-ARC graduated 32 training scholars from 10 countries in Asia and the Pacific Region through its 15th RTC. The 16th RTC, with 30 researchers and extension officers from eight countries enrolled, commenced on October 15, 1997.

Under CLVNET, 13 researchers received special training in the field of integrated pest management (IPM) of bacterial wilt of tomato (3), IPM on DBM (4), and socioeconomic survey (6). Except for the IPM course, which was conducted at AVRDC headquarters in Taiwan, these courses were conducted at AVRDC-ARC's facilities at KU Kamphaengsaen campus.

A research fellow in information joined AVRDC-ARC on 1 January 1997, and will complete her fellowship at the end of the year. Fellowship support was provided by German Agency for Technical Cooperation (GTZ) and SDC grants. Another research fellow from China joined AVRDC-ARC in June 1997 and is now conducting research on genetic diversity of the soybean collection at AVRDC-ARC.

Through the SDC project, AVRDC-ARC also conducted a series of in-country training in the countries in the Mekong Region.

International cooperation

AVRDC-ARC coordinates two projects in the Mekong Region, namely CLVNET and the Human Resource Development Project for the Mekong Region. The former is funded by the Asian Development Bank while the latter receives support from SDC. These two projects are by their very nature linked. CLVNET works towards the development of vegetable research and production in the NARS through resource complementation. On the other hand, the SDC project, which also includes the countries of Myanmar and China, complements the needs of CLVNET by providing training and other aspects of human resource development in areas not covered by the limited CLVNET budget, i.e., in-country training, information packaging, etc.

Thirteen collaborative research projects had been forged with the leading agricultural research institutions in China by mid-1997. The implementation of these research projects is now in full swing.

In collaboration with CLVNET, the project is partly supporting adaptive trials of crucifer, solanaceous, and legume crops. The work has been initiated in Cambodia, Laos, and Vietnam. The project also supported publication of several AVRDC-ARC information materials.

Human resource development project for the Mekong Region

This project is a continuation and expansion of the previous training grants provided by SDC to the AVRDC-ARC RTC. The goal is to assist Cambodia, Laos, Myanmar, Vietnam, and China to increase their capabilities to develop improved and sustainable vegetable production technologies. The project accomplished the following in 1997:

Thirteen agricultural research and extension officers from the collaborating countries, three from Cambodia, three from Laos, three from Myanmar, and four from Vietnam, were trained from October 1996 to March 1997. At present, 18 researchers and extension officers (eight from China, three from Cambodia, two from Laos, three from Myanmar, and two from Vietnam) are participating in the 16th RTC.

AVRDC-ARC conducted in-country training in field research design and data analysis in Laos and Myanmar in October 1997. A total of 43 researchers and station managers completed this one-week course, 20 in Laos and 23 in Myanmar. Several in-country training workshops are scheduled in 1998 in Laos, Cambodia, Vietnam, and Myanmar.

Survey questionnaires required for assessing the impact of the RTC were developed and distributed to all AVRDC-ARC training alumni and their immediate supervisors in 1996-97. Partial analysis of the data has shown that of the 60% of the alumni who responded, 80% considered the AVRDC-ARC training program very beneficial to their professional growth and job productivity.

Scientific information exchange

Information exchange between AVRDC-ARC and its partner countries in Asia continues. AVRDC-ARC receives publications from China and in turn sends AVRDC publications to its principal cooperators in that country.

In 1997, AVRDC-ARC published training reports containing the results of the research conducted by the 14th and 15th RTC participants. Other publications that came out in 1997 include a training information brochure, training curriculum guide, home gardening cultural practices guide (in calendar form), and a revised guide to the cultural practices for AVRDC-ARC-released mungbean varieties. A revised AVRDC-ARC information brochure is due off the press soon. Leaflets on the suggested cultural practices for tomato, vegetable soybean, and Chinese cabbage are being prepared.

AVRDC-ARC China Program

The expanded AVRDC-China Program is now under the umbrella of the Mekong Region Project on Human Resource Development, funded by SDC. This new program sees the expansion of two major activities of AVRDC-China Phase III: tomato virus control studies and study into soybean rust.

Collaborative research and scientific information and germplasm exchange are being continued and strengthened. Under the new project, eight Chinese researchers are being trained in the 16th RTC. A postdoctoral research fellow is examining the genetic diversity of the soybean collection at AVRDC-ARC. He is also working on identifying RAPD markers linked to downy mildew resistance in soybean. RAPD markers will also be used to identify the genetic relationship between Thai soybean cultivars.

ARC-GTZ Project on Human Resource Development

This project supports researchers from China, Thailand, and the Philippines to attend the AVRDC-ARC RTC; and supports research fellows mainly from China. To date, 12 researchers and 3 research fellows (2 from China and 1 from the Philippines) have been trained.

AVRDC—Africa Regional Program

The AVRDC-Africa Regional Program (AVRDC-ARP) conducts vegetable research and provides training and information services to the African national agricultural research systems (NARS). The research and training facilities of AVRDC-ARP in Arusha, Tanzania, were officially opened by his Honourable Deputy Minister for Agriculture on 15 July, 1997. The year also saw the handover of the Program to Dr. M.L. Chadha from Dr. R.T. Opeña, who is now Director of AVRDC's Asian Regional Center in Thailand.

Phase I of the training component of the Collaborative Network for Vegetable Research and Development in Southern Africa (CONVERDS) ended in March, 1997, and Phase II is in progress. Target groups for training are now to include more extension staff. Accordingly, the curriculum of the five-month vegetable production course was revised in 1997 to include extension modules. The countries covered include Angola, Botswana, Lesotho, Kenya, Malawi, Mauritius, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe. Since its inception, AVRDC-ARP has trained 128 NARS personnel. (See previous section on Collaborative Research andNetworks.)

The Program's project on highland tomato aims to develop cultivars with resistance to tomato leaf curl virus, the blight; and to introduce, evaluate, and promote the adoption of tropical tomatoes in the hot humid regions of Africa. Two AVRDC tomato lines have been selected for official release as new cultivars in Tanzania. These AVRDC tomato lines carry resistance to tomato mosaic virus (ToMV), fusarium wilt (FW), root-knot nematodes, and they show field tolerance to tomato yellow leaf curl virus (TYLCV). They also have better fruit quality than do popular cultivars Marglobe, Money Maker, and Roma VF.

The seeds of these two AVRDC lines were distributed to 12 regional NARS. Several consistently good performers were identified for further evaluation. Experiments were conducted in Malawi and Tanzania to test the durability of four previously identified sources of resistance to tomato late blight (LB). Work onLB resistance is in progress. Resistances are being incorporated into AVRDC tomato lines. Late-blight-resistant F_4 lines will soon be tested at AVRDC-ARP.

Activities on germplasm collection and evaluation of African indigenous vegetables were undertaken. Management studies were conducted on amaranth, black nightshade, African eggplant, and Ethiopian kale.

Adaptation trials of tomato germplasm in the African highlands

Two yield trials were carried out in 1997 to evaluate promising AVRDC-ARP tomato lines for yield and desirable fruit characteristics. Group I consisted of nine advanced indeterminate AVRDC-ARP tomato lines. Group II consisted of 11 new selections from last year's trial of advanced indeterminate AVRDC-ARP tomato lines.

Data gathered included yield and yield components, plant characters, such as trusses per plant and fruits per truss, and fruit characters, such as cracking, cat face, shape, and firmness. Fruit samples were taken and stored under ambient conditions for assessment of storability

Design in both trials was randomized complete block with three replications. Plot size was 1.2 x 6.0 m. Distance between rows was 60 cm and distance between hills within the row was 50 cm. Marglobe and Moneymaker served as checks in the first trial while just Marglobe was used as check in the second trial.

In Group I, there were no significant differences in the mean potential yield, although ARP 366-1 had the highest potential yield, 76.7 t/ha, while ARP 366-2 had the highest actual yield, 70.2 t/ha (Table 1).

Significant differences were observed on average fruit weight. Marglobe had the biggest fruits while Moneymaker had the smallest. Marglobe, however, had the fewest fruits per plant, while Moneymaker had the most, resulting in no-significant difference in marketable yield.

In terms of storability, ARP 367-2, an indeterminate AVRDC line recommended for release in Tanzania, had the highest percentage of firm fruits after 25 days of storage at ambient temperature, 46.7% compared to Moneymaker with 11.7% and Marglobe with 3.3% (Table 2). The results confirmed previous findings about the good keeping quality of AVRDC-ARP

Table 1. Yield and yield components of selected advanced ARP tomato lines in a replicated yield trial. Madiira Research and Training Station, Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

Entry	Potential yield (t/ha)	Actual yield (t/ha)	Ave. fruit weight (g)	Mkt. fruits per plant	% mkt. yield By no.	% mkt. yield By wt.
ARP 366-1	76.7	68.3	115.3 b	19.6 bc	95.3	96.1
Marglobe (ck)	76.1	69.8	141.9 a	16.0 c	91.9	91.9
ARP 366-2	74.8	70.2	111.4 b	19.4 bc	96.0	97.0
ARP 365-3	69.2	62.2	100.7 b	20.5 b	92.3	93.8
Moneymaker (ck)	67.4	63.4	81.1 c	24.5 a	91.5	93.7
ARP 367-2	66.1	59.9	110.3 b	17.2 bc	93.6	89.9
Mean	71.7 ns	64.4 ns	110.3 **	19.3 *	93.9 ns	94.5 ns
CV %	8.6	11.1	10.2	10.7	1.7	1.8

Table 2. Percent firm fruits during storage of best ARP tomato lines in a replicated yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

Line/variety	Days under ambient condition 5 days	10 days	15 days	20 days	25 days
ARP 367-2	96.7	93.3	70.0	65.0	46.7
ARP 365-3	93.3	78.3	51.7	48.3	30.0
ARP 366-2	90.0	78.3	63.3	53.3	26.7
ARP 366-1	91.7	76.7	56.7	48.3	21.7
Moneymaker	91.7	58.3	18.3	16.7	11.7
Marglobe	63.3	31.7	10.0	8.3	3.3
Mean	88.6	70.3	46.1	38.6	17.7

lines compared to the locally grown cultivars in Tanzania.

In Group II, ARP 365-2-5, ARP 366-1-13, and ARP 366-1-14 gave the same yield level as the check variety Marglobe (Table 3).

Marglobe had the largest fruits, 117 g; however, it had the least number of fruits per plant, 23. The average fruit weight of selected AVRDC-ARP lines ranged from 72 to 95 g, while the number of fruits ranged from 25 to 36.

No significant differences were observed on percent marketable yield by number of fruits, but significant differences were observed by weight of fruits.

In terms of storability, ARP 366-1-13 had 61.1% firm fruits after three weeks of storage and the only line left with firm fruits after four weeks of storage (Table 4). Marglobe had no firm fruits after three weeks.

Adaptability trials of onion germplasm under African highland conditions

Two evaluation trials were conducted in 1997 to select onion cultivars with high yield, resistance to major insect pests and diseases, good storability and good bulb characters.

Group I consisted of 15 yellow onion varieties from AVRDC. Group II consisted of five red onion varieties, also from headquarters. The two trials were designed to confirm the performance of varieties that did well in earlier trials. Data gathered included marketable and non-marketable yield, mean bulb weight, splitting percentage, bulb length, bulb diameter, number of bulb centers, and percentage splitting. Sample bulbs were taken and stored under ambient conditions to assess storability.

The trials were laid out in RCBD with three replications. Plot size was 1.0 × 6.0 m. Distance between rows was 30 cm and distance between plants within the row was 15 cm. Texas Grano served as the check variety for the yellow onions, while Red Creole was the check for the red onions.

Among the 15 yellow onion cultivars evaluated for yield, adaptability, and storability, Granex and Equanex were the highest yielders with 64.3 and 61.2 t/ha, respectively (Table 5). Nine other cultivars yielded higher than Texas Grano.

Highly significant differences were observed in average bulb weight. Torrens White had the largest bulb followed by Granex and Equanex. Though the bulbs of Torrens White were large, it was 12th in terms of marketable yield, mainly because of a poor plant stand of 62.4% compared to the 90.7% plant stand of Granex. Texas Grano also had large bulb size, 218.5 g, but yield suffered due to the variety's 48.3% plant stand.

The other factor that made Granex, Equanex,

Table 3. Yield and yield components of selected ARP tomato lines in an advanced replicated yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, July to November 1997

Line/variety	Potential yield (t/ha)	Actual yieldl (t/ha)	Ave. fruit wt. (g)	Mkt. fruits per plant	% mkt. yield	
					By no.	By wt.
Marglobe (check)	90.3 a	85.6 a	117.3 a	22.5 c	93.4	93.6 bc
ARP 365-2-5	88.4 ab	81.6 ab	72.5 d	35.9 b	93.6	95.0 ab
ARP 366-1-13	84.8 abc	79.8 abc	94.9 b	26.4 abc	95.9	95.3 ab
ARP 367-1-17	77.6 abcd	72.6 bcd	86.9 bcd	26.4 abc	93.5	94.3 ab
ARP 366-1-11	75.8 bcd	74.3 bcd	86.1 bcd	26.3 abc	92.5	95.2 ab
ARP 365-3-25	75.8 bcd	73.8 bcd	90.5 bc	25.1 abc	94.2	94.7 ab
ARP 365-1-18	66.5 d	63.7 d	81.0 bcd	24.6 abc	89.6	92.9 c
Mean	79.0 *	75.3 **	88.5 **	26.8 **	93.8 ns	95.1 *
CV %	8.7	7.3	8.7	13.0	1.3	1.1

Mercedes, and Granex 2000 top yielders was their high percent marketable yield. Texas Grano, on the other hand, had 91.4% marketable bulbs.

No significant differences were observed in bulb splitting. Number of bulb centers differed significantly.

Apart from high yield, the 15 cultivars matured early, had good bulb characteristics, such as size and shape uniformity, fewer bulb centers, and small necks. The storability study is ongoing.

In Group II, no significant difference was found in terms of yield. The highest yielding variety was Red Creole at 33.8 t/ha followed by Red Bone at 23.9 t/ha (Table 6).

No significant differences were observed in average bulb weight and neck thickness, but significant differences were found in the percent marketable number of bulbs and percent bolting.

Bolting, an undesirable characteristic in onion, was high in Kana Red (41.9%) and Rouge de Tana (40.1%). Bolting also contributed to the low yield of these varieties because a sizable number of bulbs were unmarketable.

Table 4. Percent firm fruit of selected ARP tomato lines after four weeks of storage at ambient conditions, Madiira Research and Training Station, AVRDC Africa Regional Program, July to Nov. 1997

Line/variety	Week 1	Week 2	Week 3	Week 4
ARP 366-1-13	100	72.2	61.1	11.1
ARP 365-1-18	100	83.3	50.0	0.0
ARP 366-1-11	100	77.8	44.4	0.0
ARP 367-1-17	100	66.7	38.9	0.0
ARP 365-3-25	100	77.8	27.8	0.0
ARP 365-2-5	100	100.0	16.7	0.0
Marglobe	100	83.3	0.0	0.0

Table 5. Yield and yield components of best yellow onion cultivars in a replicated yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to November 1997

Cultivar	% plant stand	Mkt. bulb yield (t/ha)	Average bulb wt. (g)	% mkt. yield By no.	% mkt. yield By wt.
Granex	90.7	64.3	236.0	100.0	100.0
Equanex	88.0	61.2	231.8	100.0	100.0
Granex 2000	76.7	50.5	221.6	95.8	97.2
Torrens White	62.4	46.9	251.5	97.2	99.1
Mercedes	87.8	46.4	174.2	100.0	100.0
Houston	78.0	46.2	191.9	100.0	100.0
Texas Grano (ck)	48.3	31.2	218.5	91.4	95.5
Mean	69.3 **	39.2 **	195.9 **	98.5 *	99.2 ns
CV %	14.2	26.0	20.1	1.8	1.6

Table 6. Yield and yield components of red onion cultivars in a replicated yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

Entry	% plant stand	Mkt. yield (t/ha)	Ave. bulb wt. (g)	% mkt. yield	% bolting	No. of bulb centers	% split bulbs
Red Creole	80.9	33.8	138.5	100.0 a	0.0 b	2.3	3.2
Red Bone	60.9	23.9	126.3	100.0 a	0.0 b	2.4	0.0
Kana Red	58.5	22.7	123.1	65.4 b	41.9 a	2.4	0.8
Violet de Galmi	60.0	21.3	121.0	98.4 a	4.8 b	3.1	3.2
Rouge de Tana	54.3	15.6	99.6	70.0 b	40.1 a	2.1	0.8
Mean	62.9 ns	23.5 ns	121.7 ns	86.8 **	17.4 **	2.5 ns	1.6 ns
CV %	17.1	49.7	27.3	2.2	11.7	22.0	47.8

The best materials will be distributed to African NARS for further testing and/or use in commercial production or further breeding work.

Adaptability trials of other global crops under African highland conditions

Evaluation trials of hot pepper, sweet pepper, and vegetable soybean were conducted in 1997 in an effort to select new cultivars with high yield, characters better than the local varieties, and resistance to major diseases.

Two separate yield trials were conducted involving 20 hot pepper lines from AVRDC. Both trials were laid out in RCBD with three replications. Each plot was a double-row bed, 1.2 m wide and 6.0 m long. Spacing between rows was 60 cm and between hills within the rows was 50 cm. No local check was included. The entries were scored for yield, fruit weight, fruits per plant, and pungency.

Ten sweet pepper lines and varieties from AVRDC's collection were evaluated for yield and adaptability. The trial was laid out in RCBD with three replications. Each plot was a double-row bed, 1.2 m wide and 6.0 m long. Spacing between rows was 60 cm and between hills within the rows was 50 cm. California Wonder and Yolo Wonder were used as local check. The entries were scored for yield, fruit weight, fruits per plant, fruit length and diameter, and shape.

Ten vegetable soybean accessions were evaluated from August to November 1997 for adaptability to Arusha's conditions. The trial was laid out in RCBD with two replications. Plot size was 1.2 × 5 m, with a spacing of 60 cm between rows and 15 cm between hills within rows. Data gathered included pod yield, pod length and weight, and 100-grain seed weight. Sample pods were taken, cooked, and evaluated for acceptability.

Eleven non-heading Chinese cabbage were included in a preliminary evaluation to determine their adaptability to Arusha's conditions. The trial was laid out in RCBD with three replications. Plots were 1.2 × 6.0 m with a spacing of 60 cm between rows and 50 cm between hills within rows. Data gathered included marketable yield, head weight, vigor, and reaction to common insect pests and diseases.

In the first trial, PBC 714 had the highest yield, 20.8 t/ha, double the yield of the second-highest entry, PBC 601, which yielded 10.3 t/ha (Table 7). Neither line, however, was very pungent. The most pungent line was PBC 316, the third-highest yielder.

In the second trial, PBC 146 had the highest potential yield, 22.2 t/ha, although the line was not pungent. PBC 374, the third-highest yielder at 15.9 t/ha, had moderate pungency, while PBC 142, the 7th highest yielder at 8.7 t/ha, was the most pungent.

Among the 10 sweet pepper lines and varieties, Milord, B58, and ECW-30R (Bs 3) had highest poten-

Table 7. Yield and yield components of best new hot pepper lines in a replicated yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

Line	Potential yield (t/ha)	Actual yield (t/ha)	Ave. fruit weight (g)	No. of fruits/ plant	Pungency
PBC 714	20.8	17.0	11.0	52.3	1
PBC 601	10.3	7.7	5.9	39.6	1
PBC 316	7.2	2.8	3.7	31.9	5
PBC 142a	5.6	3.6	1.8	44.5	4
PBC 559	2.7	1.3	1.3	17.8	5
Mean	5.8 **	3.7 **	4.0 **	28.7 **	-
CV %	15.3	19.9	18.9	16.8	

tial, and actual yields were better than the check cultivar, California Wonder (Table 8). The lines and varieties did not differ significantly in average fruit weight, number of fruits per plant, and percent marketable yield.

Among the 10 vegetable soybean lines evaluated, AGS 330, 336, and 339 yielded above 10 t/ha (Table 9). AGS 340 was the earliest to be harvested at 68 days after sowing, while AGS 337 and AGS 332 were harvested at 82 and 83 days, respectively. Palatability of all 10 accessions differed little, although AGS 292 was the most acceptable in terms of taste and texture, followed by AGS 340, AGS 332, and AGS 337.

The 11 Chinese cabbage accessions evaluated showed potential for production in Arusha and other areas with similar climatic conditions. Based on yield and tolerance to bacterial soft rot, five lines were found promising: B00034, B00024, B00194, B00673, and B00697 (Table 10). The highest potential yield was 76.5 t/ha, with an average head weight of 2.3 kg

The best materials will be distributed to African NARS for further testing and/or use in commercial production.

Seed production experiments on global and regional vegetable species

Seed production studies were carried out on promising indeterminate tomato line, ARP 367-2, on another promising determinate tomato line, ARP D-2, and on amaranth. The objective was to develop seed production technology for immediate use in the seed production of AVRDC-ARP tomato selections and traditional vegetables such as amaranth.

Table 8. Yield and yield components of best sweet pepper lines and varieties in a preliminary yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

	Potential yield (t/ha)	Actual yield (t/ha)	Ave. fruit wt. (g)	Fruit per plant	% mkt. yield	
					By no.	By wt.
B 58	22.9 a	17.8 ab	158.3	6.0	82.0	90.0
ECW-30R (Bs3)	22.8 a	15.4 bc	152.0	8.5	89.6	95.9
Milord	21.7 ab	21.1 a	120.1	8.6	90.4	92.6
California Wonder	19.1 bc	14.9 bc	144.4	6.6	84.0	90.9
Yolo Wonder (ck)	14.2 ef	9.5 de	159.3	7.4	69.0	87.4
Mean	18.0 **	13.8 **	145.6 ns	6.6 ns	80.3 ns	90.1 ns
CV %	7.6	13.7	19.6	37.7	2.4	0.3

Table 9. Yield and yield components of vegetable soybean accessions in a preliminary yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to November 1997

Entry	Pod length (cm)	Pod weight (g)	Plant stand at harvest	Potential yield (t/ha)	Harvest index	Pod no. per 500 g	100-seed wt. (g)
AGS 292	6.19 ab	1.62 a	111.0	7.7 bc	0.40	154.5 c	82.5 ab
AGS 329	6.33 ab	1.71 a	105.0	8.2 bc	0.37	149.0 c	65.0 ab
AGS 330	6.08 ab	1.70 a	166.5	16.8 a	0.48	148.0 c	85.0 a
AGS 332	5.91 abc	1.67 a	90.0	7.5 bc	0.52	156.5 c	72.5 ab
AGS 333	4.21 d	1.58 a	118.5	9.3 b	0.38	190.5 bc	60.0 ab
AGS 336	5.83 abc	1.59 a	126.5	10.3 b	0.44	165.5 bc	70.0 ab
AGS 337	5.99 abc	1.56 a	106.0	7.7 bc	0.46	221.5 b	51.0 b
AGS 338	5.70 bc	1.62 a	112.0	7.2 bc	0.36	140.5 c	65.5 ab
AGS 339	6.53 a	1.71 a	130.0	11.3 b	0.41	150.5 c	59.0 ab
AGS 340	5.31 c	1.30 b	117.5	4.8 c	0.43	338.0 a	50.3 b
Mean	5.81 **	1.61 *	118.3 ns	9.1 **	0.43 ns	181.5 **	66.1 **
CV %	5.0	5.7	25.3	19.3	10.3	13.5	6.6

A trial of ARP 367-2 was conducted to evaluate the effect of staking and pruning on seed yield. The experiment was arranged in RCBD with three replications. Two levels were used for each factor: staking vs. no staking and pruning to two main stems vs. no pruning. Plot size was 4.8 × 6 m with a spacing of 60 cm between rows and 50 cm between hills within the rows. Data gathered included seed yield, 1000-seed weight, seeds per fruit, and fresh yield and yield components.

Table 10. Yield and yield components of 11 Chinese cabbage accessions in a preliminary yield trial, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Sept. 1997

Accession	Plant survival	Marketable yield Potential (t/ha)	Marketable yield Actual (t/ha)	Ave. head wt. (kg)	% rotten head
01B00042	73.5	76.5	55.8	2.30	7.1
02B00601	76.5	61.5	45.4	1.84	16.7
03B00194	96.5	58.6	56.6	1.76	0.0
04B00673	95.0	58.6	56.1	1.76	1.8
05B00001	89.5	58.2	52.1	1.75	10.0
06B00675	88.5	55.9	49.0	1.68	7.6
07B00079	78.5	55.0	43.0	1.65	6.5
08B00034	93.5	54.7	51.2	1.64	0.0
09B00024	93.5	52.4	49.3	1.57	0.0
10B00697	96.5	51.1	49.8	1.53	3.5
11B00061	81.5	50.9	43.3	1.53	27.8
Mean	87.5 ns	57.6 ns	50.1 ns	1.73 ns	7.4 ns
CV %	15.2	19.1	26.5	19.1	94.8

Staking gave a seed yield of 351.0 kg/ha compared to 135.8 kg/ha without staking. The unstaked plot produced a lot of non-marketable fruits, the main reason for the low seed yield. Eighty-eight percent of fruits from the staked plots were suitable for seed extraction, compared to 45% for the unstaked plot. Pruning resulted in a reduction in seed yield, from 268.8 to 217.9 t/ha. Therefore, this procedure is not advisable for tomato seed production (Table 11).

The second seed production trial of ARP 367-2 assessed the effect of spacing and nitrogen fertilizer rate on seed yield. The trial was laid out in split plot design with the spacing test assigned to the main plot and N fertilizer rate test assigned to the subplot. Three levels of spacing were used: 60 × 60, 60 × 75, and 60 × 90 cm. Likewise, three levels of nitrogen were used: 50, 100, and 150 kg/ha. Data gathered included seed yield, 1000-seed weight, seeds per fruit, and fresh yield and yield components. No significant differences were observed in seed yield and seed yield components. Likewise, there were no significant differences in interaction. The only significant difference noted was in fresh fruit yield where 60 × 60 spacing produced higher yield.

The trial of ARP D-2 was conducted to evaluate the effect of nitrogen and potassium fertilization on seed yield. The experiment was arranged in RCBD with three

Table 11. Effect of staking and pruning on seed yield and seed yield components of indeterminate tomato line ARP 367-2, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to Nov. 1997

Treatment	Seed yield (kg/ha)	1000-seed wt. (g)	Seeds per fruit
Pruning/Staking	328.4	2.87	105.4
Pruning/No staking	107.4	2.81	249.2
No pruning/Staking	373.5	2.56	104.7
No pruning/No staking	164.2	2.68	108.6
CD (critical difference)	ns	ns	ns
Pruning	217.9	2.84	177.3
No pruning	268.8	2.62	107.1
CD (critical difference)	**	**	ns
Staking	351.0	2.72	105.0
No staking	135.8	2.74	179.4
CD (critical difference)	**	ns	ns
Grand mean	243.4	2.73	153.2
CV %	7.6	2.9	50.9

replications. Plot size was 2.4 × 6 m with a spacing of 60 cm between rows and 50 cm between hills within rows. Data gathered included seed yield, 1000-seed weight, seeds per fruit, and fresh yield and yield components. No significant differences were observed.

In the amaranth experiment, no significant differences were observed in seed yield for the different seed rates and seed-sand mixing ratios used, nor in the interactions (Table 12). The highest seed yield, 2.3 t/ha, was obtained with a seed rate of 1 kg/ha at a seed-sand ratio of 1:100. The lowest was with a seed rate of 1 kg/ha but at a seed-sand ratio of 1:150 (Table 13).

No significant differences were observed in the 1000-seed weight obtained under the different seed rates and seed-sand ratios. However, the highest seed weight obtained, 1.6 g, was had using a seed rate of 1 kg/ha and a seed-sand ratio of 1:100. The lowest was had using a rate of 1 kg/ha and a seed-sand ratio of 1:150.

The results confirmed the findings of last year, that a seeding rate of 1 kg/ha is optimum to produce amaranth seed. A sand-seed ratio of 1:100 is advised since it gives the most even distribution of seeds in the plot.

Tomato multilocation evaluation trials

Two groups of tomato cultivars, one determinate and one indeterminate, were evaluated for general adaptability, from 1994 to 1996, as part of Tanzania's national tomato testing program. The determinate set included seven cultivars and breeding lines, two of which were from AVRDC-ARP. A total of 11 trials were conducted in four locations. The indeterminate set consisted of 10 varieties and breeding lines, six of which came from AVRDC-ARP. A total of seven trials were

Table 12. Effect of staking and pruning on fresh fruit yield and yield components of indeterminate tomato line ARP 367-2, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, July to November 1997

Treatment	Potential yield (t/ha)	Actual yield (t/ha)	Ave. fruit wt. (g)	Fruits per plant	% mkt. yield By no.	% mkt. yield By wt.
Pruning/Staking	68.4	64.5	111.0	11.7	86.9	88.6
Pruning/No staking	18.4	16.9	121.8	4.5	42.0	45.6
No pruning/Staking	67.3	65.5	88.9	11.2	89.2	91.2
No pruning/No staking	32.0	31.3	94.1	9.2	48.2	53.1
CD (critical difference)	**	**	ns	*	ns	ns
Pruning	43.4	40.7	116.4	8.1	64.5	67.1
No pruning	49.7	48.4	91.5	10.2	68.7	72.2
CD (critical difference)	*	*	*	**	ns	ns
Staking	67.9	65.0	100.0	11.4	88.1	89.9
No staking	25.2	24.1	108.0	6.8	45.1	49.4
CD (critical difference)	**	**	ns	**	**	**
Grand mean	46.6	44.5	104.0	9.1	66.6	69.6
CV =	8.0	8.9	11.0	12.8	12.6	11.8

Table 13. Seed yield (kg/ha) of amaranth by seed rate and seed:sand ratio, Madiira Research and Training Station, AVRDC Africa Regional Program, Arusha, Tanzania, August to Nov. 1997

Seed rate	Seed:sand ratio 1:50	Seed:sand ratio 1:100	Seed:sand ratio 1:150	Mean
0.5 kg/ha	1782.4	1685.2	1509.3	1659.0
1.0 kg/ha	1870.4	2287.0	1463.0	1873.5
1.5 kg/ha	1708.3	1879.6	1819.4	1802.5
Mean	1787.0	1950.6	1597.2	1778.3

CV = 16.82%

CD: Seed Rate, Mixing Ratio, SR x MR = ns conducted in four locations. The trials were conducted jointly with the Tanzania national program.

The four locations used were Tengeru, Dodoma, Morogoro, and Iringa. Tengeru and Iringa represent the cool highlands, Dodoma is a cool and dry area, and Morogoro, at a low elevation, is relatively warmer.

The trials were in RCBD with three replications. Data gathered included yield and yield components, fruit characters, disease and insect incidence, and storability.

The three AVRDC-ARP lines in the determinate set, D-1, D-2, and D-3, yielded better than the check variety, Roma VF, across locations and seasons (Table 14). Two hybrids, however, Xina and Rossol, yielded better than the AVRDC-ARP lines. Of the three AVRDC-ARP lines, ARP D-2 gave the highest average yield. This line has been submitted to the Release Committee in Tanzania by HORTI-Tengeru for release as a variety under the name Tanya. Aside from higher yield, Tanya has desirable fruit characters, such as good storability and transportability.

In the indeterminate set, all six AVRDC-ARP lines out-yielded the two locally grown check varieties, Marglobe and Moneymaker (Table 15). Among the AVRDC-ARP lines, the top three in terms of yield were ARP 365-3, ARP 367-1, and ARP 367-2. ARP 367-2 has also been submitted to the Release Committee by HORTI-Tengeru for release as a variety for northern Tanzania (Arusha region) under the name Tengeru-97. Aside from high yield potential, Tengeru-97 has very good fruit characters, such as thick flesh, firmness, sweet taste, long shelf life, and good transportability. It is also resistant to root knot nematode and FW, and tolerant to TYLCV.

Table 14. Yield (t/ha) of determinate tomato lines and varieties in Tanzania, 1994 to 1996

	Location				
Line/variety	Tengeru	Dodoma	Morogoro	Iringa	Mean
1994					
ARP D-1	43.7 bc	17.7	-	12.4 cde	24.6
ARP D-2	61.9 a	21.4	-	9.7 de	31.0
ARP D-3	43.6 bc	19.0	-	10.3 cde	24.3
Caraibo	35.4 bc	18.3	-	19.4 b	24.4
Mecline	52.2 ab	19.8	-	-	36.0
Roma VF (ck)	51.3 ab	20.7	-	10.1 cde	27.4
Romitel	46.8 abc	18.8	-	7.3 e	24.3
Rossol	51.9 ab	21.8	-	10.6 cde	28.1
Xina 8-4-1-11	51.1 ab	22.7	-	26.7 a	33.5
Xina GF	31.8 c	14.4	-	17.0 bc	21.0
Mean	47.0 *	19.6 ns	-	13.8 **	
LSD (0.05)	15.2	-	-	6.2	
CV %	18.9	22.8 -		26.2	
1995					
ARP D-1	116.9 ab	23.5	40.8 cd	24.1	51.3
ARP D-2	78.1 d	41.8	52.5 c	18.9	47.8
ARP D-3	103.8 abc	21.4	30.9 d	19.0	43.8
Caraibo	86.9 bc	26.8	46.6 cd	21.1	45.4
Mecline	82.1 cd	21.0	46.2 cd	20.6	42.5
Roma VF (ck)	89.4 bc	23.4	54.7 bc	23.3	47.7
Romitel	104.1 abc	33.4	64.9 b	25.4	57.0
Rossol	92.2 bc	41.2	53.1 c	22.0	52.1
Xina	136.2 a	40.0	77.4 a	24.3	69.5
Xina GF	79.6 d	79.6	46.6 cd	-	68.6
Mean	99.9 *	30.3 ns	50.6 **	21.9 ns	
LSD 0.05	32.2	-	8.1	-	
CV %	18.8	37.8	12.1	29.7	
1996					
ARP D-1	64.6	43.5	63.3	50.8 b	55.5
ARP D-2	91.6	47.7	66.8	91.1 a	74.3
ARP D-3	68.7	40.1	74.6	81.1 a	66.2
Caraibo	81.8	55.6	80.4	69.6 ab	71.8
Mecline	78.5	55.6	79.4	79.4 b	73.2
Roma VF (ck)	70.9	55.8	71.1	79.6 a	69.4
Romitel	68.1	51.2	68.3	86.9 a	68.6
Rossol	84.4	59.9	94.7	-	79.7
Mean	76.1 ns	51.2 ns	74.8 ns	73.7 **	
LSD 0.05	-	-	-	20.9	
CV %	16.7	19.9	15.6	15.9	
Summary					
ARP D-1	75.1	28.2	52.0	29.1	45.6
ARP D-2	77.2	37.0	59.6	39.9	52.9
ARP D-3	72.0	26.8	52.8	36.8	46.6
Caraibo	68.0	33.6	63.5	36.7	49.3
Mecline	71.0	32.1	62.8	33.3	50.2
Roma VF (ck)	70.5	33.3	62.9	37.7	50.0
Romitel	73.0	34.5	66.6	39.8	52.3
Rossol	76.2	41.0	73.9	16.3	53.2
Xina	87.8	37.9	76.1	41.6	61.3
Xina GF	42.2	37.3	30.3	12.6	30.6
Grand mean	71.3	34.2	60.2	32.4	49.2

Field evaluation of AVRDC-ARP tomato lines for resistance to fusarium wilt

Fusarium wilt is a major tomato disease in eastern and southern Africa. The popular tomato cultivars Marglobe and Moneymaker are susceptible. Some AVRDC-ARP tomato lines were found resistant to FW under laboratory conditions. It was necessary to confirm the resistance under field conditions.

Table 15. Yield (t/ha) of indeterminate tomato lines and varieties in, Tanzania, 1995 to 1996

	Location				
Line/variety	Tengeru	Dodoma	Morogoro	Iringa	Mean
1995					
ARP 365-1	66.7	20.0 abc	27.9 c		38.2
ARP 366-4	88.2	17.4 c	39.0 b		48.2
ARP 367-1	94.2	-	37.4 b		65.8
ARP 367-2	87.7	16.6 c	51.8 a		52.0
ARP ID-1	74.4	23.9 a	34.9 bc		44.4
ARP ID-2	76.9	-	28.4 c		52.7
Marglobe (ck)	83.9	20.2 abc	40.3 b		48.1
Marmande	55.9	21.3 ab	31.4 bc		36.2
Moneymaker (ck)	69.3	18.4 bc	38.6 b		42.1
Motelle	93.6	22.8 a	39.9 b		52.1
Mean	79.1 ns	20.2 **	50.6 *		
LSD 0.05	-	3.5	7.2		
CV %	16.4	10.2	12.1		
1996					
ARP 365-1	71.1	-	68.4 abc	49.7 a	63.1
ARP 365-3	69.1	86.8	66.1 abc	48.0 a	67.5
ARP 366-1	68.8	-	58.4 cd	36.4 a	54.6
ARP 366-4	75.9	77.3	63.8 bc	41.2 a	64.5
ARP 367-2	84.9	84.2	63.4 bc	43.4 a	69.0
ARP ID-1	56.2	-	76.5 a	45.4 a	59.4
Marglobe (ck)	63.3	77.0	49.4 d	19.6 b	52.3
Marmande	74.8	-	68.8 abc	48.7 a	64.1
Moneymaker (ck)	73.7	54.2	72.0 ab	47.1 a	61.8
Motelle	93.5	-	70.0 abc	38.3 a	67.3
Mean	73.1 ns	75.9 *	65.7 **	42.4 **	
LSD 0.05	-	20.7	7.6	4.0	
CV %	19.4	14.5	9.8	16.7	
Summary					
ARP 365-1	68.9	20.0	48.2	49.7	50.6
ARP 365-3	69.1	86.8	66.1	48.0	67.5
ARP 366-1	68.8	-	58.4	36.4	54.6
ARP 366-4	82.0	47.4	51.4	41.2	57.5
ARP 367-1	94.2	-	37.4	-	65.8
ARP 367-2	86.3	50.4	57.6	43.4	61.7
ARP ID-1	65.3	23.9	55.7	45.4	51.9
ARP ID-2	76.9	-	28.4	-	52.7
Marglobe (ck)	73.6	48.6	44.8	19.6	50.5
Marmande	65.4	21.3	50.1	48.7	50.2
Moneymaker (ck)	71.5	36.3	55.3	47.1	53.3
Motelle	93.6	22.8	54.9	38.3	59.7
Grand mean	76.31	39.72	50.69	41.78	56.3

Seeds of seven AVRDC-ARP lines, 365-2, 365-3, 366-2, 366-3, 366-4, 367-1, and 367-2, and one popular variety Marglobe, were germinated in seedling trays. Tomato variety Moneymaker was used as the local check. Seedlings were transplanted 31 days after sowing. The experiment was conducted at Makutupora research station, Dodoma, Tanzania, in an area previously found to be polluted with fusarium. The experiment was arranged in RCBD with three replications. Symptoms were recorded at the end of the trial. Yield data of all entries were also recorded.

All of the AVRDC-ARP tomato lines were resistant to FW under field conditions. Moreover, the AVRDC-ARP lines 366-2, 366-4, and 367-1 outyielded the local check, Moneymaker (Table 16).

Evaluation of tomato late blight resistance sources

Late blight caused by *Phytophthora infestans* is a major tomato disease in southern Africa. In this region, the use of fungicides such as Ridomil and Mancozeb is the only control method. Breeding of tomato varieties with high levels of resistance to LB will provide an alternative for disease control.

Twelve *Lycopersicon* accessions were screened for efficiency of resistance to LB under field conditions in

Table 16. Yield of different entries and disease incidence (in % of infected plants)

Tomato accession	Yield (t/ha)	Fusarium wilt incidence
ARP 365-2	37.17	0
ARP365-3	34.52	0
ARP366-2	41.17	0
ARP366-3	34.40	0
ARP366-4	47.77	0
ARP367-1	40.31	0
ARP367-2	37.82	0
Marglobe	21.30	19
Moneymarker (ck)	27.82	40
LSD (P = 0.05)	9.82	

two locations, Madiira Research Farm, Arusha, Tanzania, and Bvumbwe Agricultural Research Station, Malawi. In these two locations, severe epidemics of LB occur annually on tomato crops. Seeds were germinated in seedling trays, and one-month-old seedlings were planted in the field. Disease severity was rated weekly, beginning one month after transplanting.

In Madiira, *L. peruvianum* (L 3707), *L. pimpinellifolium* (L. 3708), and *L. hirsutum* (L. 3683 and L. 3684) were the most resistant accessions (Table 17). Preliminary observations at Bvumbwe Agricultural Research station also indicated that L 3683, L 3684, L 3707, and L 3708 are resistant to LB.

Table 17. Disease severity ratings of Lycopersicon accessions evaluated at Madiira Research Farm

Accession number	Disease severity
LO 3683	0
LO 3684	0
LO 3707	0
LO 3708	0
WV 700	1.4
WV 106	5.5
WV 63	6
Fline	6
TS 33	5.95
TS 19	5.82
Moneymaker	5.9
Roma VF	6

Disease severity was rated according to the following scale: 0 = no visible symptoms; 1 = 1-10% leaf area affected; 2 = 11-20% leaf area affected; 3 = 21-40% leaf area affected and/or 1-10% stem area affected; 4 = 41-70% leaf area affected and/or 11- 50% stem area affected; 5 = 71-90% leaf area affected and/or 51-l00% stem area affected; 6 = 91-100% leaf area affected and/or plant dead.

Screening single plant selections of AVRDC-ARP tomato lines for resistance to tomato mosaic virus and root-knot nematodes

ToMV and root-knot nematodes are widespread and economically damaging in tomato growing areas of Southern Africa. It was found that AVRDC-ARP tomato lines proposed for release as new cultivars in Tanzania, are segregating for resistance to ToMV and root-knot nematodes. It was therefore important to purify these lines and select new lines with resistance to both pathogens.

Seeds of single-plant selections of 29 AVRDC-ARP tomato lines and one local check, Moneymaker, were germinated in plastic pots. Two-week old seedlings were mechanically inoculated with ToMV (pathotype 0). Inoculum was prepared by grinding infected tomato leaves in a phosphate buffer (0.03 M phosphate buffer plus 1% sodium sulfite). Prior to inoculation, carborundum was added to the inoculum. Three weeks after inoculation, seedlings were transplanted on a Meloidogyne-javanica-infected plot for

Table 18. Screening tomato lines for resistance to tomato mosaic virus and root-knot nematodes

		Tomato mosaic virus		Nematodes	
Selection code	No. of inoculated plants	No. of infected plants	% of infected plants	No. of infected plants	% of infected plants
ARP2PH-1-10	34	0	0	0	0
ARP2PH-2-10	38	0	0	0	0
ARP2PH-3-1	31	0	0	1	3
ARP2PH-4-20	39	0	0	1	3
ARP5-2-10	33	0	0	19	58
ARP5-2-11	37	0	0	21	57
ARP5-10-3	35	0	0	8	23
ARP5-10-8	40	0	0	6	15
ARP5PH3-11	34	0	0	2	5
ARP5PH3-13	35	0	0	1	3
ARP5PH5-2	29	0	0	14	48
ARP5PH5-8	34	0	0	21	62
ARP5PH5-10	33	0	0	12	36
ARP5PH5-12	36	0	0	11	31
ARP9-10-2	34	0	0	2	6
ARP9-10-4	31	0	0	1	3
ARP9-10-11	40	0	0	1	3
ARP9-10-29	36	0	0	2	6
ARP9-10-30	26	0	0	70	27
ARP9-10-31	33	0	0	0	0
ARP9PH-1-2	38	0	0	0	0
ARP9PH-1-18	39	0	0	0	0
ARP9PH-2-18	35	0	0	3	9
ARP9PH-3-1	34	0	0	0	0
ARP9PH-5-7	40	0	0	3	8
ARP9PH-5-12	36	0	0	1	3
ARP9PH-6-10	37	0	0	10	27
ARP9PH-6-17	40	0	0	2	5
ARP9PH-6-18	39	0	0	1	3
Moneymaker	33	33	100	33	100

root-knot screening. ToMV symptoms were recorded 30 days after inoculation. Symptoms of root-knot nematodes were recorded after the last harvest.

All selections were found to be resistant to ToMV. Six selections were resistant to root-knot nematodes, while 23 are segregating (Table 18). Selections resistant to both ToMV and root-knot nematodes will be screened again.

Cooperative Programs

AVRDC maintains cooperative research programs with national agricultural research systems (NARS) in Asia. These research programs include germplasm evaluation and exchange, and adaptive research and trials on various globally and regionally important vegetables.

AVRDC-USAID Bangladesh Project

AVRDC-USAID Bangladesh Project introduced 189 lines/varieties in 1997 from AVRDC and South Asian Vegetable Research Network (SAVERNET) member countries. The germplasm was given for testing to the Horticulture Research Center (HRC) and Spice Research Center (SRC) of the Bangladesh Agricultural Research Institute (BARI). The AVRDC-USAID project is assisting BARI to identify promising lines and to screen for resistance to various biotic and abiotic stresses.

Mungbean line NM 92, introduced from AVRDC, has been registered and released under the name BARI Mung-5 by BARI's Pulse Research Centre (PRC). Promising lines of tomato, radish, kangkong, mungbean, malabar spinach, eggplant, chili, summer cauliflower, garden peas, and vegetable soybean have been identified and are undergoing secondary and regional yield trials. Improved varieties are expected to greatly increase vegetable yields per unit area which should increase total production, consumption, and farmers' incomes.

Heat tolerant cherry tomato hybrids introduced from AVRDC in 1996 were found to be quite promising, both with and without the application of hormone to promote fruit set and development. Seeds of these hybrids are being produced locally from AVRDC parent lines. This will help in the effort to make tomatoes available year-round. Introduction of betacarotene-rich tomatoes will help improve nutrition.

During the summer and rainy season 1997, more than 200 summer tomato demonstrations were arranged throughout the country using varieties BARI Tomato-4 (TM0111) and BARI Tomato-5 (TM0367), developed from AVRDC germplasm. The project participated in BARI's research reviews for pulses and vegetable crops, and worked with BARI's On-farm Research Division (OFRD) to help identify research priorities.

With financial support from the project, one BARI scientist completed the 15th Regional Training Course, 15 October 1996 to 15 March 1997, at AVRDC's Asian Regional Center (AVRDC-ARC). Another BARI scientist was sent to the 16th Regional Training course which started on 15 October 1997. The project helped six scientists from Bangladesh participate in the SAVERNET phase II joint planning workshop for South Asia, held in Sri Lanka, 4-9 May 1997, and another four BARI scientists and one scientist each from the Bangladesh Institue of Nuclear Agriculture (BINA) and Gono Kallyan Trust participated in the International Mungbean Consultation Workshop for South Asia held 7-11 September 1997, in New Delhi, India. A training-of-trainers course on mungbean sprouts production and uses, was held from 30 March to 1 April. Speakers were from AVRDC and national institutes. Some 42 participants from 14 organizations attended the practical course. The project also arranged 35 transfer-of-technology courses on new vegetable varieties and technologies. A total of 1225 extension workers, NGO personnel, and farmers participated.

More than 9598 field demonstrations were conducted throughout the country on new vegetable varieties, technologies, and nutrition models. The project also organized three field days in collaboration with BARI and extension agencies, in which 450 farmers and extension workers, including NGO personnel, participated.

The project helped in the building of field, laboratory, and library facilities. Two follow-up workshops on mungbean were conducted for mungbean farmers and extension workers in Sherpur (two locations) and Rajbari (three locations) districts in November. A farmers training course on watermelon cultivation was also planned for Sherpur.

Vegetable crops agribusiness: proceeedings of a workshop held at the Bangladesh Agricultural Research Council (BARC), was published, as were leaflets on new varieties and technologies, namely, radish variety BARI Mula-2; tomato varieties BARI Tomato-3, BARI Tomato-4, and 5; red amaranth, BARI Lalshak-1; bottle gourd, BARI Lau-1; okra, BARI Dharosh-1; and Mungbean, BARI Mung-2, BARI Mung-3, BARI Mung-4, and BARI Mung-5. A leaflet on Coriander, BARI Dhania-1, and another on onion, BARI Piyaj-1, are in production.

Aside from the services of AVRDC specialists from AVRDC, the project engaged two local consultants in 1997, one specialist in Peri urban/urban vegetable crops, retained for four months, and a vegetable agribusiness specialist, retained for six months (with three more months in 1998).

Dr. D. P. Singh joined the project on 12 September in place of Dr. M. L. Chadha, who was transferred to head AVRDC's Africa Regional Program.

In collaboration with BARI and BARC, AVRDC, is introducing and identifying new varieties and technologies to increase year-round availability of vegetables in Bangladesh. Processing tomato, highbetacarotene tomatoes, cherry tomatoes, large-fruited fresh market tomatoes, peppers, white-stem kangkong, summer cauliflower, virus-free okra, mungbean, and new vegetables, such as asparagus, vegetable soybean, edible podded peas, were added to the BARI germplasm collection. These new introductions are helping BARI to develop high-yielding vegetable varieties resistant to abiotic and biotic stresses.

Protected cultivation techniques for growing vegetables during the summer and rainy season have been devised making use of bamboo, GI pipes, and transparent polythene sheets. To help transfer these varieties and technologies to farmers, a large number of farmer field demonstrations and a number of field days were held involving different research and extension organizations, including NGOs and the private sector. Emphasis is being given to growing more nutritious vegetables year-round in homestead gardens. Progress in the project's activities was made possible through the active support and cooperation of BARI, BARC, USAID, AVRDC headquarters, and AVRDC-ARC.

Table 1. Yield and yield-contributing characters of betacarotene-rich tomato lines

Entry	Plant ht. (cm)	Maturity (days)	Fruits/plant (no.)	Fruit size (cm) Length	Fruit size (cm) Dia.	Yield/plant (kg)	Yield (t/ha)	TSS (%)
TM0833 (CLN 1315 BC_1 F_3 57A-30-26)	129.7	84	22	5.2	6.5	1.8	65.0	4.8
TM0834 (CLN 1314 BC_1 F_3 51-25-16-6-2)	149.1	81	24	5.3	6.8	1.9	68.0	4.5
TM0835 (CLN 1314 BC_1 F_3 51-25-16-6-113)	161.3	81	25	5.4	7.1	2.2	88.0	5.1
TM0836 (FMTT 22 (CK) F_1 Fresh market)	124.1	82	28	5.0	6.0	2.0	84.7	4.0
CV %	10.7	5	5.1	2.3	3.4	7.6	13.2	10.4

Tomato

Secondary yield trial of betacarotene-rich tomato lines

A secondary yield trial of four AVRDC betacarotene-rich and-high yielding tomato lines was conducted at HRC, Joydebpur, during winter 1996-97. Line TM0835 (CLN 1314 $BC_1 F_3$-51-25-16-6-113) produced the highest mean yield with large fruit size and early maturity (Table 1). It produced attractive orange-colored fruits. This line was evaluated by the technical committee at Joydebpur for release as a new variety.

Secondary yield trial of processing tomato lines

From the preliminary yield trial conducted last year with 12 AVRDC processing type tomato lines, six lines were selected for a secondary yield trial in winter 1996-97.

Seedlings were transplanted to the field at BARI, Joydebpur, on 15 November. Line PT008 (PT 4719B) produced the highest mean yield with medium fruit size. PT008 and PT 009 (PT 4719A) were found superior

Table 2. Yield and yield-contributing characters of six processing tomato lines

Entry	Plant ht. (cm)	Days to harvest	Fruits/plant (no.)	Fruit size		Yield/plant (kg)	Yield (t/ha)	TSS (%)
				Length	Dia.			
PT004 (PT 4679B)	66.7	85	20	6.2	5.8	1.7	62	3.3
PT006 (PT 4675B)	86.4	83	20	5.6	5.7	1.6	66	3.3
PT007 (PT 4716A)	75.9	82	24	5.6	5.5	1.8	70	4.6
PT008 (PT 4719B)	78.3	82	28	6.1	5.7	2.2	85	5.2
PT009 (PT 4719A)	71.1	80	35	6.1	4.8	2.0	80	5.1
PT01065.9 (CLN 1352A)	80	25	5.8	5.5	1.4	55	3.1	
CV %	13.4	3.9	12.3	3.9	4.7	15.8	11.4	4.5

Table 3. Yield and yield-contributing characters of tomato lines in RYT at Joydebpur, winter 1996-97

Entry	Plant height (cm)	Days to harvest	No. of fruits/ plant	Fruit size (cm)		Yield/plant (kg)	Yield (t/ha)	TSS (%)
				Length	Dia.			
TM0611 (CHT 280)	83.5	73	27	5.4	6.7	1.9	68.0	4.1
TM0620 (FMTT 301)	122.4	73	23	5.3	6.3	2.2	80.0	6.6
TM0621 (FMTT 304)	148.0	73	29	5.2	5.7	2.6	90.0	6.0
TM0825 (CL 5915-206D_4-2-2-0)	123.5	80	31	5.4	5.6	2.8	90.0	4.1
Ratan (ck)	78.8	72	32	5.5	5.5	2.1	75.0	3.9
CV%	12.9	6.5	15.2	4.9	4.3	18.0	12.5	2.5

Table 4. Performance of tomato lines in RYTs at various BARI stations in winter, 1996-97

Line/ Variety	Yield (t/ha)						
	Joydebpur	Hathazari	Akbarpur	Rahmatpur	Jessore	Jamalpur	Ishurdi
TM0621	90.0	89.7	58.6	84.4	73.3	53.7	59.8
TM0611	38.0	94.4	72.8	98.6	72.9	56.6	87.9
TM0825	90.0	-	62.8	93.0	87.1	87.8	80.3
TM0620	80.0	-	62.8	50.4	54.2	76.0	58.7
Ratan	75.0	55.2	70.1	84.8	64.6	67.0	71.5

for fruit production, total soluble solids (TSS), and yield, with attractive fruit color (Table 2). BARI's Technical Committee has recommended that these lines be released as varieties.

Regional yield trial of promising tomato lines for winter

Four promising lines selected from AVRDC germplasm were evaluated in regional yield trials (RYT) at seven locations in Bangladesh in winter 1996-97 (Tables 3 and 4). The best lines will be registered for general cultivation in the country.

Summer tomato

Hybrid cherry tomato for summer

In 1996, three cherry tomato hybrids introduced from AVRDC were sown on different dates in order to assess the influence of time of planting on growth and yield. Planting date did not significantly affect the characters studied, except for TSS (Table 5). All of the hybrids gave higher yield when sown on 15 July, but these hybrids can be grown throughout the summer season.

A trial in the summer of 1997 gave similar results. Line CHT 501 was found to be a high yielder. Data are still being analyzed.

A trial of cherry tomato germplasm conducted in summer 1997 under polytunnels, indicated that lines

Table 5. Effect of time of planting and variety on the yield and yield-contributing characters of hybrid cherry tomatoes, summer 1996

Treatments	Plant ht. (cm)	Fruits/plant (no.)	Fruit size Length	Fruit size Dia.	Yield/plant (kg)	Yield (t/ha)	TSS (%)
15 May							
TM0831	110.0	76	3.5	3.2	1.7	48.0	4.4
TM0832	100.0	70	3.4	3.2	1.8	51.3	4.2
TM0830	115.2	69	3.6	3.1	1.4	40.4	3.7
15 June							
TM0831	113.2	80.0	3.5	3.0	1.8	50.0	4.4
TM0832	109.2	75.0	3.4	3.0	1.8	52.7	4.2
TM0830	123.0	72.0	3.5	3.1	1.4	42.2	3.8
15 July							
TM0831	105.8	83.0	3.4	3.0	1.8	51.8	4.5
TM0832	100.0	80.0	3.4	3.0	1.9	54.2	4.3
TM0830	117.2	75.0	3.5	3.0	1.5	44.	4.0
CV %	15.1	9.4	10.1	12.8	9.0	14.1	4.5

Table 6. Yield and yield-contributing characters of seven selected tomato hybrids, summer 1996

Entry	Plant height (cm)	Days to first harvest	Fruits/plant (no.)	Fruit Length (g)	Fruit Dia (cm)	TSS (%)	Yield/plant (g)	Yield (t/ha)
TH003	167.0	53	42	4.0	3.1	4.9	1700	49.8
TH070	182.3	53	40	3.4	3.4	4.7	1619	47.4
TH001	209.7	52	36	3.5	3.3	4.9	1215	35.6
TH002	230.0	52	42	3.4	3.2	4.8	1417	41.5
TH005	205.0	58	30	3.8	3.6	3.8	1000	29.3
TH006	165.7	54	47	4.2	3.4	4.3	1602	46.9
TH004	193.3	70	18	4.5	4.1	4.1	1000	29.3
CV %	16.4	7.7	39.6	13.9	13.9	14.5	44.2	44.2

CHT 151, 152, and 155 responded to hormone (Tomatotone 2%) treatment. Line CHT 157 did not. Line CHT 151 gave the highest yield.

Performance of selected hybrids in summer rainy season

Thirty hybrids, made by crossing different heat tolerant germplasm during winter 1995, were tested in the summer rainy season of 1996. Seven hybrids performed well (Table 6) and these have been selected for RYT.

Farmers field trials on summer tomato

In collaboration with OFRD, HRC conducted 89 farmer field trials in different agroecological zones (AEZ). From these trials it can be concluded that a summer tomato crop can be grown successfully in Bangladesh and farmers can make a good profit (Tables 7 and 8).

Chili peppers and sweet peppers

A germplasm evaluation trial was conducted at SRC, Joydebpur, during winter 1996-97. Sixty lines collected from AVRDC, SAVERNET, and local sources were sown on 16 October. Of 51 lines transplanted in

Table 7. Economics of summer tomato cultivation at Jessore during Kharif-II, 1996 (average of 22 replications)

Items	Yield/dec.	Value (BDT)	Yield/ha	Value (BDT)
A.Gross return	56 kg	1750	14000 kg	4,37,500
B.Total cost :				
Labor		126		31,500
Polythene		308		77,000
Bamboo		210		52,500
Rope		21		5,250
Fertilizer		40		10,000
Insecticide		11		2,750
Fungicide		15		3,750
Hormone		75		18,750
Total cash cost		806		2,01,500
C. Net profit		944		2,36,000
D. Cost/Benefit ratio		2.2		2.2

Tomato sale price = 31/25 BDT/kg, Labor = 42 BDT/day/person

Table 8. Economics of summer tomato cultivation due to extended harvesting at Jessore during Kharif - II, 1996 (average of 6 replications)

Items	Yield/dec.	Value (BDT)	Yield/ha	Value (BDT)
A.Gross return	133 kg	2,926	33250 kg	731,500
B.Total cost :				
Labor		210		52.500
Polythene		308		77,000
Bamboo		210		52,500
Rope		23		5,750
Fertilizer		45		11,250
Insecticide		15		3,750
Fungicide		20		5,000
Hormone		75		18,750
Total cash cost		2020		5,05,000
C. Net profit		2020		5,05,000
D. Cost/Benefit ratio		3.2		3.2

Tomato sale price = BDT 22/kg, Labor = BDT 42/day

Table 9. Yield and yield-contributing characters of 11 selected chili lines, winter 1996-97

Acc. no.	Plant height (cm)	Plant spread (cm)	leaf length (cm)	Leaf breadth (cm)	Fruit length (cm)	Yield/ plot (g)	Yield (t/ha)	Hot-ness
C0045 (Rangpur-3)	59.6	23.5	5.9	2.2	3.6	508	2.81	V.H.
C0100 (Jessore-33)	63.0	41.2	6.2	2.4	3.5	416	2.30	V.H.
C0265 (Home Garden)	98.0	58.0	5.0	2.9	6.2	519	2.88	V.H.
C0272 (NARC-4)	73.0	45.0	5.8	3.5	4.5	412	2.29	V.H.
C0275 (Loungi)	71.0	48.0	5.9	2.1	6.1	417	2.31	V.H.
C0277 (Yatsufusa)	85.0	45.2	6.7	2.3	4.3	412	2.29	V.H.
C0291 (PBC065)	33.4	37.2	4.9	1.6	3.9	455	2.52	V.H.
C0292 (PBC075)	43.0	37.2	4.8	1.5	3.8	445	2.47	V.H.
C0295 (PBC549)	53.8	29.2	5.0	2.4	4.7	465	2.58	V.V.H.
C0371 (PBC600 LC-sendang)	93.2	40.8	4.8	2.3	4.8	465	2.58	M.H.
GZPR-Local	101.0	48.2	5.2	3.1	1.7	440	2.44	V.V.H.

V.V.H. = very very hot, V.H. = very hot, M.H. = medium hot

Table 10. **Performance of AVRDC 21st International Mungbean Nursery, set-I, kharif-II, 1996, at RARS, Ishurdi**

Entry	Days to flowering	Days to maturity	Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed wt. (g)	Pod length (cm)	Plants/ m²	Yield (t/ha)	YMW (%)
VC6144B-12	38	58	79	11	8.9	6.5	9.9	34	1.24	6
VC6144(47-28-2)	37	56	75	10	9.4	6.5	12.1	34	1.03	2
VC6148(50-12)	37	57	66	11	10.8	6.4	10.2	31	1.00	5
VC6153B-9	35	53	62	10	10.0	6.6	9.5	32	.90	3
VC6153B-20P	36	57	73	10	10.9	7.4	10.3	35	1.11	2
VC6173B-6	35	54	58	11	9.1	6.3	11.5	31	1.10	5
VC6173B-10	34	52	61	9	9.3	7.3	10.7	28	1.30	3
VC6173B-11	38	57	62	10	9.9	7.3	11.4	27	1.32	3
VC6173B-13	36	54	55	10	10.9	7.1	11.8	21	.96	2
VC6173B-14	37	55	67	10	9.0	7.2	11.6	33	1.17	2
VC6173B-33	35	53	71	11	9.6	7.4	10.2	28	1.01	5
VC6367(44-55-2)	35	54	71	9	11.4	7.8	12.3	31	.96	4
VC6372(45-8)	33	52	59	9	8.7	7.8	9.2	37	1.09	10
VC6375(41-13-6)	37	56	67	12	9.2	7.2	10.3	25	1.01	5
VC6141-96	35	52	73	9	9.3	5.9	9.6	32	.95	3
VC6379(23-11)	36	57	75	11	9.6	6.1	9.7	35	1.38	2
VC6370-92	32	48	52	10	9.0	5.2	8.6	33	.73	4
Kanti	35	56	69	10	8.4	6.6	6.8	41	.86	5
F-Test	**	**	**	NS	NS	**	NS	**	**	
CV %	3.5	3.0	8.4	16.9	16.3	5.7	6.2	19.7	1.4	
LSD(0.05)	1.8	2.3	7.9	2.5	2.2	0.5	0.9	8.9	20.8	

Table 11. **Performance of AVRDC 21st IMN set-II, kharif-II, 1996, at RARS, Ishurdi**

Entry	Days to flowering	Days to maturity	Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed wt. (g)	Pod length (cm)	Plants/ m²	Yield (t/ha)	YMV (%)
VC3960A-88	34	55	71.7	18	10.5	5.2	8.7	38	1.28	2
VC3960A-89	33	51	64.7	15	11.4	3.8	7.5	45	1.17	5
VC6141-90	34	52	67.9	17	11.8	3.4	7.1	50	1.00	4
VC6173A	35	52	62.4	15	11.5	7.2	10.1	36	1.22	0
VC6173C	33	51	61.3	15	11.4	6.6	10.4	44	1.29	2
VC6368(46-7-2)	32	49	63.0	12	10.4	5.7	9.4	43	1.12	2
VC6368(46-40-4)	31	51	54.7	14	11.3	5.4	9.3	37	1.06	5
VC6369(53-97)	37	50	73.7	16	11.4	5.1	9.2	44	1.11	6
VC6371-93	35	53	77.5	16	11.5	6.9	9.6	47	1.22	2
VC6370(30-65)	34	51	53.5	15	11.1	5.7	9.4	39	.99	3
VC6370-92	34	55	50.4	15	11.3	5.7	10.1	33	.94	2
VC6371-94	34	54	62.7	15	11.3	5.6	12.4	40	.95	0
VC6372(45-8-1)	34	56	65.5	14	10.9	5.3	9.1	40	1.07	2
Kanti	35	55	74.9	16	10.9	3.3	7.2	59	1.02	2
F-Test	**	**	**	NS	NS	**	**	**	**	
CV %	3.1	3.3	9.7	17.6	10.7	10.8	18.2	19.9	1.4	
LSD 0.05	1.5	2.5	9.0	3.8	1.7	0.8	2.4	12.1	21.4	

Table 12. **Performance of cabbage line CE 001 at six locations, 1996-97**

	Yield (t/ha)					
Entry	Joydebpur	Hathazari	Akbarpur	Rahmatpur	Jessore	Jamalpur
CE 001	80.5	39.5	42.7	46.6	60.7	63.9
K.K.Cross	80.0	42.7	54.6	51.1	65.9	75.9
Atlas-70	100.2	47.3	52.2	52.3	59.3	79.1

the field on 2 December, 11 were identified as promising and slated for further trials (Table 9).

Mungbean

International Mungbean Nursery 1996

Seed sets of the 21st International Mungbean Nursery (IMN), 1996, received from AVRDC-ARC, were sown during August-September, kharif II season, at five locations: PRC, Joydebpur; Regional Agricultural Research Station (RARS), Ishurdi; RARS, Jessore; Institute for Post-graduate Studies in Agriculture, Salna; and BINA, Mymensingh. The data from Ishurdi (2), Jessore (2), and BINA (1) are presented in Tables 10 and 11. From the data it is clear that most of the new AVRDC lines are quite early, uniform in maturity, have high yield potential, and are highly tolerant to Mungbean Yellow Mosaic Virus (MYMV).

Lines VC 6144B-12, VC 6173B-6, VC 6173B-10, VC 6173B-11, and VC 6379 (23-11) from Set I, and lines VC 3960 A-88, VC 6173 A, VC 6173 C, and VC 6368 (46-7-2) from the Set II, were found quite promising at RARS, Ishurdi.

At Jessore, lines VC 6144 B-12, VC (6148-50-12), VC 6173B-10, VC 6173B-13, VC 6367(44-55-2), VC 6379(23-11), and VC 6370-92, all from Set-I, yielded more than 800 kg/ha and were selected for further testing. Six lines from Set-II, VC3960A-88, VC6141-90, VC6368(46-7-2), VC6368(46-40-4), VC6369(53-97), and VC6372(45-8-1), were selected for further testing.

At BINA, Mymensingh, nine lines from the Set-I and three lines from Set-II were selected. These lines

Table 13. Yield and yield-contributing characters of 23 eggplant varieties/lines

Entry	No. of fruits/ plant	Wt. of fruits/ plant (g)	Av. fruit wt. (g)	Fruit length (cm)	Fruit dia. (cm)	Av. plant ht. (cm)	Yield (t/ha)	% infested fruit	Days to 1st harv.	Fruit color	First shape
BLO56	28	2357	86	12.8	4.9	70.8	31.4	12.2	95	P	O
BLO32	18	2509	137	9.6	7.3	68.6	33.4	18.5	84	P	R
BLS_4	31	3809	122	16.8	6.1	70.9	50.8	9.8	99	P	O
BOO3	23	2841	126	18.9	5.2	86.6	37.9	11.3	84	P	O
BL117	25	2155	83	26.5	3.2	89.6	28.7	9.7	84	G	L
ISD006	9	2537	289	13.3	8.7	74.5	33.8	15.4	105	P	R
Islampuri	17	3113	185	10.1	8.5	81.4	41.5	13.8	94	P	R
BLS_3	39	1802	46	18.1	3.0	85.5	24.0	5.7	122	P	L
BOO9	29	2383	74	30.8	3.1	107.2	31.8	11.9	118	P	L
BL114	54	3902	72	11.6	5.8	75.7	52.0	8.8	95	P	O
BL083	22	1687	76	31.4	2.8	83.5	22.5	10.0	118	P	L
BL072	22	2471	111	10.3	7.1	55.3	32.9	7.2	84	G	O
ISD011	24	2034	88	17.8	3.0	83.4	27.1	8.9	105	P	L
BL099	41	2068	51	25.9	2.4	91.8	27.6	5.5	105	P	L
BLS_2	13	2003	53	9.9	7.8	72.6	26.4	27.5	94	P	R
BL039	19	1933	100	8.5	6.4	75.6	25.8	11.2	84	P	R
BLS_{18}	23	2418	106	9.5	7.0	65.3	32.2	12.9	84	P	R
BL118	22	1783	80	25.0	3.1	79.1	23.8	10.3	84	P	L
BL034	51	3344	65	16.0	3.9	77.7	44.6	7.0	95	P	O
BLS_5	27	1363	51	19.3	2.6	67.0	18.2	8.9	92	P	L
BLS_1	61	2222	47	16.6	3.9	72.9	26.6	5.5	114	P	L
Tarapuri	21	3056	144	15.7	6.4	82.6	40.7	10.8	105	P	O
Uttara	55	3032	56	14.6	3.6	79.8	40.4	10.1	100	P	L
CV%	24.4	18.6	12.9	13.8	12.2	6.6	18.7	38.6	-	-	-

P-Purple, G-Green, O-Oblong, R-Round, L-Long yielded more than 1 t/ha and were highly tolerant to MYMV, Cercospora Leaf Spot (CLS), and Powdery Mildew (PM).

Mungbean line NM92 registered and released for general cultivation in Bangladesh as BARI Mung-5

AVRDC's promising line NM 92 has been registered and released for general cultivation under the name BARI Mung-5. This line has also been used as parent in a series of cross combinations at PRC. Some of these crosses are quite promising. More than 475 demonstrations of NM92 were conducted in 1996.

Results of other trials, laid out in Kharif 1997, will be included in next year's report.

Table 14. Yield and yield-contributing characters of 12 selected onion lines from AVRDC germplasm collection

Entry	Plant height (cm)	Av. bulb wt. (g)	Neck thickness (cm)	Bolting (%)	TSS (%)	Dry recovery (%)	Yield/ plot (kg)	Yield (t/ha)
ON0165 (AC325 isolation)	70.8	75.6	1.8	14	4.4	26.6	9.7	32.3
ON0166 (AC451-CG)	64.2	129.7	1.4	2	7.2	46.5	17.9	59.6
ON0167 (AC459(y)(C)-NB)	65.2	84.7	1.5	1	9.9	20.1	10.9	36.4
ON00170 (AC506-CG 3163)	68.1	114.6	1.6	0	12.8	17.0	14.1	47.0
ON0177 (TA 377-CG)	67.4	156.7	1.5	0	8.2	11.7	22.7	75.7
ON0178 (Granek 429)	70.5	129.3	1.5	0	4.9	28.4	15.9	53.0
ON0179 (Texas Grano 502)	71.1	131.7	1.4	0	4.6	19.4	16.1	53.6
ON081 (AC 11)	67.2	103.0	1.5	0	9.7	30.8	14.1	47.1
ON0186 (AC453)	61.3	163.4	1.7	2	4.0	15.0	18.8	62.6
ON0187 (AC461)	68.8	103.1	1.9	0	9.2	22.7	16.3	54.3
ON0188 (AC514)	70.7	62.7	0.9	0	4.5	19.2	9.3	33.9
ON0189 (AC542)	58.6	115.6	1.2	10	5.56	23.7	11.9	39.7

Table 15. Yield and yield-contributing characters of selected onion lines

Acc. no.	Plant height (cm)	No. of leaves/ plant	Leaves length (cm)	Bulb shape (cm)	Av. bulb wt. (g)	Yield/ plot (kg)	Yield (t/ha)	Pungency
ON0056 Red Creole	67.6	10	52.0	Thick flat	75	13.29	44.3	High
ON0064 Arad (H)	73.9	11	57.0	Flat globe	171	21.45	71.52	Low
ON0067 Gladalan brown	67.7	9	48.9	Narrow ovate	169	20.29	67.64	Medium
ON0068 Dessex (H)	68.1	10	51.0	Flat	138	12.86	42.86	Medium
ON0069 Rio.Raj. Red (H)	71.5	11	56.7	Rhombi	101	14.38	41.26	High
ON0070 Granoble	67.4	11	49.2	Globe	103	15.00	50.00	Medium
ON0073 Pera IPA6	77.5	14	68.4	Spindle	111	16.88	56.25	Medium
ON0074 Jenin (Hazera)	68.1	10	62.9	Narrow ovate	111	16.86	56.20	Medium
ON0079 Arka Kalyan	72.7	11	60.0	Spindle ovate	88	12.71	42.36	High
ON0141 Rio Raji Red (F_1)	78.6	9.7	45.8	Globe	136	16.34	54.46	Medium

Cabbage

Regional yield trials of the new seed-producing cabbage line CE 001, along with KK Cross and Atlas 70, were completed at six locations in the last week of February 1997 (Table 12). The seed production capability of CE 001 was found to be quite satisfactory.

Eggplant

Twenty-three eggplant lines selected in germplasm trials in 1996 were evaluated during September 1996 to March 1997. Two lines yielded more than 50 t/ha and the first harvesting was conducted in less than 100 days. A breeding line, BL 114, gave the highest yield, 52.03 t/ha, followed by BL S-4 at 50.28 t/ha (Table 13).

Twelve elite varieties received from AVRDC under the SAVERNET program were tested in winter 1995-96. Khatkhatia, from Bangladesh, gave the highest yield, followed by Pusa Kranti and PPL from India. Pusa Kranti and PPL will be tested in farmers' fields in Bangladesh.

Onion

Two germplasm evaluation trials, one including 30 lines received from AVRDC and the other including 29 lines from SAVERNET and other sources, including local lines, were conducted in winter 1996-97. Twelve promising lines from the AVRDC collection and 11 from other collections were selected for a secondary yield trial (Tables 14 and 15) at SRC.

Table 16. Seed crop performance of new radish line RH 021

	Seed yield kg/ha				
Line/variety	Ishurdi	Akbarpur	Rahmatpur	Jessore	Jamalpur
RH 021	1220	305	176.7	1220	1690
Tasaki	1670	333	187.3	1337	1500

Radish

RYT of an advance radish line RH021

Promising radish line RH 021 was evaluated in different agro-ecological zones (Table 16).

Kangkong

RYT of an advanced kangkong line

Line Broad Leaf, introduced from AVRDC, was evaluated at six locations in 1996 (Table 17). This new line is ready for registration and release.

Homestead vegetable production

Two homestead models developed at BARI were tested, along with the released Kalikapur model as a check, at the Olericulture Division of HRC, Joydebpur, for three years from September 1993. The new models made use of seven raised beds, 3.0 × 0.80 m, and four corner beds each 0.75 × 0.75m. The Kalikapur consists of five raised beds of (5.05 × 0.80 m) on 25 m^2. The new models are designed for intensive, year-round cultivation employing a cropping system with vegetables for higher yield per unit area and time, better nutrition, and more profit.

The performance of vegetable production models I and II, growing 24 and 22 different vegetables, respectively, and spices and quick-growing fruits, was compared with the Kalikapur model which incorporates 14 vegetables. Model-II gave the highest yield, 306.8 kg/year, followed by Model-I, 282.48 kg/year. Kalikapur produced 259.8 kg/year.

Table 17. Performance of new kangkong line, Broad Leaf, in summer 1996

	Yield					
Line/variety	Hathazari	Akbarpur	Rahmatpur	Jessore	Jamalpur	Ishurdi
Kangkong (Broad leaf)	80.3	60.8	70.7	56.9	50.9	61.3
Gima kalmi	70.6	77.7	62.5	54.5	45.9	52.4

AVRDC – Philippines Outreach Program

The objective of the AVRDC – Philippines Outreach Program is to increase farming productivity and profitability by developing improved varieties of field and vegetable legumes, and other vegetables. The Program is conducted in partnership with the Department of Agriculture, Bureau of Plant Industry, Los Baños National Crop Research and Development Center (NCRDC), Laguna, Philippines.

Evaluation and selection of mungbean lines

As part of an effort to develop non-lodging and non-shattering mungbean varieties with high and stable yield, uniform and early maturity, and resistance/tolerance to major pests and diseases, 25 entries from the AVRDC International Mungbean Nursery were evaluated during the dry and wet seasons of 1997. During the dry season, yield was low and the differences between varieties was insignificant.

In the wet season, VC 6379-23-11 produced the highest yield, 859 kg/ha, but its yield was comparable to the check, BPI-Mg9, which yielded 790 kg/ha. VC-3902 A gave the heaviest 100-seed weight, 7.9 g. All entries were rated highly to moderately resistant to CLS, virus, and lodging.

Initial results of the 18 entries evaluated in Set IV showed that VC 6173-B-10, VC 6173-A, VC 6173-B-14, VC 6173-B-6, and VC 6173 C outperformed the check PSB-Mg1 (Table 18). All the entries were rated moderately resistant to CLS and virus, and highly to moderately susceptible to lodging.

Mungbean general yield trial

Twenty-eight advanced lines were evaluated in two sets of trials for yield potential, adaptability to local agroclimatic conditions, and resistance to common diseases, particularly CLS and virus.

Of the 16 entries in Set II, VC 4420-B-12 signifi-

Table 18. Field performance of the 18 entries (Set IV), preliminart yield trial, wet season 1997[a]

Entry	Yield (kg/ha)	100-seed weight (g)	Days to Flower	Days to Mature	Number of Pods/plant	Number of Seeds/pod	CLS[b]	Virus[b]	Lodging[b]
VC 6173-B-10	1416	6.3 d	31 dc	53 d	9	12	2.0	2.0	3.0 ab
VC 6173 A	1388	7.0 ab	31 de	54 c	9	12	2.0	2.0	3.0 ab
VC 6173-B-14	1321	6.9 bc	33 bc	54 c	8	12	2.0	2.0	2.0 b-d
VC 6173-B-6	1248	6.7 c	33 bc	54 c	8	12	2.0	2.0	1.5 cd
VC 6173 C	1221	6.7 c	30 e	53 d	8	11	2.0	2.0	3.0 ab
PSB-Mg1 (ck)	1201	5.1 g	33 bc	54 c	9	12	2.0	2.0	2.0 b-d
VC 6148 (50-12)	1160	7.0 ab	34 ab	54 c	7	12	2.5	2.0	4.0 a
VC 6153-B-19	1151	6.0 ef	30 e	53 d	8	11	2.5	2.5	2.5 bc
VC 6091-5	1113	5.2 g	33 bc	54 c	9	13	2.5	2.5	1.0 d
VC 6112-9	1092	5.9 f	35 a	56 a	7	11	2.0	2.5	2.0 b-d
VC 1973 A	1092	6.2 de	33 bc	54 c	8	11	2.5	2.0	1.0 d
VC 6173-8-11	1040	7.2 a	33 bc	55 b	9	12	2.0	2.5	3.0 ab
VC 6309 (22-4)-2	1003	6.4 d	34 ab	55 b	8	12	2.0	3.0	1.5 cd
VC 6153 B-20P	934	5.1 g	30 e	53 d	8	11	2.0	2.0	2.0 b-d
BPI-Mg9 (ck)	881	5.9 f	34 ab	54 c	8	11	2.5	2.5	2.0 b-d
VC 3960-88	753	5.1 g	32 dc	53 d	8	11	2.0	2.5	1.5 cd
VC 6347 (44-55-2)	728	5.2 g	33 bc	53 d	8	12	2.0	2.0	1.5 cd
VC 6368 (46-40-4)	622	5.0 g	30 e	53 d	10	11	2.0	2.5	1.0 d
Grand mean	1075.53	6.03	32.19	53.69	8.24	11.48	2.19	2.25	2.08
CV %	20.0	1.95	2.59	0.61	13.90	5.65	16.58	19.43	24.0

[a] Planted 24 June 1997. Data mean of 4.8 m^2. subplots distributed in RCBD with two replications.
[b] Rated on a scale of 1 to 5, where 1 = highly resistant and 5 = highly susceptible.
Means followed by the same letter are not significantly different at 5% level using DMRT.

cantly out-yielded the check, PSB-Mg1, during the dry season. However, three entries, VC 4390-B-6 (7.2 g), VC 4366-B-2 (7.2 g) and VC 4390-B-10 (7.1 g), produced the heaviest 100-seed weight. All the entries were rated highly resistant to moderately resistant to CLS (Table 19).

National Cooperative Testing of mungbean and maintenance of breeder seed stock

National Cooperative Testing (NCT) was conducted to evaluate the performance of promising lines/varieties in 8-9 locations throughout the country in terms of bean yield, reaction to pests, and other desirable agronomic characters.

In the Los Baños dry-season trial, EGM 3995 produced the highest yield at 0.6 t/ha, while EGM-3885A produced the heaviest 100-seed weight at 6.4 g (Table 20). All entries were rated highly resistant to moderately resistant to CLS and virus.

Based on eight wet and 13 dry season trials in 1995-1997 across locations, EGM-3995 was recommended by the National Seed Industry Council for seed increase for possible approval as a new variety. EGM-3395 produced a mean yield of 1.17 t/ha and 1.00 t/ha during the wet and dry seasons, respectively.

During the wet season, IPBM 86-49-3 (0.78 t/ha) and IPBM 86-26-43 (0.77 t/ha) outperformed the check PSB-Mg4 (0.68 t/ha). EGM-3885 produced the heaviest 100-seed weight at 6.0 g. All the entries were rated moderately resistant to CLS and virus, and highly to moderately resistant to lodging.

Some 34.1 kg of breeder seed was produced, enough to plant about 2 ha. Some 19.5 kg of seed was distributed for research and seed production by the interested clients (Table 21).

Evaluation and selection of soybean breeding lines

The objective of the soybean work is to develop non-shattering soybean varieties with high yield potential, early maturity, wide adaptability, tolerance to

Table 19. Field peroformance of the 16 entries (Set II), general yield trial, dry and wet seasons 1997

	Yield (kg/ha)		100-seed wt. (g)		Days to flower		Days to mature		No. of pods/plant		No. of seeds/pod		CLS rating[c]		Virus[c]	Lodging[c]
Entry	DS[a]	WS[b]	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	WS	WS
VC 4420-B-12	378 a	563	6.2 de	5.6 ab	41	34	60	55 a	8 a	8	11 a	11 b	1.5 bc	1.8	2.3	1.5
PSB-Mg1 (ck)	226 b	673	6.0 f	5.6 ab	41	34	60	54 ab	7 ab	8	11 a	12 a	1.3 cd	2.0	2.5	1.5
VC 4390-B-6	193 bc	792	7.2 a	5.2 ef	41	33	60	55 a	4 c	8	7 d	11 b	1.3 cd	1.5	2.3	1.0
VC 3767-3B-2-B	171 b-d	581	6.2 de	4.9 h	41	34	60	54 ab	6 bc	8	9 bc	11 b	2.0 a	2.3	2.8	1.3
BPI-Mg9 (ck)	165 c-e	647	6.2 de	4.9 h	39	35	59	55 a	5 bc	9	10 ab	11 b	1.8 ab	1.8	2.0	1.8
VC 3767-3B-2-B	171 b-d	551	6.4 bc	5.4 cd	41	33	60	54 ab	6 bc	9	10 ab	11 b	1.3 cd	2.5	2.3	1.3
VC 3690-B-5-B-4-B	160 c-e	582	6.0 f	5.3 de	40	34	60	55 a	5 bc	8	8 cd	11 b	1.8 ab	2.5	1.8	1.0
VC 3732-B-3-B-2-B	146 c-e	683	6.0 f	5.0 gh	40	34	60	54 ab	6 bc	8	9 bc	11 b	1.5 c	2.3	2.3	1.5
VC 3751-3-B-2-2-B	142 c-e	833	6.1 ef	5.5 bc	40	34	60	54 ab	5 bc	10	8 cd	12 a	1.3 cd	1.8	1.8	1.0
VC 4366-B-2	132 c-e	535	7.2 a	5.7 a	42	34	60	54 ab	5 bc	8	8 cd	11 b	1.0 d	2.5	2.5	1.5
VC 3844-2B-4-1-B	130 c-e	699	5.6 g	4.5 l	40	33	60	54 ab	5 bc	8	9 bc	11 b	1.3 cd	2.3	2.5	1.3
VC 3912-2B-1-1-2-1-B	121 de	552	6.4 bd	5.1 fg	42	34	60	55 a	5 bc	8	9 bc	11 b	1.0 d	2.3	2.5	1.3
VC 3753-B-1-2-B	121 de	481	6.5 h	5.4 cd	42	34	60	55 a	5 bc	9	8 cd	11 b	1.0 d	2.5	2.5	1.0
VC 4420-B-1	108 de	658	5.4 h	5.1 fg	42	34	60	55 a	6 bc	9	10 ab	11 b	1.0 d	2.0	2.3	1.0
VC 3543-B-2-1-1-B	107 de	692	6.3 cd	5.7 a	41	34	60	53 b	4 c	8	9 bc	11 b	1.0 d	2.8	2.5	1.3
VC 4390-B-10	99 e	741	7.1 a	5.7 a	40	34	60	54 ab	5 bc	9	8 cd	11 b	1.5 bc	1.8	2.0	1.0
Grand mean	142.0	641.4	6.3	5.3	41.0	33.7	60.0	54.4	5.0	8.5	9.0	11.1	1.30	2.1	2.3	1.3
CV %	27.7	24.8	1.6	2.2	2.8	2.0	0.7	1.4	24.7	11.4	10.8	3.5	15.4	26.4	21.1	37.5

[a] Planted 28 Jan. 1997. Data mean of 4.8 m^2. subplots distributed in RCBD with two replications.
[b] Planted 24 June 1997. Data mean of 4.8 m^2. subplots distributed in RCBD with two replications.
[c] Rated on a scle of 1 to 5, where 1 = highly resistant and 5 = highly susceptible.
Means followed by the same letter are not significantly different at 5% level using DMRT.

drought, resistance to pests and diseases, and with good processing qualities.

Out of 17 lines evaluated, 13 outyielded the check variety, BPI-Sy4, which had a bean yield of 0.84 t/ha. G-9017 had the highest yield, 1.69 t/ha.

In work to develop improved varieties of soybean through hybridization and selection, of the 27 lines evaluated during the dry season, line AGS-135 gave the highest bean yield at 1.39 t/ha.

Grain soybean preliminary yield trial

Of the 17 lines/accessions of grain soybean (16 from AVRDC and one from Central Luzon State University) evaluated during the dry season, 10 entries produced bean yields comparable to the check, BPI-Sy4, while line G-9956 A significantly outyielded the check (Table 22).

Soybean regional yield trial

Ten test entries were evaluated against two national checks and one regional check simultaneously in different regions in the 1996-97 dry season and the 1997 wet season.

Out of the six test entries evaluated during the dry season at NCRDC, only EGSy 96-6-1 (3.12 t/ha) outyielded the highest yielding check, PSB-Sy6 (2.98 t/ha), but the difference was not significant (Table 23).

For the wet season, none of the five test entries outyielded the highest yielding national check variety, PSB-Sy3, which had a bean yield of 3.05 t/ha. EGSy 96-7-8 and EGSy 28-1, however, with bean yields of 3.04 and 2.97 t/ha, respectively, gave yields comparable to PSB-Sy3.

Table 21. The breeder seeds produced and distributed by NCRDC

Varieties planted	Available seeds (kg)	Amount distributed[a] (kg)
PSB-Mg1	10.9	3.6
PSB-Mg2	8.45	4.65
PSB-Mg3	5.2	5.15
BPI-Mg9	9.55	6.05
Total	34.1	19.45

[a] Carried over from 1995.

Table 20. Field performance of mungbean entries under the NCT, dry season 1997, conducted at NCRDC[a]

Entry	Yield (kg/ha)	100-seed weight (g)	Days to Flower	Days to Mature	Number of Pods/plant	Number of Seeds/pod	Number of Plants harv.	CLS[b]	Virus[b]
EGM 3995	593 a	6.1 b	38 b	60 a	8	11 a	136	2.3 ab	1.3
MG 50-10A (reg ck)	466 ab	6.1 b	40 a	59 b	7	11 a	137	2.3 ab	1.0
EGM 3737	419 bc	5.2 d	39 ab	60 a	9	11 a	95	1.5 bc	1.0
PSB Mg1 (Nat ck)	419 bc	6.0 b	39 ab	59 b	8	11 a	100	2.3 ab	1.0
EGM 4488	398 bc	5.9 b	39 ab	60 a	8	11 a	110	1.8 bc	1.0
IPBM 85-45-4	356 b-d	4.5 f	40 a	60 a	8	10 b	95	1.5 bc	1.3
PSB Mg 2 (Nat ck)	343 b-d	6.1 b	40 a	60 a	7	11 a	102	1.5 bc	1.0
BPI Mg9 (Nat ck)	331 b-d	5.6 c	40 a	60 a	8	11 a	86	2.3 ab	1.0
IPBM 85-45-1B	296 cd	5.0 de	40 a	60 a	7	11 a	108	2.0 a-c	1.3
IPBM 84-56-11	294 cd	5.1 de	39 ab	59 b	7	11 a	116	2.8 a	1.0
IPBM 85-35-18	294 cd	4.9 e	39 ab	60 a	8	11 a	83	1.8 bc	1.0
EGM 4477	286 cd	5.6 c	39 ab	59 b	8	10 b	88	2.3 ab	1.5
IPBM 85-34-4	224 d	4.4 f	40 a	60 a	8	11 a	86	1.8 bc	1.3
EGM 3885	222 d	6.4 a	40 a	60 a	6	11 a	75	1.3 c	1.0
Grand mean	352.89	5.47	39.36	59.66	7.6	10.91	101.2	1.93	1.0
CV %	25.42	2.31	1.57	0.61	13.43	5.11	29.8	28.85	34.79

[a] Planted 28 Jan. 1997. Data mean of 6.0 m^2. subplots distributed in RCBD with four replications.
[b] Rated on a scale of 1 to 5, where 1 = highly resistant and 5 = highly susceptible.
Means followed by the same letter are not significantly different at 5% level using DMRT.

Tomato improvement

The work in tomatoes is intended to develop high yielding fresh market tomato varieties adapted to hot-wet conditions (rainy season) and resistant to bacterial wilt (BW), and to develop high yielding processing tomato varieties with good processing qualities (high solid content, firm fruit, and deep intense red color).

Tomato general yield trial

Fresh market tomatoes evaluated during the dry season showed good yield performance, while pest and disease problems were high during the wet season. Of the 13 indeterminate F_1 hybrids screened against Pope and Maigaya (check varieties) during the dry season, FMTT-114, FMTT-13B, and FMTT-586, with total yields of 52.4, 52.1, and 49.5 t/ha, respectively, significantly outyielded the check Pope, which yielded 36 t/ha (Table 24). Fruit size varied significantly, ranging from 31 to 138 g/fruit. The highest yielders produced medium-sized fruits.

Twelve determinate entries were evaluated against Pope and Maigaya in the dry and wet seasons. Total yield during the dry season ranged from 32.7 t/ha for Ant-9 to 48.7 t/ha for CL 5915-93 D4-1-0-1-2, with a grand mean of 40.8 t/ha (Table 25). The highest yielder, CL 5915-93 D4-1-0-1-2, produced comparable yield to Pope (41.4 t/ha) and Maigaya (42.7 t/ha). In the wet season, Ant-7 and Ant-9 produced total yields comparable to Maigaya (9.5 t/ha), with a grand mean of 5.13 t/ha.

Marketable yield in both seasons significantly varied with a grand mean of 39.30 t/ha in the dry season and 4.51 t/ha in the wet season.

Significant differences in fruit size among entries were observed in both seasons with a range of 18 to 80 g/fruit in the dry season and 13 to 37 g/fruit in the wet season. CLN 236 BC 1 F3-42-2-2-12-0 (dry season) and CLN 466 BC1 F2-44-7-5-0 (wet season) had the biggest fruits at 80 g/fruit and 37 g/fruit, respectively.

Table 22. Mean bean yield and other agronomic characters of grain soybean lines, preliminary yield trial, dry season, 1996-97[a]

Entry	Bean yield (t/ha)	100-seed weight (g)	Days to Maturity	Pest rating[b] mites
G 9956-4	1.21 a	13.23	81.00 c	2.0 a
SJ-4	0.97 ab	15.43 c	80.67 c	1.5 b
GC 50259-2-19-6-7-65-2	0.96 ab	22.17 a	77.00 f-h	2.0 a
GC 84040-27-1	0.96 ab	15.47 c	78.67 gh	2.0 a
GC 50259-2-19-6-7-65-6	0.95 a-c	20.03 b	76.67 gh	1.8 ab
GC 87028-35-1	0.88 a-d	10.67 f	83.67 a	1.6 ab
GC 87022-35-1	0.86 a-d	10.47 f	82.67 b	1.8 ab
GC 50227-5-22-6-9-48-8	0.84 a-d	19.97 b	76.00 h	1.5 b
GC 50227-5-22-6-9-21-6	0.82 a-d	14.87 c-e	76.00 h	1.5 b
GC 50227-5-22-6-9-21-8	0.77 b-d	20.67 ab	76.33 gh	1.8 ab
GC 50227-5-22-6-9-48-6	0.75 b0d	22.20 a	76.67 gh	2.0 a
BPI-Sy4 (ck)	0.70 b-d	15.37 cd	77.33 e-g	2.0 a
EGSy 93-63-9	0.69 b-d	14.70 c-e	78.33 de	1.5 b
GC 87028-3S-3	0.67 b-d	10.57 f	78.00 d-f	1.8 ab
GC 87022-1S-1	0.63 b-d	13.67 c	80.00 c	1.8 ab
GC 87022-5S-1	0.55 c-d	12.88 e	81.00 c	1.6 ab
GC 50259-2-19-6-7-65-3	0.49 d	19.90 b	76.33 gh	1.6 ab
Grand mean	0.81	16.01	79.00	1.77
CV %	25.36	7.31	0.73	11.46

[a] Planted 10 Jan. 1997. Data means of 5 m^2. subplots, distributed in RCBD with three replications.
[b] Rated on a scale of 1 to 5, where 1 = highly resistant and 5 = highly susceptible.
Means followed by the same letter in each column are not statistically different at 5% level by DMRT.

Tomato regional yield trial

Nine fresh market tomatoes were evaluated in the regional yield trial under the NCT for vegetables during the 1996-97 dry season. At Los Baños, total yield ranged from 40.1 to 52.1 t/ha with a grand mean of 44.4 t/ha. Two AVRDC hybrids, FMTT-138 (52.1 t/ha) and CL 6046 (51.9 t/ha), significantly outyielded all entries, including the check (Table 26). The good crop environment contributed to the high yields of the different entries.

Table 23. Mean bean yield and other agronomical characters of soybean lines, regional yield trial, dry and wet seasons 1996-97[a]

Entry	Bean yield (kg/ha)		100-seed weight (gm)		Days to mature		Pests and disease rating[b]	
	DS	WS	DS	WS	DS	WS	Mites	Rust
EGSy 96-6-1	3116 a	2698	18.42 a	20.8	82 c	99.75	2.0 b	1.0
PSB-Sy6 (N. ck)	2978 a	2949	10.72 e	13.5	84 b	103.25	1.7 bc	1.0
PBI-Sy4 (R. ck)	2519 b	-	15.75 b	-	80 d	-	2.0 b	1.0
IPBSy 91-10-01	2355 bc	2364	11.27 e	14.1	97 a	117.5	1.7 bc	1.0
EGSy 96-7-8	2312 bc	3037	15.10 b	18.1	80 d	101.0	2.4 a	1.0
EGSy 99-7-8	2299 bc	-	16.87 b	-	82 c	-	1.5 c	1.0
EGSy 95-17-2-2	2050 b-d	-	13.95 c	-	79 e	-	2.0 b	1.0
IPBSy 91-11-18	1897 c-e	2742	13.02 cd	14.1	97 a	117.5	1.9 b	1.0
LGSy 28-1	1696 de	2978	13.47 cd	16.0	79 e	100.25	2.0 b	1.0
PSB-Sy3 (N. ck)	1535 e	3054	12.50 b	16.1	79 e	102.0	2.0 b	1.0
Grand mean	2276	2831.4	14.10	16.1	84	105.85	1.9	1.0
CV %	13.7	-	5.3	-	0.6	-	10.6	

[a] Dry season (DS) planted 10 Jan. 1997 and wet season (WS) planted 26 June 1997. Data means of 5 m^2. subplots, distributed in RCBD with three replications.

[b] Rated on a scale of 1 to 5, where 1 = highly resistant and 5 = highly susceptible.

Means followed by the same letter in each column are not statistically different at 5% level by DMRT.

Table 24. Yield, horticultural characters, pest and physiological disorders, indeterminate tomatoes,general yield trial, dry season, 1996-97[a]

Entry	Yield (t/ha)		Days to	Fruit size	Pest & physiological disorders[b]			
	Total	Marketable	Mature	(g/fruit)	FM	BER	SS	Cr
Set I								
FMTT-105	45.7 a-c	44.8 a-c	70 b	89 cd	1.05 b	1.58 a-c	1.63 b	2.85 a
FMTT-18	44.1 a-c	38.4 b-d	73 a	74 c	0.88 b	4.08 a	0.85 c-e	0.73 c
FMTT-13B	52.1 a	51.2 a	75 a	74 c	1.05 b	0.95 bc	0.85 c-e	0.85 bc
CLN 657 F2-285-0-20-0-24	29.4 d	29.1 d	77 a	108 cd	0.85 b	0.73 c	1.05 c-e	0.70 c
CLN 595-206 D4-2-5-0	37.6 b-d	36.6 b-d	75 a	111 cd	1.00 b	1.05 bc	1.18 c	0.70 c
CLN 595-206 D4-2-4-0	38.5 b-d	37.6 b-d	77 a	89 cd	0.85 b	3.43 a-c	1.95 a	0.70 c
CLN 595-206 D4-2-2-0-0	38.2 b-d	36.9 b-d	75 a	74 c	1.25 ab	1.58 a-c	1.15 cd	0.70 c
Pope	36.0 cd	34.1 cd	70 b	46 b	0.88 b	1.70 a-c	1.20 c	0.70 c
CL 6046 BC1-1-22-51-1-1-25-5-10-1B	42.2 a-c	39.9 a-d	73 ab	31 a	1.23 ab	2.43 a-c	0.78 e	0.75 c
FMTT-589	46.5 a-c	44.3 a-c	73 ab	138 d	1.60 a	3.88 ab	0.88 c-e	0.70 c
FMTT-586	49.5 ab	46.7 ab	77 a	129 d	1.10 b	2.95 a-c	0.80 de	0.70 c
FMTT-22	45.4 a-c	43.2 a-c	75 a	98 cd	1.00 b	3.38 a-c	0.90 c-e	1.05 bc
FMTT-110	47.1 a-c	45.3 a-c	73 ab	100 cd	1.60 b	4.25 a	0.80 de	0.80 c
FMTT-114	52.4 a	49.9 a	70 b	74 c	1.10 b	2.83 a-c	0.85 c-e	1.15 b
Grand mean	43.2	41.3	74	76.5	1.10	2.48	1.06	0.93
CV %	17.2	16.8	3.9	22.75	26.8	72.0	20.6	22.4

[a] Transplanted 27 Jan. 1997, harvested six times from 1 o 28 April 1997.

[b] Percent incidence based on total yield.

Table 25. Yield, horticultural characters and reactions to pests, disease and physiological disorders of entries in the general yield trial, dry season 1996-97; wet season 1997[a]

Entry	Total yield (t/ha)		Marketable yield		Days to mature		Fruit size (g/fruit)		Blossom end rot	TMV	Fruit worm	
	DS 1996-97	WS 1997	DS 1996-97	WS 1997	DS	WS	DS	WS	DS[c]	WS[d]	DS[c]	WS[d]
Set II												
CLN 95-280 D5-1-7-0	37.9 b-d	3.9 c-d	36.8 bc	3.3 c	68 a-c	67 ab	69 e-g	33 ab	1.7 ab	3.2 ab	0.9 ab	1.7 ab
CLN 698 BC1 F3-371-0-8-0	39.1 a-d	2.6 d	37.7 a-c	2.0 c	67 a-c	71 ab	61 ef	25 b-d	2.0 ab	3.0 a	0.8 ab	2.2 ab
CL 5915-93 D4-1-0-1-2	48.7 a	3.5 d	47.1 a	3.0 c	68 a-c	69 ab	59 e	30 a-d	1.6 ab	2.7 ab	0.8 ab	2.0 a
CLN 236 BC1 F3-42-2-2-12-0	41.2 a-d	3.0 d	38.0 a-c	2.6 c	63 c	71 ab	80 g	35 ab	2.5 a	3.7 a	0.8 ab	1.7 ab
CLN 466 BC1 F2-44-7-5-0	38.2 b-d	3.0 d	35.9 bc	2.6 c	65 c	68 ab	39 c	37 a	2.0 ab	3.7 a	0.8 ab	1.5 b
CLN 637 BC1 209-0-0	39.9 a-d	3.0 d	39.2 a-c	5.2 b-d	67 a-c	71 a	73 e-g	29 a-d	1.4 ab	3.7 a	0.9 ab	1.7 ab
CLN 65-349 D5-2-0	44.8 a-c	7.8 a-c	44.2 ab	7.3 a-b	65 c	66 ab	39 c	18 d-e	1.1 b	3.5 a	0.7 b	1.7 ab
CLN 698 BC1 F3-512-0-12	47.3 ab	5.0 b-d	46.7 a	4.6 bc	66 bc	71 ab	46 d	25 b-d	1.3 b	2.7 ab	0.8 ab	2.0 ab
CLN 475 BC1 F3-265-12-9-1	41.7 a-d	1.8 d	40.7 a-c	1.6 c	74 a	70 ab	41 cd	25 b-d	1.4 ab	3.2 ab	1.0 ab	2.0 ab
CLN 452 BC1 F5-65-22-1	36.0 ad	3.6 d	35.0 bc	2.1 c	66 bc	66 ab	78 f-g	30 a-c	1.2 b	3.7 a	1.1 a	2.7 a
Ant-7	39.2 a-d	8.7 a-b	37.9 a-c	8.0 ab	65 c	72 b	66 e-g	29 a-d	1.5 ab	2.2 ab	1.0 ab	1.7 ab
Ant-9	32.7 d	8.2 ab	31.9 c	7.1 ab	72 ab	69 ab	43 cd	24 b-d	1.6 ab	2.5 b	0.7 b	2.0 ab
Maigaya	42.7 a-c	9.5 a	40.0 a-c	8.9 a	65 c	67 ab	18 a	13 e	1.2 b	2.0 b	0.8 ab	2.0 ab
Pope	41.4 a-d	5.2 b-d	39.4 a-c	4.9 bc	65 c	67 ab	31 b	19 c-e	2.2 ab	3.0 ab	0.8 ab	1.5 b
Grand mean	40.8	5.13	39.3	4.51	67	69.14	45.0	26.7	1.62	3.04	0.85	1.91
CV %	14.23	49.0	14.33	58.0	6.4	5.3	10.72	27.2	43.0	25.0	26.2	37.5

[a] Dry season (DS) trial transplanted 6 Jan. 1997 and harvested from 6 March to 3 April 1997. Wet season (WS) transplanted 30 June 1997 and harvested 25 Aug. to 15 Sept. 1997.
[b] Peak of harvest.
[c] Transposed data to /8 + .5
[d] Ratings from 1 to 5, where 1 = none (no damage/infection) resistant; 2 = less than 10% damage, moderately resistant; 3 = 11-40% damage, moderately susceptible; 4 = 41-70% damage, susceptible; 5 = more than 71% damage, very susceptible.

Table 26. Yield and horticultural characteristics of entries in NCT, dry season 1997[a]

Entry	Yield (t/ha) Marketable	Total	Fruit size (g/fruit)	Days to 1[st] harvest	Days to last harvest	Shelf life[b]	BER[c]
1. PT06	41.3 b	43.6	29 a	56 c	96 c	76 a	2.00 c
2. 17B	41.0 b	42.6	43 bc	56 c	97 bc	36 b	2.25 bc
3. 8 h-2	41.3 b	45.6	36 a-c	56 c	101 b	80 a	3.00 a
4. CL 5915-93	38.9 b	40.6	35 a-c	56 c	99 bc	68 a	2.25 bc
5. CL-143	39.2 b	40.1	30 a	58 c	97 bc	69 a	2.00 c
6. BPI-Tm1 (ck)	38.0 b	40.9	34 a-c	56 c	101 b	74 a	2.75 ab
7. FMTT-138	51.1 a	52.1	43 bc	64 a	116 a	63 a	2.00 c
8. DSF 88-7-21	41.2 b	42.2	45 c	56 c	96 c	32 b	2.00 c
9. CL-6046	51.2 a	51.9	33 ab	61 b	114 a	75 a	1.75 c
Grand mean	42.6	44.4	36.4	57.5	101.8	63.7	2.22
CV (%)	14.3	-	16.2	2.3	2.5	17.3	19.12

[a] Transplanted 12 Dec. 1996 and harvested nine times from 19 Feb. to 15 April 1997. Subplot area = 10 m^2.
[b] Percent good fruits after seven weeks of storage in ambient conditions.
[c] Rated 1 to 5, where 1 = resistant; 2 = moderately resistant; 3 = moderately susceptible; 4 = susceptible; 5 = very susceptible

Eggplant improvement through introduction and selection

A set of 20 accessions from AVRDC headquarters and a local check variety were field-evaluated for yield, desirable horticultural characteristics, and BW resistance in the 1996-97 dry season and 1997 dry and wet seasons. Eight entries gave very poor germination and were dropped from the trials. During the dry season, EG 195 and EG 203 were promising in terms of yield and resistance to BW (Table 27). EG 195 highly significantly outperformed the two checks, EG Long Purple and EG 120, which were highly susceptible to natural incidence of BW. The AVRDC accessions were rated moderately resistant to resistant to BW.

Also in the 1996-97 dry season, introduced entries Slim Jim and EG 199 were found promising with yields of 6.2 and 6.0 t/ha, respectively. Fruit length of the different entries in this batch ranged from 12.9 to 27.0 cm, while width ranged from 2.2 to 4.2 cm.

Pepper improvement through introduction and selection

Seventeen hot pepper entries form the 6th International Chili Pepper Nursery (6th ICPN) and two local checks were evaluated in the 1996-1997 dry season and 1997 wet season. Significant differences were observed for yield, number of fruits per plant, fruit size, and plant height among entries in the 1996-1997 dry season.

PBC 973 and PBC 601 significantly outperformed the highest yielding check, Matikas, which yielded 4.9 t/ha (Table 28).

Pepper preliminary yield trial

Four Szechuan selections from AVRDC were evaluated against two checks, Matikas and Hotshot, during the 1996-97 dry season. Two entries, 921206 and 921207, outperformed Matikas.

Table 27. Field performance of the 13 eggplant entries evaluated for bacterial wilt resistance, dry season 1996-97[a]

Entry	Yield (kg/ha)	No. of fruits per plant	Fruit size (cm) Length	Width	Days to[b] 1st harvest	Bacterial wilt rating[c]	Growth habit	Color of fruits
EG-195	17,322 a	20 a	6.4 d	3.9 bc	143 c	R	spreading	green
EG-203	15,728 ab	10 bc	7.7 d	4.5 a	143 c	R	spreading	purple
EG-190	11,236 a-c	16 ab	11.7 bc	2.5 l	146 c	MR	erect	light green
EG-014	10,861 a-c	18 a	10.4 c	2.6 hi	146 c	MR	semi-erect	purple
S-7	10,403 a-c	9 c	15.8 a	2.6 hi	143 c	R	spreading	light purple
S-47A	9,719 a-c	4 cd	17.8 a	3.2 eg	143 c	R	erect	green
S-90	8,153 a-c	9 c	4.1 e	4.1 ab	143 c	R	spreading	light green
S-64	6,988 a-c	4 cd	13.4 b	3.0 f-h	148 c	MR	spreading	light purple
S-69	6,806 a-c	10 bc	3.4 e	3.7 cd	156 b	R	spreading	green
S-87	4,603 a-c	8 cd	3.4 e	3.5 c-e	143 c	MR	erect	green
S-56 B	3,416 bc	6 cd	3.4 e	3.4 d-f	143 c	MR	erect	green
EG-Long (local ck)	2,680 bc	4 cd	16.5 a	2.8 g-l	143 c	S	erect	purple
EG-120 (Taiwan ck)	2,142 c	2 d	15.7 a	3.4 d-f	164 a	S	erect	dark purple
Level of significance[d]	**	**	**	**	*			
Grand mean	8,458.6	9.0	10.0	3.3	146			
CV %	24.9	26.6	12.3	7.4	3.2			

[a] Transplanted 21 Nov. 1996 in a 6.0 m^2. subplot, distributed in RCBD with three replications, harvested eight times from 24 March to 16 May 1997.
[b] Number of days after sowing.
[c] Based on percentage survival in the field and visual observation of BW occurrence.
[d] ** = highly significant; * = significant
Means followed by the same letter are not significantly different from each other using DMRT.

Table 28. Field performance of 17 hot pepper/chili entries from 6th ICPN and two local checks, dry season 1996-97[a]

Entry	Yield (kg/ha)	No. of fruits/plant	Fruit size (cm) Length	Fruit size (cm) Width	Dry matter yield (kg/ha)	Days to flower	Growth habit
PBC-973	9666 a	24 ef	11.7 bc	1.64 a	13.8	91 g	erect
PBC-601	8263 ab	40 c-f	13.4 a	0.91 c-e	16.9	97 c-f	semi-compact
PBC-586	6427 bc	81 a-c	8.9 d	0.65 fg	25.6	97 c-f	compact
PBC-367	5888 cd	116 a	13.2 a	0.61 f-h	22.4	100 a-c	erect
PBC-142 A	5611 c-e	102 a	7.5 ef	0.62 f-h	26.6	98 b-e	compact
PBC-634	5488 c-f	48 c-f	7.6 eg	1.46 a	24.1	94 e-g	erect
PBC-972	5291 c-f	22 ef	12.1 b	1.24 b	15.4	98 b-e	erect
Matikas (ck)	4944 c-g	46 c-f	11.0 bc	0.91 c-e	16.9	98 b-e	compact
PP-921206	4520 c-h	55 c-f	10.7 c	0.65 fg	19.1	93 fg	compact
PB-585	4514 c-h	75 a-d	7.7 ef	0.56 gh	24.7	97 c-f	semi-compact
Hotshot (ck)	4180 d-h	37 c-f	11.6 bc	0.80 d-f	22.5	102 ab	compact
PBC-368	4038 d-h	65 b-e	13.8 a	0.39 h	20.0	99 a-d	erect
PBC-316	3994 d-h	79 a-c	3.1 f	0.71 e-g	19.9	98 b-e	semi-erect
PBC-714	3514 e-h	35 c-f	11.3 bc	1.45 a	27.8	95 d-g	compact
PBC-137	3333 f-h	77 a-d	8.4 de	0.54 gh	21.7	94 e-g	compact
PBC-364	2810 gh	57 b-f	3.9 g	1.11 bc	18.9	91 g	compact
PBC-739	2347 hi	13 f	9.1 d	1.02 cd	18.0	99 a-d	erect
PBC-556 B	722 I	33 d-f	2.8 h	0.40 h	27.2	103 a	semi-compact
PBC-497	440 i	49 c-f	2.0 h	0.52 gh	35.1	98 b-e	compact
Level of significance[b]	**	**	**	**	ns	*	
Grand mean	4354	55.0	9.15	0.85	21.9	97	
CV %	26.6	28.83	7.0	14.7	25.9	2.6	

[a] Transplanted 21 Jan.1997 in a 6.0 m^2 subplots replicated three times in RCBD and harvested five times from 15 April to 13 May 1997.
[b] ** = highly significant; * = significant; ns = not significant
Means followed by the same letter are not significantly different from each other at 5% level of significance for plant width and days to flower and 1% for other parameters using DMRT.

Table 29. Yield performance and other horticultural characteristics of onions, dry season, 1996-97

Entry	Total yield (t/ha)	Total number of buds/ha	Bulb character dia. (cm) Polar	Bulb character dia. (cm) Equatorial	Horticultural traits No. of leaves	Horticultural traits Plant ht. (cm)	Horticultural traits Neck thick-ness (mm)	Days to harvest	Storage loss % rotten bulb	Storage loss % sprouted bulb
AC-47	23.0 c	481,000	4.8 c	5.2 b	12.0	52.2	0.26 c	116	72	28
AC-453	67.0 a	559,000	6.3 a	7.4 a	7.3	51.1	0.66 a	116	36	28
AC-173	46.0 b	422,000	5.6 b	6.3 b	7.7	51.1	0.26 c	116	36	0
AC-2	37.0 b	637,500	4.8 c	5.5 b	9.3	51.6	0.43 b	120	28	56
AC-319	34.0 b	614,000	4.3 c	6.0 b	9.3	59.3	0.30 b	120	8	8
AC-45	21.8 c	509,500	4.5 c	5.3 b	9.7	55.7	0.40 b	127	52	24
AC-11	19.0 d	465,000	4.5 c	5.2 b	9.7	47.5	0.40 b	122	48	4
Grand mean	35.4	526,857.14								
CV (%)	38.0	26.7	13.4	7.43	30.0	8.05	16.5			

Onion evaluation trial

A set of 12 accessions from AVRDC headquarters were evaluated for yield and other important horticultural traits during the 1996-97 dry season. Seven accessions were screened in RCBD with three replications. The other five entries had very low germination and were dropped from the trial.

Significant differences were observed in yield, yield components, and other horticultural characters. Entry AC-453, with 67.0 t/ha bulb yield, significantly outperformed the other accessions (Table 29). Its high yield was attributed to its big bulbs, which had the highest polar (6.3 cm) and equatorial (7.4 cm) diameters. It also had the thickest bulb neck, significantly different from the other accessions tested.

Early maturity of 116 days after sowing was noted in AC-453, AC-47, and AC-173. After five months of storage at ambient conditions, the longest shelf life was observed in AC-173 and AC-319 with 0 and 8% sprouting, respectively. The highest yielder, AC-453, had the highest percentage of sprouted bulbs.

Bulb size, shape, color, and other characteristics of various onion accessions evaluated are reported in Tables 30 and 31.

Table 31. Bulb size and shape of the different onion accessions, DS 1997

	Bulb size (%) [a]			Bulb shape (%) [b]				
Entry	S	M	B	F	TF	G	HG	S
1. AC-47	97.9	2.1	-	-	37.0	36.6	26.0	-
2. AC-453	24.5	54.5	21.1	18.3	52.0	28.7	-	-
3. AC-173	23.6	60.6	15.9	6.3	34.3	35.3	20.5	3.5
4. AC-2	59.4	40.6	-	-	57.8	23.7	28.5	-
5. AC-319	58.0	42.0	-	48.2	28.3	23.5	-	-
6. AC-45	63.8	36.2	-	48.0	52.0	-	-	-
7. AC-11	75.9	24.1	-	-	34.7	52.2	13.0	-

[a] Bulb size: S = small (3-5 cm); M = mediem (5.1-7.0 cm); B = big (7.1-9 cm)

[b] Bulb shape: F = flat; TF = thick flat; G = globe; HG = hi-globe; S = spindle

Table 30. Bulb color and other characteristics of different onion accessions, DS 1997

	Bulb color (%)[a]						Split	Bolter	Rotten	Firmness
Entry	Y	W	VLR	LR	DR	R	(%)	(%)	(%)	(%)
AC-47	0.6	-	-	99.0	-	-	19.0	-	1.1	Firm
AC-453	99.5	0.5	-	-	-	-	-	-	1.9	Firm
AC-173	100.0	-	-	-	-	-	0.8	-	2.7	Firm
AC-2	0.9	-	-	99.0	-	-	5.0	3.2	7.4	Firm
AC-319	0.4	-	-	99.6	-	-	6.3	-	1.0	VF
AC-45	1.4	-	51.4	47.0	-	-	5.7	-	2.1	Firm
AC-11	2.0	-	-	98.0	-	-	11.2	-	22.0	Firm

[a] Bulb color: Y = yellow; W = white; VLR = very light red; LR = light red; DR = dark red; R = red

AVRDC-ROC Cooperative Program

The AVRDC-ROC Cooperative Program continues to undertake adaptive research and trials in cooperation with the national agricultural research program of ROC. The program is supported by the Council of Agriculture (COA), ROC. Promising AVRDC vegetable varieties/lines are evaluated in the field in different seasons and locations in Taiwan in cooperation with various District Agricultural Improvement Stations (DAIS). The research and trials aim to strengthen the national vegetable research system and to identify promising vegetable varieties for release to Taiwan farmers.

A total of 15 AVRDC vegetable varieties have been named and released by the national program. In 1996, all areas planted to mungbean in Taiwan grew an AVRDC-released variety, Tainan No.5. Two fresh-market tomato hybrids, Taichung ASVEG No.4 and Hualien ASVEG No.5, occupied 88.6% of the total area devoted to summer tomato production. The planted acreage of the newly released cherry tomato, Tainan ASVEG No.6, was estimated to be 560 ha in 1996-97. The area of vegetable soybean, Kaohsiung (KS) No.1, decreased from 91% of the total area in 1994 to 27.6% in 1996 due to the promotion of new varieties, KS No.2 and KS No.5. These AVRDC-developed varieties have made significant contributions to farmers' incomes.

Regional yield trials

A total of 39 regional yield trials (RYTs) were conducted in cooperation with Tainan, Taichung, and Kaohsiung DAIS in 1996-97. The RYT evaluated promising AVRDC varieties/lines of vegetable soybean, mungbean, fresh market tomatoes, and cherry tomatoes, along with locally developed varieties, at different locations in various seasons.

Vegetable soybean

In summer 1996, vegetable soybean RYTs were held in six locations. Eleven lines, along with three check varieties, were evaluated. Two AVRDC lines, GC87012-20-B-2 and GC87012-20-B-8-2, gave a relatively high yield of 10.5 t/ha, significantly higher than the yields of all the other entries except KVS568 in Pu-tzu (Table 32).

Nine new vegetable soybean lines were tested in autumn 1996 and spring 1997 at three and eight locations, respectively (Table 33). In autumn 1996, KVS544 had the highest yield, 5.5 t/ha, which differed significantly from the best check, KSS No.1, in the AVRDC trial. At the other two locations, none of the entries was superior to the best check. In spring 1997, the crop at AVRDC produced excellent yields, all exceeding 11 t/ha. Two entries, TS82-01V-03 and GC87021-10-B-1-1, had yields of 13.0 and 12.8 t/ha, respectively, which differed significantly from the yields of all three checks.

Quality analysis revealed differences in dry matter, protein, oil, sugar, starch, and fiber content among the entries (Table 33). TS82-01V-03 had the highest dry matter (37.1%) and protein content (43.7%).

Table 32. Marketable pod yield (t/ha) of vegetable soybean, regional yield trial, summer 1996

Entry	Pu-tzu
KVS 490	7.4
KVS 508	9.3
KVS 565	7.9
KVS 568	9.5
GC 87010-34-3-1	7.5
GC 87010-66-1-19	5.4
GC 87012-20-B-2	10.5
GC 87012-20-B-8-2	10.5
TS 81-105	6.7
TS 81-115	5.5
TS 81-135	5.4
KS No.2	4.6
KS No.3	8.8
Ryokkoh	3.9
Mean	7.3
LSD (5%)	1.4

Fresh-market tomato

Five new fresh-market tomato hybrids were evaluated in RYTs at five locations in summer 1996. Yields at Hsinyi and Jen-I (at elevations of 600 and 1000 m, respectively) were much higher than yields at the other locations. The yields of all entries were lower than the check, Taichung ASVEG No.4, in the three lowland trials; however, FMTT553 had yields comparable to the check. In Hsinyi, FMTT593, FMTT553, and FMTT591 outyielded the check, Taichung ASVEG No.4, while in Jen-I, FMTT552 and FMTT591 yielded best among five entries. All five hybrids produced more than 70 t/ha in Hsinyi. Comparing the mean yields of five locations, Taichung ASVEG No.4 was still superior to other entries with an average yield of 54.9 t/ha. FMTT591 had the largest fruit, 163 g, but had a high incidence of cracking and malformation. In addition, the green fruit shoulders of FMTT553, FMTT556, and FMTT593 were darker than the fruit shoulder of the check variety preferred by the local consumers.

Cherry tomato

Cherry tomato RYTs were conducted in four locations in autumn 1996 and spring 1997 to evaluate five new cherry tomato lines, along with Tainan ASVEG No.6 (CHT154) and Santa, two check varieties (Table 34). Tainan ASVEG No.6 was the most impressive variety, yielding the best among entries in seven out of the eight trials. In addition, it produced an extremely high yield of 176.5 t/ha at Tainan DAIS in autumn 1996, a record for the cherry tomato trials. The average yields of Tainan ASVEG No.6 were 99.7 and 51.8 t/ha in autumn 1996 and spring 1997, respectively, while the overall mean of eight trials was 75.7 t/ha.

In autumn 1996 trials, the five new lines produced comparable yields to the check variety Santa, but the differences were not significant. Yields obtained from the trial in Tainan DAIS were much higher than yields from other locations. The average yield of 131 t/ha from Tainan DAIS was twice the yield from Chia-Li and four times the mean yield achieved in AVRDC's trial. CHT164 had the largest fruit weight, 13 g, but it was not significantly different from the other six lines. CHT160 had the highest soluble solid content (6.7° Brix) among the five lines, however, it was lower than that of Santa (6.9° Brix).

In spring 1997 trials, when comparing the average yields of four locations, none of the five lines outyielded the two checks (Table 34). However, CHT163,

Table 33. Marketable pod yield (t/ha) of vegetable soybean, regional yield trials, autumn 1996 and spring 1997

	AVRDC		Mei-Long		Wan-Dan		Mean [a]		Dry	Protein
Entry	AU96 [b]	SP97	AU96 [b]	SP97	AU96 [b]	SP97	AU96 [b]	SP97	matter [c] (%)	(% DM) [c]
KVS515	4.5	11.0	7.0	3.1	5.8	2.1	5.8	5.4	34.5	42.1
KVS534	3.0	11.1	7.8	2.9	6.1	2.1	5.6	5.4	33.5	42.5
KVS541	3.9	11.9	8.0	3.1	6.3	3.1	6.1	6.0	33.8	41.4
KNS544	5.5	11.4	8.2	3.3	7.0	3.4	6.9	6.0	33.8	42.0
TS 82-01V-03	-	13.0	-	5.7	-	2.9	-	7.2	37.1	43.7
TS 82-02V-14	-	11.3	-	6.1	-	3.8	-	7.1	34.5	43.6
TS 83-108V	-	11.0	-	4.5	-	2.6	-	6.0	33.8	43.3
GC 87021-10-B-1-1	4.6	12.8	7.9	5.3	5.8	4.1	6.1	7.4	34.6	41.2
GC 87012-10-B-4	4.3	12.0	7.3	3.3	5.7	3.9	5.8	6.4	33.6	41.7
KSS No.1	4.4	11.7	7.6	3.6	6.8	4.0	6.3	6.4	34.9	38.6
KS No.2	3.3	11.7	8.8	4.3	6.8	3.1	6.3	6.4	34.0	41.9
KS No.5	4.2	11.1	7.2	4.4	5.0	2.8	5.5	6.1	35.2	42.5
Mean	4.2	11.7	7.8	4.1	6.1	3.2	6.0	6.3		
LSD (5%)	0.7	0.9	0.8	1.8	1.1	0.9				

[a] AU96: mean of three locations; SP97: mean of eight locations.

[b] - : poor germination.

[c] mean of three locations from the spring 1997 trials.

CHT164, and CHT165 produced yields comparable to Santa, even though their yields were significantly lower than that of Tainan ASVEG No.6. The mean fruit size of the entries ranged from 10.1 to 13.0 g, but none was larger than the two checks. CHT163 and CHT165 had Brix of 7.52° and 7.49°, respectively, which were significantly higher than the two checks.

Collection and evaluation of nonprincipal vegetables

AVRDC has successfully grown and identified, through collection, evaluation, and selection, promising varieties of several nonprincipal vegetables for recommendation to the ROC national program. Currently, lettuce, snap bean, yard-long bean, broccoli, and cauliflower are included in the project.

Lettuce

Four lettuce types, crisphead, butterhead, leaf, and romaine, were tested again in autumn 1996, but poor germination problems were encountered. Among 34 entries planted, data were only obtained from 26 varieties. Six crisphead entries yielded more than 30 t/ha; the highest was Saladin RZ at 32.9 t/ha (Table 35). Among butterhead entries, Nevada was the highest

Table 34. Yields (t/ha) of cherry tomato, regional yield trials, autumn 1996 and spring 1997

	Spring '97					Autumn '96					Mean of
Entry	AVRDC	Tung-Shih	Chia-Li	Tainan DAIS	Mean	AVRDC	Tainan DAIS	Chia-Li	Liw-Chiaw	Mean	8 trials
CHT160	37.7	38.3	28.0	23.1	31.8	35.6	115.3	64.4	46.3	65.4	48.6
CHT163	32.6	39.3	35.5	29.7	36.8	38.2	121.2	65.3	39.9	66.1	51.4
CHT164	38.6	43.5	34.1	35.1	37.8	36.2	122.6	62.3	38.4	64.8	51.3
CHT165	36.0	47.7	35.1	23.8	35.6	34.8	127.7	58.7	44.7	66.5	51.1
CHT166	38.8	36.1	30.8	25.2	32.7	34.6	126.0	60.3	42.0	65.7	49.2
CHT154 (ck)	60.6	59.4	35.0	52.2	51.8	53.1	176.5	70.2	99.1	99.7	75.7
Santa	42.0	56.8	37.8	35.3	42.9	23.4	122.6	62.3	45.1	64.9	53.9
Mean	40.9	47.3	33.8	32.0	38.5	36.6	131.0	63.4	50.8	70.4	54.5
CV	9.7	11.6	11.9	25.6	14.8	9.1	5.3	12.9	18.0	10.3	12.0
LSD (5%)	5.9	8.1	6.0	12.2	7.9	4.9	10.4	12.2	13.6	15.0	8.7

Table 35. Top performers in lettuce observation trial, autumn 1996[a]

Type/Entry	Yield (t/ha)	Days to harvest	Type/Entry	Yield (t/ha)	Days to harvest
Crisphead			**Butterhead**		
Saladin RZ	32.9	55	Nevada (CH)	48.7	61
Santis RZ	31.4	52	V1016	32.3	57
Ontario	31.3	52	Elvira RZ	28.5	49
Anuenue	30.9	55	Summer Green	27.7	43
Georgia	30.6	55	Kangranager Summer	26.0	35
Calmar	30.4	59	**Mean**	**32.6**	**49**
V1008	29.6	53			
Centennial	29.4	57	**Leaf**		
Sun	24.5	53	Prizemor Oscura VML	46.7	65
Vanity	23.9	44	New Red Fire	41.9	66
Mean	**29.5**	**54**	Rapidmor Oscura VML	32.8	53
			Raisa RZ	30.8	68
Romaine			Marsala (CH)	29.0	60
Augustus PVP	46.2	53	Red Salad Bowl	24.8	74
Romulus PVP	32.4	44	Prizehead	21.1	45
Maravimor Clara VML	27.5	43	Sunglow	18.8	38
Mean	**34.5**	**47**	**Mean**	**30.7**	**59**

[a] Planting dates: sowing, 22 Oct.; planting, 19 Nov. 1996.

yielder at 48.7 t/ha. Prizemor Oscura VML had the best yield, 46.7 t/ha, among the eight leaf lettuce entries, followed by New Red Fire at 41.9 t/ha. Again, Augustus was the best romaine type. It yielded 46.2 t/ha. When comparing the performances across the three seasons in 1996, the promising varieties in terms of stable yield were butterhead: V1016; crisphead: Sun and V1008; leaf lettuce: Prizemor Oscura VML and Rapidmor Oscura VML; and romaine: Augustus.

Snap bean and yard-long bean

The snap bean trial in spring 1997 was unsuccessful. Rain just after sowing caused a very poor stand. Yields of all entries were very low; however, NY91-2504 and NY2458 still produced 8.7 and 7.0 t/ha, respectively. They also matured quite early at about 52 days after sowing.

Yard-long bean varieties were observed in a replicated trial in autumn 1996. Yields of 20 entries ranged from 5.5 to 14.4 t/ha with a mean of 11.3 t/ha. The highest yield was produced by Green Arrow, which had fairly long pods (56.8 cm). The promising entries in terms of yield and pod length were Green Arrow, Tun210, Tun209, and White Pod. Another 89 accessions collected from AVRDC-ARC, Thailand, were observed in spring 1997. Among them, five accessions produced yields more than 15 t/ha. They were VU110, VU028, VU097, VU072, and VU057. VU110 had the highest yield, 20.3 t/ha, with 45.2-cm long pods.

Broccoli

Twelve broccoli varieties were evaluated in autumn 1996 (Table 36). Head yields ranged from 11.3 to 14.1 t/ha. The three top yielders were Mercedes F_1, Everest F_1, and Dark Horse F_1, which produced head yields of 14.1, 13.5, and 13.2 t/ha, respectively. Dark Horse F_1 was the earliest variety, maturing by 49 days after transplanting (DAT), but its average head size was as large as 26 × 15 cm. Another early-maturing variety was Green Treasure, which matured at 53 DAT and yielded 13.0 t/ha.

Cauliflower

Twenty-five cauliflower varieties were observed in a replicated trial in autumn 1996 (Table 36). Head yields differed significantly among the entries, ranging from 12.1 to 28.3 t/ha. The highest yield was produced by Guardian, followed by OE3120 F_1 (27.4 t/ha); however, they matured late at 111 and 83 DAT, respectively. It is worth pointing out that an early variety, OE3121 F_1, from Denmark, matured at 48 DAT, but yielded 20.4 t/ha. Another six entries in the early-maturing group (within 60 DAT), all produced low yields, about 12-14 t/ha.

Seed production and distribution

AVRDC produced stock seeds of released varieties for the national seed production program, with the support of the Provincial Department of Agriculture and Forestry (PDAF), and COA, ROC. In 1996-97, 29.8 kg of cherry tomato (Tainan ASVEG No.6), 1089 kg of

Table 36. Top performers in broccoli and cauliflower observation trials, autumn 1996[a]

Variety	Days to harvest	Total yield (t/ha)	Head yield (t/ha)
Broccoli			
Mercedes F1	55.7	34.8	14.1
Everest F1	59.3	35.4	13.5
Dark Horse F_1	49.3	34.7	13.2
Gallant (S-130)	61.8	37.5	13.1
Green Treasure	52.5	36.3	13.0
Mean of 12	**58.9**	**37.1**	**12.4**
LSD (5%)	8.2	7.2	2.6
Cauliflower			
Guardian	110.7	74.1	28.3
OE 3120 F1	82.7	56.5	27.4
Speedy	83.3	56.5	26.0
Minuteman	92.3	63.8	25.6
Fremont F1 RS	102.7	58.8	24.1
45 Days F1(507)	80.0	49.4	23.0
White Corona F1	66.3	43.8	20.9
OE 3121 F1	47.7	46.5	20.4
Mean of 25	**72.3**	**42.1**	**18.3**
LSD (5%)	8.1	13.2	4.8

[a] Planting dates: sowing: 9 Sept.; planting: 4 Oct. 1996.

vegetable soybean (KSS No.1 and KS No.5), 2319 kg of soybeans (TNS No.1, TN No.2, and KSS No.10), and 200 kg of mungbean (Tainan No.5) were produced. These stock seeds passed through all inspections by the Seed Laboratory of the PDAF. They are being distributed to the national program.

Board

[a] Left during 1997 [b] Assumed office during 1997

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Farm Operations

Teng-sheng Tu, B.S., Superintendent[e]

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a Left during 1997
b Arrived during 1997
c On study leave
d Transferred from another unit
e Changed title in 1997
f Promoted in 1997

Meteorological Information 1997

Meteorological Information, 1997

Meteorological data (monthly mean) collected at AVRDC weather station, 1997

		January	February	March	April	May	June	July	August	September	October	November	December
Humidity (%)	Daily avg.	79.84	84.43	73.77	71.73	72.58	76.05	75.05	79.17	76.28	73.31	69.43	72.08
Air temperature (°C)	Daily max.	22.29	20.89	26.87	29.86	31.24	30.43	31.79	30.41	29.45	29.17	27.41	24.66
	Daily min.	12.67	13.51	16.92	20.32	22.58	23.51	23.45	23.66	21.42	20.96	18.09	15.42
Soil temperature 10 cm (°C)	Daily max.	21.28	20.90	25.55	27.93	29.10	29.50	30.46	29.85	29.90	28.13	25.76	23.34
	Daily min.	18.35	18.31	21.57	24.32	26.43	27.03	27.78	27.62	27.04	26.04	23.09	20.86
Soil temperature 30 cm (°C)	Daily max.	21.09	20.50	23.95	26.14	27.91	28.46	29.24	29.04	28.71	27.86	25.46	23.26
	Daily min.	20.04	19.52	22.64	24.99	26.93	27.53	28.26	28.09	27.75	26.95	24.45	22.42
Wind velocity (m/s)	Daily avg.					2.00	2.42	1.76	2.31	1.75	1.79	1.92	2.44
Solar radiation (w/hr/m²/day)	Daily avg.	2781.97	2697.75	3842.52	4445.55	4312.57	4030.37	4320.23	3238.78	3938.77	3446.35	3469.39	2725.61
Precipitation (mm)	Monthly	27.00	70.00	74.00	19.00	124.00	450.00	519.00	560.00	200.00	0.00	0.00	10.00
Evaporation (mm)	Daily avg.	3.08	2.75	4.46	5.04	5.66	5.61	5.70	4.27	4.76	4.57	4.12	3.26

Financial Statements

Audited financial statements for the year are available from the Office of the Director General, AVRDC.

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF ASSETS, LIABILITIES AND FUNDS
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	December 31	
ASSETS	1997	1996 (Restated)
CASH	$3,321,345	$3,432,128
ADVANCES AND REFUNDABLE DEPOSITS (Note 3)	325,341	181,966
ARC-AVRDC ACCOUNT (Note 9)	801,978	561,623
PREPAYMENTS	42,742	7,171
TOTAL ASSETS	$4,491,406	$4,182,888
LIABILITIES AND FUND BALANCES		
RECEIPTS FOR CUSTODY (Note 4)	$ 325,142	$ 278,878
RESERVES FOR EMPLOYEE BENEFITS (Note 5)	1,051,010	1,188,575
FUNDS		
Core fund	734,219	221,880
Working capital fund (Note 7)	900,000	900,000
Restricted core fund	(69,158)	(63,618)
Special projects fund	1,296,616	1,455,220
Self-sustaining operation fund	253,577	201,953
Total Funds	3,115,254	2,715,435
TOTAL LIABILITIES AND FUNDS	$4,491,406	$4,182,888

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1998)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN CORE FUND (Note 6)
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	Years Ended December 31	
	1997	1996
ADDITIONS		
Contributions		
Republic of China	$4,604,014	$4,177,912
Japan	883,000	1,033,000
Federal Republic of Germany (Note 6)	658,963	542,173
United States of America (Note 6)	650,000	600,000
Thailand	126,090	204,993
Republic of Korea	150,000	150,000
Australia	156,012	148,658
Philippines	47,670	100,000
France	368,971	-
	7,644,720	6,956,736
Grants		
Japan International Cooperation Agency	42,960	12,990
Taiwan Kagome Co., Ltd.	1,535	1,822
Non-Tai Seeds Co.	-	1,822
Other (Note 6)	1,034,427	679,958
Translation adjustment (Note 2)	(742,897)	(3,218)
Total Additions	7,980,745	7,650,110
DEDUCTIONS		
Capital expenditures (Notes 2 and 6)	96,708	130,060
Operating expenditures (Note 6)	7,361,158	8,412,332
Total Deductions	7,457,866	8,542,392
NET INCREASE (DECREASE) IN FUND	522,879	(892,282)
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	221,880	1,169,584
Translation adjustment (Note 2)	(10,540)	(55,422)
As restated	211,340	1,114,162
FUND BALANCE, END OF YEAR	$ 734,219	$ 221,880

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1998)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN RESTRICTED CORE FUND (Note 8)
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	Years Ended December 31	
	1997	1996
ADDITIONS		
From German Agency for Technical Cooperation	$ 558,313	$ 758,084
From U.S. Agency for International Development	550,000	300,000
Total Additions	1,108,313	1,058,084
DEDUCTIONS		
Transfers to Core Fund as contributions of :		
Federal Republic of Germany	658,963	542,173
United States of America	450,000	400,000
Total Deductions	1,108,963	942,173
NET INCREASE (DECREASE) IN FUND	(650)	115,911
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	(63,618)	(193,592)
Translation adjustment (Note 2)	(4,890)	14,063
As restated	(68,508)	(179,529)
FUND BALANCE, END OF YEAR	($ 69,158)	($ 63,618)

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1998)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN SPECIAL PROJECTS FUND (Note 9)
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

Sponsors	Year Ended December 31, 1996 (Restated)					Year Ended December 31, 1997				
	Balance, Beginning of Year	Translation Adjustment (Note 2)	Additions	Deductions	Balance, End of Year	Translation Adjustment (Note 2)	Additions	Deductions	Balance, End of Year
Japan	$ 248,308	$ -	$ 340,000	$ 240,151	$ 348,157	$ -	$ 310,000	$ 304,473	$ 353,684
Asian Development Bank	(41,195)	-	463,420	304,719	117,506	-	344,770	432,637	29,639
Federal Republic of Germany	28,180	-	326,416	239,774	114,822	-	121,504	385,051	(148,725)
Council of Agriculture/ROC	213,892	(1,480)	682,762	790,248	104,926	(16,513)	697,359	668,451	117,321
U.S. AID	136,356	-	245,814	285,708	96,462	-	403,358	535,309	(35,489)
Rural Development Administration/Korea	6,755	-	19,980	8,398	18,337	-	15,013	10,481	22,869
National Science Council/ROC	23,037	(160)	16,071	31,997	6,951	(1,093)	61,126	50,191	16,793
International Development Research Center	3,276	-	30,096	33,372	-	-	-	-	-
Swiss Agency for Development and Cooperation/ SADC (Note 9)	-	-	838,053	276,430	561,623	6,979	569,802	336,426	801,978
Others	69,339	(112)	257,034	239,825	86,436	206	276,278	224,374	138,546
	$ 687,948	($ 1,752)	$3,219,646	$2,450,622	$1,455,220	($ 10,421)	$2,799,210	$2,947,393	$1,296,616

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1998)