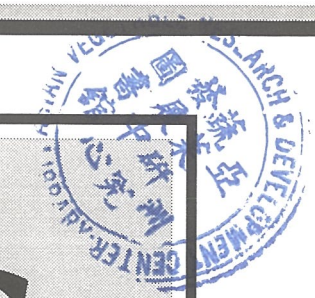
AVRDC

1995

Report

ASIAN VEGETABLE RESEARCH & DEVELOPMENT CENTER 1971



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Foreword

The Asian Vegetable Research and Development Center has evolved in a number of ways over the past two decades. To streamline research management at the center, a project management system (PMS) was developed in 1991, evaluated, and gradually refined over the last four years. A software was developed in house to allow management and staff to access the system using local networking.

The new system offers the opportunity to carefully review and monitor research projects; provides the bases for resource allocation; identifies the integrated, interdisciplinary nature of research and collaboration with the NARS or other international agricultural research centers; and ensures accountability among the researchers.

Since 1972, AVRDC has published its record of researches in the form of an Annual Progress Report on the basis of programs and commodities and research disciplines. The format of this year's report has been changed to accommodate and fully implement the PMS. The major projects are under three programs: Crop Improvement, Production Systems, and International Cooperation. There is also a section on the regional centers/programs of AVRDC. The use of the PMS format facilitates the communication of research results and strengthens the communication function.

Only the important results under each activity have been highlighted and condensed for brevity. Those interested in more information on any activity may write directly to the concerned scientists or the Office of Publications and Communications.

By bringing about these changes in reporting research results, AVRDC demonstrates its dynamism and willingness to innovate.

AVRDC hopes that this new format of the annual progress report will better serve the needs of our readers and other clientele.

Samson C.S. Tsou
Director General

Abbreviations and acronyms

acc. — Accession
ADB — Asian Development Bank
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
BARI — Bangladesh Agricultural Research Institute
BePMV — bell pepper mottle virus
BLM — black leaf mold
BMZ — German Ministry for Economic Cooperation
BP — bacterial pustule
Bt — *Bacillus thuringiensis*
BW — bacterial wilt
cfu — colony-forming units
CHC — cabbage head caterpillar
ck — check
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
CTA — Technical Centre for Agricultural and Rural Co-operation (EC)
cv. — cultivar
CV — coefficient of variation
CVMV — chili veinal mottle virus
DAE — days after emergence
DAI — days after inoculation
DAIS — District Agricultural Improvement Station (Taiwan)
DAS — days after sowing
— double antibody sandwich
DAT — days after transplanting
DBM — diamondback moth
diam. — diameter
DM — downy mildew
DMRT — Duncan's multiple range test
DNA — deoxyribonucleic acid
DSR — disease severity ratings
DTM — days to maturity
EDTA — ethylenediaminetetraacetic acid
ELISA — enzyme-linked immunosorbent assay
EVT — elite variety trial
FM — fresh market
FMTT — fresh market tropical tomato
FMV — feathery mottle virus
GA — gibberelin
GCLV — garlic common latent virus
GRSU — Genetic Resources and Seed Unit
GTZ — German Agency for Technical Cooperation (Germany)
GYT — general yield trial
HS — heat-sensitive
HSI — head shape index
HSP — heat shock protein
HT — heat-tolerant
IBWDN — International Bacterial Wilt Disease Nursery
ICMV — Indian cassava mosaic virus
ICW — imported cabbageworm
IDRC — International Development Research Centre (Canada)
IMN — International Mungbean Nursery (AVRDC)
IMPMN — International Mungbean Powdery Mildew Nursery (AVRDC)
IMYMVN — International Mungbean Yellow Mosaic Virus Nursery (AVRDC)
INTHOPE — International Hot Pepper Trial Network (AVRDC)
IPB — Institute of Plant Breeding, University of the Philippines Los Baños
IPM — integrated pest management
IYT — intermediate yield trial
LEHRI — Lembang Horticultural Research Institute (Indonesia)
LSD — least significant difference
LYSV — leek yellow stripe virus
MAb — monoclonal antibody
MARDI — Malaysian Agricultural Research and Development Institute
m asl — meters above sea level
MB — mungbean

MbFV — mite-borne filamentous virus
MC — moisture content
MDS — multidimensional scaling
MPC — membrane protein complex
MR — moderately resistant
MY — marketable yield
MYMV — mungbean yellow mosaic virus
NARS — national agricultural research systems
NC — nitrocellulose
NGO — nongovernmental organization
NIRS — near-infrared reflectance spectroscopy
NPGRL — National Plant Genetic Resources Laboratory (Philippines)
NSIC — National Seed Industry Council (Philippines)
OP — open-pollinated
OPC — Office of Publications and Communications
OT — observation trial
OYDV — onion yellow dwarf virus
OYT — observational yield trial
PBNV — peanut bud necrosis virus
PCR — polymerase chain reaction
PDA — potato dextrose agar
PeMV — pepper mottle virus
PMMV — pepper mild mottle virus
Ps — *Pseudomonas solanecearum*
PVMV — pepper veinal mottle virus
PT — processing tomato
PVX — potato virus X
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
RFLP — restriction fragment length polymorphism
RH — relative humidity
ROC — Republic of China
RYT — regional yield trial
S — susceptible
SA — soil amendment
SB — soybean
SAVERNET — South Asian Vegetable Research Network
SD — standard deviation
SDC — Swiss Development Cooperation
SDI — selective dissemination of information
SDS-PAGE — sodium dodecyl sulfate-polyacrylamide gel electrophoresis
SLV — shallot latent virus
SST — summer stress tolerance
SSD — single-seed -escent
SYT — standard yield trial
SYSV — shallot yellow stripe virus
TARI — Taiwan Agricultural Research Institute
TBSV — tomato bushy stunt virus
TEV — tobacco etch virus
TFW — tomato fruitworm
TLCV — tobacco leaf curl virus
TLCV Tai or TTLCV — Taiwan tomato leaf curl virus
TMV — tobacco mosaic virus
TOA — tomato oatmeal agar
ToMV — tomato mosaic virus
TSS — total soluble solids
TSWV — tomato spotted wilt virus
TTC — triphenyl tetrazolium chloride
TuMV — turnip mosaic virus
TVDF — Tropical Vegetable Data File (AVRDC)
TVMV — tobacco vein mosaic virus
TYLCV — tomato yellow leaf curl virus
TYTV — tomato yellow top virus
VSB — vegetable soybean
YVMV — yellow vein mosaic virus
WSWV — watermelon silver mosaic virus

ALLIUM IMPROVEMENT

AVRDC initiated its bulb alliums improvement project in 1992 to improve the productivity of onion (*Allium cepa*), garlic (*Allium sativum*), and shallot (*Allium cepa* var. *aggregatum*) crops in the tropics by alleviating the major production constraints. Research activities are currently focused on: (1) development of breeding lines with resistance to major diseases (Stemphylium leaf blight, purple blotch, and anthracnose) and insect pests (thrips and beet armyworm); (2) summer stress tolerance; (3) long bulb storage quality; (4) virus elimination and indexing in garlic and shallot; (5) generation of basic information on the effect of daylength, temperature, and flooding on growth and development; and (6) applications of biotechnology in the improvement project.

During the year major success was achieved in the (1) identification and confirmation of summer stress tolerance (SST) in seven onion genotypes and the development of a rapid screening method for SST; (2) identification of plants with fairly good fertility in five A. *cepa* x *A. fistulosum* hybrids intended to transfer Stemphylium leaf blight resistance in onion; (3) identification of highly stable male sterility trait in tropical short-day onion line AC 26; (4) development of high yielding clonally selected lines in garlic; (5) identification of virus resistance in four garlic lines; (6) selection for high bulb yield in meristem-derived virus-free garlic and shallot lines under field evaluation; and (7) development of RAPD markers and their successful use in the phylogenetic study in garlic.

Genetic resources enhancement and varietal development

Genetic resources activities

The center maintains an *Allium* germplasm collection for use in its crop improvement program and for various research purposes. In 1995, a total of 127 accessions were acquired bringing the total number of accessions in the *Allium* collection to 645 (table 1).

A descriptor set for *Allium* has been prepared and will be tested.

Bulb onions of 43 accessions were regenerated in the field under net cages using storage bulbs produced the previous year. Presently, a total of 83 accessions have produced seeds for medium-term storage.

Table 1. AVRDC Allium germplasm collection, 1995

Species	No. of accessions
A. ampeloprassum	1
A. cepa	267
A. cepa aggregatum	20
A. fistulosum	23
A. porrum	12
A. sativum	275
A. tuberosum	4
A. sp.	43
Total	645

For garlic, two multiplication media were tried: MM1, MS + 30 g/l sucrose + 7 g/l agar + 0.5 mg/l NAA + 2 mg/l 2-ip; and MM2, B5 + 30 g/l sucrose + 7 g/l agar + 0.5 mg/l NAA + 2 mg/l 2-ip. From an initial culture of 116 tubes of 16 accessions, 208 plantlets were obtained, an increase of 79%. In the initial culture, 40% did not produce any plantlet, 32% produced only 1 to 2 plantlets, and only 7% had 5-6 plantlets. Vitrification took place in 1% of the cultures. In the second cycle of multiplication, only 26% produced 1 to 2 plantlets. The rest died: 15% of contamination and 53% of vitrification.

For shallot, two multiplication media used were: MM3, MS + 30 g/l sucrose + 7 g/l agar + 0.5/l NAA + 2 g/l BAP; and MM4, MS +30 g/l sucrose + 7 g/l agar + 0.5 mg/l NAA. After the initial culture in MM3, 52% of the surviving cultures produced 1 to 2 plantlets each. Only 22% had five or more plantlets. Vitrification occurred in 19% of the cultures. Four cultures produced calli, majority of which later vitrified. In a few instances, plantlets developed from calli. After the second cycle, 166 cultures were produced, an increase of 110% in 5 months from the original. However, vitrification worsened as subculturing proceeded.

Garlic and shallots were maintained as virus-free clones in the screenhouse and in vitro culture. Two media were used: CM1, MS + 30 g/l sucrose + 7 g/l agar + 0.5 mg/l NAA; and CM2, MS+30 g/l sucrose + 7 g/l agar + 0.5 mg/l NAA + 2% mannitol.

A total of 28 accessions of garlic were put in CM1. All the cultures produced 1 to 2 plantlets. No vitrification took place during the first cycle. In CM2, 2.3% vitrification took place. In CM1 the number of cultures increased by 74% while in CM2 the number decreased by 39%. During the second cycle of culture, 57.5% vitrification took place in CM1 and 52% in CM2.

In shallot, only 61% of the initial number of cultures remained after the third cycle of culture in CM1. Majority was lost due to vitrification (10-14%/cycle). The result for CM2, a slow growth medium was better. Reduction after the second cycle was only 6%. Vitrification rate was 3-11%/cycle.

Table 2 shows the distribution of *Allium* germplasm. A total of 164 samples were sent to 16 countries and territories.

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

Table 2. Distribution of *Allium* germplasm in 1995

Country	No. of samples
Bangladesh	20
Ethiopia	5
Grand Cayman	5
India	50
Marshall Is.	5
Mauritius	6
Nepal	10
Pakistan	12
Philippines	6
Sri Lanka	23
Others[a]	22
Total	164

[a] Bhutan, France, Malawi, Nigeria, Solomon Is., USA

Storage studies at ambient condition in onion

To identify suitable materials for breeding long storability, bulbs of 120 onion lines were stored under ambient conditions in a well-ventilated room in perforated plastic crates. The temperature during the 5-month storage period ranged from 28 to 32°C. Observations were recorded at monthly intervals for sprouting, rotting, and weight loss.

Of 120 lines evaluated for 5-month storage, six lines had good bulb storage qualities (table 3). Total losses in these lines ranged from 33 to 66%. Compared to these check Granex 429 and Texas Early Grano had significantly high (> 90%) losses. Losses due to rotting

Table 3. Quality performance of promising onion lines for bulb storage at ambient condition

Entry	Yield (t/ha)	Rotting loss (%)	Sprouting (%)	Total loss (%)	Dry matter (%)
AC 319	28.1	29.0d	14.3bc	33.0d	15.9
AC 50	34.7	33.3cd	15.3bc	41.7cd	11.3
AC 141	12.0	36.0bd	38.0a	66.0b	14.7
TA 377	46.7	52.7b	1.7d	52.7bd	9.9
TA 364	22.1	49.0bc	18.0bc	56.5bd	12.2
TA 382	25.5	46.0bd	24.3b	62.7bc	15.3
TG 502 (ck)	67.5	74.7a	13.7bc	98.7a	7.0
Granex 429 (ck)	62.7	86.0a	10.0cd	95.3a	5.9
Mean		50.9	16.9	63.6	-
CV		18.5	35.4	19.3	-

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

were more serious. However, AC 319 had significantly low bulb rotting (29.0%). Lowest sprouting (1.7%) was noted in TA 377, which was possibly because of the long dormancy of the bulbs. All these lines also showed good bulb storability during the earlier studies. Lines with long bulb storability also had high dry matter content (up to 15.9%), indicating a positive correlation between these traits. These lines are now being further used in the breeding activity.

Eleven F_1 hybrids produced with the intention to transfer storability traits to other useful onion genotypes were evaluated for storability under ambient conditions. Variations were observed in storability among the crosses with total losses ranging from 15.3 to 100% during the 4-month storage period. One of the crosses (TA 69 x AC 50) had a minimum storage loss of 15.3%.

Of 35 onion lines evaluated at low temperature (10°C) for 4 months, seven lines were found promising with total storage losses ranging from 10.0 to 40% (fig. 1). TA 377, TA 70, and AC 497 were identified with extremely low sprouting (≤ 10%) and rotting (≤5%) losses. Total loss during the period was only up to

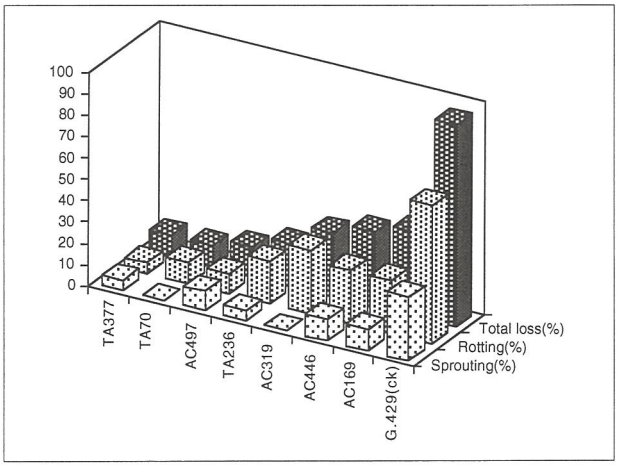


Fig. 1. Onion storage at 10°C

13.6% in these lines. Sprouting loss was generally higher than rotting under low temperature storage. TA 377 and TA 70 are being used in the breeding program to improve the storage quality of onion.

Dormancy of onion bulbs is one of the important components to enhance the storage life of onion bulbs. For this experiment bulbs were planted in trays in vermiculite and kept in a low temperature (10°C) facility. The trays were irrigated regularly. The

experiment resulted in the identification of a line, TA 377, with good bulb dormancy. In this line, as in other lines there was profuse root development 1 month after planting of bulbs; however, sprouting did not start. In most of the lines sprouting was more than 70% by the second month; in TA 377 it was only 10%. This line had very low storage losses under low temperature condition. It also had minimum sprouting loss under ambient condition. TA 377 may thus be used in improving storage quality.

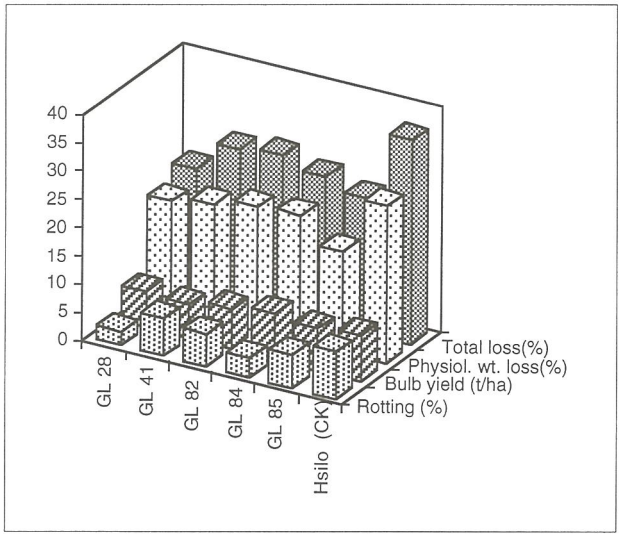


Fig. 2. Promising garlic germplasm lines for storage quality

Storage studies in garlic

Storage studies were conducted under ambient conditions (28-32°C) for 4 months to identify storable lines.

Of 50 germplasm lines evaluated for storability, five were promising with total losses between 21.6 to 27.8% during 4 months of storage (fig. 2). Compared to these, the check Hsilo had 36% storage losses. The major storage loss in garlic was due to weight loss. No sprouting was noted during the storage period.

Evaluation of 25 promising clonal selections presently in the second generation selection (vg_2) resulted in the identification of GL 68-2 and GL 79-3 with good storability and total losses less than 25% during the 4-month storage (fig. 3), and high yield (>14 t/ha).

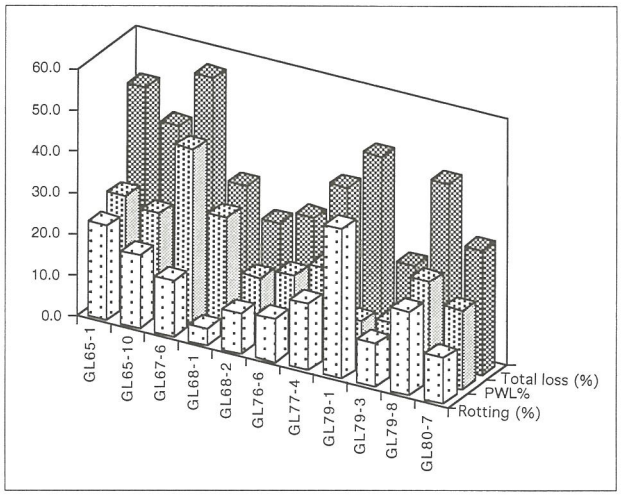


Fig. 3. Promising clonal selections evaluated for storage quality

Development of high yielding, better quality onions

Germplasm evaluation and selection for bulb yield and quality

Two hundred ten germplasm were evaluated during the winter and spring seasons. Trials were conducted using RCBD with three replications. Each plot consisted of a 1.5-m-long and 0.6-m-wide bed. Spacing between two rows in a bed was 15 cm and 10 cm between plots in a row. Yield ranged from 6.6 to 76.3 t/ha. About 30% of the lines had yields above 50 t/ha during winter; however, during spring yields were below 40 t/ha. Twelve lines were identified for high bulb yield, low bolting and splitting tendency and less rotting of bulbs (table 4). Marketable yield in these lines ranged from 50.9 to 76.3 t/ha; showing an increase of 2.6 to 53.8% over the check Granex 429. Most of these lines had poor bulb uniformity and high splitting of bulb. During spring yield ranged from 11.1 to 38.5 t/ha. Large variations were observed in plant growth and bulb size. Selections were made for desirable traits in both winter and spring trials for further improvement.

Table 4. Promising onion lines for high bulb yield and other traits

Entry	Mkt. yield (t/ha)	Unmkt. yield (t/ha)	Rotting %	Splitting %	Bulb Color[a]	Bulb Shape
AC 138	57.9 cd	9.6 be	11.2 a	2.0 d	Y	Globe
AC 139	50.9 de	19.1 ac	2.0 bc	23.7 ab	Y	Globe
AC 428	53.9 de	16.5 ad	1.0 c	22.4 ab	Y	Globe
TA 206	60.5 bd	16.2 ad	4.0 bc	17.1 bc	DR	Globe
TA 212	51.2 de	15.1 be	2.1 bc	18.2 bc	Y	Globe
TA 217	76.3 a	2.3 e	2.0 bc	1.0 d	Y	F G
TA 236	45.6 e	22.9 ab	1.1 c	28.0 ab	Y	Globe
TA 358	59.7 bd	4.0 de	5.4 bc	1.0 d	Y	Globe
TA 366	68.5 ac	9.7 be	1.9 bc	7.8 cd	Y	Globe
TA 369	70.9 ab	3.7 de	3.1 bc	1.0 d	Y	F G
TA 376	60.1 bd	8.1 ce	6.9 ab	4.9 cd	Y	F G
TA 377	56.3 de	3.1 de	1.0 c	2.1 d	Y	Globe
TG 502 (ck)	54.9 de	12.7 be	0.0 c	17.6 bc	Y	H G
Granex 429 (ck)	49.6 de	28.6 a	3.0 bc	33.3 a	Y	Globe
Mean	58.3	12.3	3.2	12.8		
CV	8.2	45.3	71.6	47.3		

[a] Y = yellow, DR = dark red, FG = flat globe, HG = high globe

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

In another trial progeny testing was carried out in 114 previously selected onion lines for yield and quality traits during winter using the same design as above. Twelve promising lines with marketable yields more than 50 t/ha and large bulbs (above 200 g avg. weight) were identified (fig. 4). Splitting was low in AC 168-⊗, AC 170-#, and AC 325-*f*. Further selections were made for (1) high yield [AC 132 #NB (100.8 t/ha), AC 168-*f* (93.3 t/ha), ACC 16-# NB (82.7 t/ha), and AC 170-#NB (68-6 t/ha)]; (2) low spit bulbs [AC 168-⊗ and AC 170 #NB both with 0% splitting]; and (3) low bolting tendency [AC 132 (1.2%) and AC 133 (7.9%)].

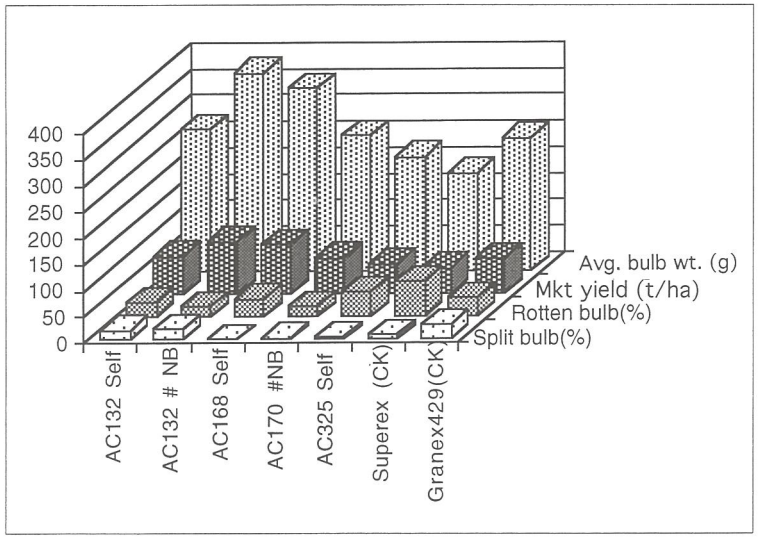


Fig. 4. Performance of selected onion lines for bulb yield and other traits

Evaluation of short-day tropical onion lines

About 75 short-day lines of tropical origin were evaluated during winter. Yield in these lines ranged from 5.3 to 52.3 t/ha. Five lines had yields above 30 t/ha. Yield increase in these lines was 32.1 to 111% over the check Red Creole. Most of these lines had red colored bulbs except AC 50 and AC 384 which had yellow bulbs. These lines also performed well in terms of bulb splitting and premature bolting; however, rotting was high in AC 13 and AC 384-4 (>60%). Further selections were made for bulb shape and quality.

A varietal trial was conducted on eight onion varieties from India, Pakistan, Bangladesh, and Nepal collected under SAVERNET. Variety 'Arka Niketan' from India, had the highest yield (32.4 t/ha) with lowest rotten bulbs (6.0%). In other varieties yield was 20.9 to 28.6 t/ha. In general, bulb splitting and premature bolting were high in all these lines.

Hybridization and selection program

Sixty-three hybrids developed to combine bulb storability, earliness, high dry matter, high yield, and others were evaluated for yield and quality. Ten F_1 hybrids were identified with high yields ranging from 47.1 to 85.3 t/ha and large bulbs ranging from 162 to 320 g. A few hybrids also had early bulb maturity. These lines are also being evaluated for earliness, storability, dry matter, and other traits and are now used in generation advancement by producing F_2 progeny for the selection of desirable plants.

Heterosis breeding in onion

Studies on the cytoplasmic-genic control of male sterility

The male sterile line, AC 26, was crossed with 10 plants each of 19 onion lines (AC 10, AC 15, AC 43, AC 45, AC 47, AC 49, AC 50, AC 132, AC 136, AC 144, AC 149, AC 170, AC 172, ACC 1, ACC 23, TA 4, TA 56, TA 57, and Texas Yellow Grano 502) to identify a suitable maintainer line. These were evaluated for male sterility by using the pollen staining method. Pollen grains which did not stain were considered sterile. All the F_1 hybrids were male-sterile indicating a possible strong cytoplasmic factor(s) controlling the male sterility trait or possible widespread prevalence of maintainer lines. The first possibility seems to be more likely, as in general only up to 5% of the population is expected to have the capacity to act as a maintainer line or 'B' line.

Transfer of male sterility to different genetic backgrounds

Backcrossing was initiated to transfer the male sterility trait to other useful genotypes, i.e., summer stress tolerance (AC 47 and AC 21), long bulb storability (AC 50), early maturity (TA 69 and TA 70), tropical short-day line (AC 8 and AC 9). These backcross progenies will be evaluated next year and further backcrossing will be continued to transfer the male sterility trait in these genotypes.

Evaluation of inbred lines

Selfing was carried out in a large number of onion lines using net bags to produce inbred lines. Eighty-two inbred lines developed during the year were evaluated. Inbreeding depression was observed in a large number of lines leading to poor bulbs. However, 40 inbreds which performed well were selected for second cycle inbreeding. Seven inbreds had yields of more than 50 t/ha and bulb weights of more than 200 g (fig. 5). These were also selected for further inbreeding. In this case, only unsplit bulbs were selected.

Development of summer stress-tolerant lines

About 30 onion lines previously identified for summer stress tolerance (SST), 36 F_1 hybrids developed using SST lines, and 11 F_2 and backcross progenies were evaluated during the summer (June-September) in a

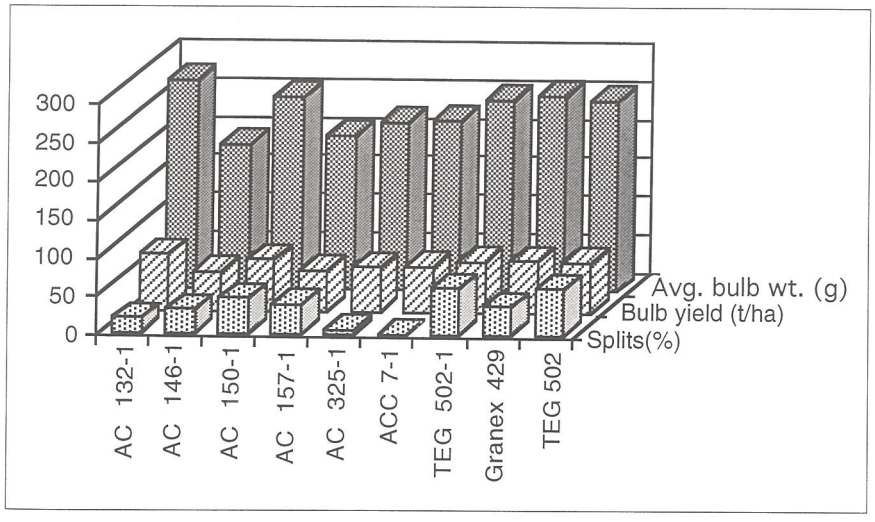


Fig. 5. Evaluation of inbred lines for various traits

replicated yield trial. Observations were recorded for survival rate, growth, and yield. Apart from these 32 F_1 hybrids and 11 F_2 progenies of *A. cepa* x *A. fistulosum* were evaluated for summer stress tolerance.

Rapid screening technique to identify summer stress tolerance in onion

A rapid screening method has been developed to screen onion lines for summer stress tolerance at nursery stage. The method is based on the growth parameters at the seedling stage. Summer stress-tolerant (AC 11, AC 47, AC 325, AC 425, AC 426) and sensitive (Granex 429, TEG 502, Superex) genotypes were used in this study. Observations for various traits recorded on 7-week-old seedlings grown in flats in June-July indicated positive correlation between summer stress tolerance and root dry weight and leaf number, whereas, negative correlation was found for bulb diameter. Using bulb diameter and leaf number, which are easily measurable traits it is possible to identify summer stress-tolerant and susceptible genotypes at the nursery stage.

Performance of summer stress-tolerant and sensitive genotypes after transplanting

Seedlings of summer stress-tolerant (AC 47, AC 325, AC 426, AC 427, AC 429) and sensitive (TEG 502, Granex 429, Superex) genotypes were planted in the field after 7 weeks in the nursery. Observations taken 4 weeks after planting indicated positive correlation of summer stress tolerance to number of leaves, plant height, top dry weight, and root dry weight. Negative correlation was found for bulb diameter and bulbing ratio. These findings clearly indicated that vegetative growth continued in summer stress-tolerant lines whereas in sensitive genotypes vegetative growth was inhibited and bulbing process continued, which lead to early senescence of plants.

Varietal evaluation and selection of summer stress-tolerant lines in onion

Thirty onion lines previously identified for summer stress tolerance were evaluated during the summer. Most of these lines performed well in terms of survival and vegetative growth. Lines were identified for better development, and further selections lead to improved yield. Seven lines with comparatively higher bulb yield were identified (table 5). AC 429, AC 325, and AC 47 performed well with yields of

25.4, 20.5, and 17.2 t/ha, respectively. Further selections have been made in all these lines for large bulb and better vegetative growth. Compared to these, the commercial checks Granex 429 and TEG 502 had very poor survival, growth rate, and yield. TA 238 had large tops with many leaves; however, its bulbing capacity is low. This line and other summer stress-tolerant lines are being used to improve yield potential of onion lines during summer.

Hybridization and selection program for summer stress tolerance

Thirty-six F_1 hybrids developed using 11 summer stress-tolerant onion lines and onion lines with storability, earliness, male sterility, and other traits were evaluated. Most of the hybrids had comparatively better survival and growth than the sensitive parents used in the crosses, indicating a possible dominant gene control of SST.

The SST lines found promising in hybrid combinations were AC 47, AC 325, TA 188, and AC 425. Seven hybrids were identified to have high survival rate, average bulb weight and yield (table 6). Yield ranged from 18.7 to 27.4 t/ha and average bulb weight ranged from 60.5 to 95.8 g. Yield was only 17.2 and 20.5 t/ha in SST parents (AC 47 and AC 325, respectively). Variations were observed between various hybrids for summer stress tolerance when different summer stress-tolerant and sensitive lines were used as parents.

Summer stress tolerance in A. cepa x A. fistulosum *progenies*

Thirty-two F_1 hybrids out of 45 produced between six *A. fistulosum* lines (TA 104, TA 105, TA 108, TA 198, TA 204, AF 468) and 22 onion lines were evaluated during the summer. All the F_1 hybrids and *A. fistulosum* parents had normal growth during the entire season indicating a high level of summer stress tolerance.

Table 5. Performance of promising onion lines for summer stress tolerance

Entry	Survival (%)	Plant ht. (cm)	Leaf no.	Yield (t/ha)	Avg. bulb wt. (g)	Bulb color
AC 47-1	92	38.3bc	6.9ab	17.2bc	42.6bc	Red
AC 148	92	41.4b	6.9ab	17.3b	46.6bc	Yellow
AC 325-1#	93	42.9ab	6.1bc	20.5ab	68.2a	Yellow
AC 425	91	35.5b	5.7ce	11.9df	32.4c	White
AC 426	85	38.3bc	6.4ac	10.2f	45.5bc	Red
AC 429	90	43.4b	6.5ac	25.4a	60.6b	Yellow
AC 444-1#	92	36.2c	4.9e	13.0cf	36.7c	Red
TA 238	95	47.0a	7.2a	9.6f	32.0	Yellow
TA 246	90	39.4bc	5.3de	16.0bd	48.3bc	Yellow
Granex 429	10	27.3d	3.0f	5.0f	20.2d	Yellow
Mean		38.3	5.8	14.4	45.6	
CV		5.0	7.1	8.9	14.4	

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

Table 6. Performance of onion hybrids for summer stress tolerance

Entry	Survival (%)	Plant ht. (cm)	Leaf no.	Yield (t/ha)	Avg. bulb wt. (g)	Bulb color
AC 171 x AC 325	90	37.6b	7.8a	27.4	86.9ac	Red
AC 426 x AC 325	88	41.6ab	7.4ab	27.2	95.8ab	Red
AC 325 x AC 131	80	44.4a	6.6ab	18.7	67.2bd	Yellow
AC 383 x TEG 502	89	41.4ab	5.8b	22.3	83.8ac	Red
AC 47 x TA 188	95	44.2a	7.2ab	21.8	92.8ab	Red
AC 425 x AC 429	95	42.8ab	7.8a	21.1	82.1ac	Red
TA 382 x AC 429	88	41.0ab	6.0b	21.5	60.5cd	Red
AC 47 (ck)	92	38.3b	6.9ab	17.2	42.6d	Red
AC 325 (ck)	93	42.9ab	6.1b	20.5	68.2bd	Yellow
Mean		39.2	6.2	21.4	71.9	
CV		3.6	6.4	25.3	6.5	

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

Eleven F_2 and one backcross progeny were evaluated for summer stress tolerance. Plant growth was normal in all the plants in all the populations. Variations were observed for leaf length and thickness, and bulbing ability. Few segregants with good bulb size and summer stress tolerance were selected for further studies. The backcross progeny (AC 325 x TA 198) x AC 325 produced vigorous plants with large leaves and red colored bulbs with 70 g average weight. A dominant gene control of summer stress is expected from these results.

Some of the promising progenies were derived from the following crosses: TA 198 x AC 50; TA 198 x AC 47; TA 198 x AC-2; AC 50 x TA 198; AC 15 x TA 198; TA 198 x AC 325; and AF 468 x AC 47.

Breeding for Stemphylium leaf blight resistance in onion

Evaluation under field conditions

Five lines of *A. fistulosum* resistant to Stemphylium leaf blight disease were crossed with 22 elite onion lines selected for useful traits, e.g., summer stress tolerance, earliness, storability, and high bulb yield.

Forty-five F_1 hybrids were produced from *A. fistulosum* and *A. cepa* parents. These F_1 hybrids were evaluated for their reaction to Stemphylium blight disease during winter and spring 1994-95 under field conditions. The susceptible parents of *Allium cepa* and resistant *A. fistulosum* parents were planted in the field along with the F_1 hybrids in a replicated trial. No pesticide was sprayed and the disease was allowed to build up. All the F_1 plants in various crosses were resistant to Stemphylium blight. Compared to these all the onion parental lines were severely infected by the disease. The *A. fistulosum* lines remained resistant throughout the growing period. These observations indicate a possible control of dominant gene(s) for resistance.

Although sterility of F_1 hybrid remains a big problem in advancing the generation in these crosses, variations towards fertility were observed in some crosses. The crosses found promising with reasonably good seed set were AC 50 x TA 198, TA 198 x AC 2, TA 198 x AC 50, and AC 468 x AC 47. F_2 progenies as well as backcrosses were produced in several crosses.

Evaluation for disease reaction under controlled conditions

Six *A. fistulosum* lines identified as resistant to Stemphylium blight under field conditions, 14 *A. cepa* lines, 5 F_1 hybrids, and 4 F_2 progenies were evaluated under controlled conditions after artificial inoculation.

Variations were observed for disease reaction among all the six *A. fistulosum* lines evaluated. Resistant as well as susceptible plants were observed in all *A. fistulosum* lines. Plants showing resistant reactions were selected for further use. All the 14 *A. cepa* lines were classified either as susceptible or highly susceptible.

In F_1 hybrids from *A. cepa* x *A. fistulosum* variations were observed in disease reactions. The best cross was TA 198 x AC 50 in which all the plants were resistant. Among other crosses the number of resistant plants ranged from 12.5 to 33.3%. The cross TA 198 x AC 45 did not have any resistant plants. Out of four F_2 populations evaluated, resistant plants were identified in the range of 9.1 to 11.8% in two of the populations. In the other two populations no resistant plants were found. The plants that showed resistant reactions were selected for further use.

Improvement of garlic through clonal selections and mutation breeding

Clonal selections

First generation selections (Vg_1) A total of 402 selected bulbs from 50 lines were planted individually during the winter season. Each line had about 5 to 10 bulbs. Variations in growth, leaf type, bulb size, and disease reaction were observed among the clones of each of the lines. Selections were made for better vegetative growth, larger bulb size, larger clove size, and tolerance to Stemphylium leaf blight and viruses. One hundred fifty-one clonal selections were made based on various traits. Of these, 10 clones had high yield ranging from 13.8 t/ha (GL 105-10) to 18.8 t/ha (GL 98-6). Compared to these, commercial checks had 8.1 t/ha (Hsilo) and 10.5 t/ha (Homei) yield.

Selections were also carried out for tolerance to viral disease (25 clones) and Stemphylium leaf blight (26 clones) under field condition.

Second generation selections (Vg_2) Seventy selected clones from last year's clonal evaluation trial (Vg_1) were evaluated in a replicated trial during the year. These lines were evaluated for disease incidence and vegetative growth in addition to yield and bulb quality. Yield increase in these lines was 32.3 to 50.4% over the commercial check. Five lines had yields of more than 15 t/ha. Majority of these lines were very healthy with high levels of field tolerance to viruses and Stemphylium leaf blight. Fifty-one lines were selected for further studies. Bulbs from 29 selected promising lines have also been used for virus elimination. GL 79-3, GL 68-2, and GL 26-7 also had good bulb storability.

Mutation breeding

VgM_1 generation Twenty-two garlic lines were irradiated with gamma rays at 0.75 K rad and 1.0 K rad doses at the Institute of Nuclear Energy Research at Tau-Yan. Varietal differences were noted for plant survival. Survival rate in general was very low at 1.0 K rad. The lines with good survival at 1.0 K rad were GL 103 (30%) and GL 111(48%). Vegetative growth was also severely affected in treated populations; this was more conspicuous in the 1.0-K rad dose treatment. Bulbs were very small compared to the check. These will be planted in the next season to identify suitable mutations.

VgM_2 generation Two varieties (Hsilo and FG1) were evaluated after irradiating at 0.5, 0.75, and 10 K rad last year. Bulbs were selected and planted this year to raise the VgM_2 generation. Large variations in plant growth, leaf type, and bulb quality were observed in the progenies of 0.75- and 1.0-K rad treated plants.

Selections were made for bulb yield, vegetative growth, bulb quality, and reaction to virus and Stemphylium diseases. These promising mutants will be evaluated and further selection will be carried out in the next generation.

Resistance to virus diseases in garlic

Screening was carried out in germplasm lines to identify plants with no or less virus symptoms. GL 42, GL 49, GL 50, and GL 98-5 had few plants with no or less virus symptoms in the leaves. One plant in the irradiated progeny (0.5 K rad gamma rays) of Hsilo was identified for mild virus symptoms. ELISA tests were carried out on these plants for onion yellow dwarf virus (OYDV), leek yellow stripe virus (LYSV), garlic common latent virus (GCLV), and shallot latent virus (SLV). Two plants from GL 42 had negative reactions to all these viruses. Seven plants in line GL98 had negative reactions to OYDV and SLV. One GL 50 plant had a negative reaction to OYDV, GCLV, and SLV.

A plant identified in GL 49 for mild symptoms of viruses had a negative reaction to OYDV, GCLV, and SLV. Similarly the plant obtained from the irradiated progeny (VgM_2) was also found to have a negative reaction to OYDV, GCLV, and SLV.

Breeding for true seed shallot

Evaluation of shallot lines produced through seeds

Selected bulbs of 21 shallot lines were planted under net cages for seed production. Houseflies were released during the flowering period for pollination. Seeds were successfully produced in these lines; these were evaluated in winter (October to March) as well as in summer (May to September).

Of 21 lines evaluated during winter for yield, seven lines performed very well with yields ranging from 13.8 to 17.0 t/ha. Bulbs in these lines were uniform with deep red color and bulblets ranged from 5 to 15. Plants with large bulbs were selected for further seed production and evaluation. Compared to these the check S 28, which was planted through bulbs had a yield of 16.6 t/ha.

Twenty lines were evaluated during summer for yield and quality traits. Survival and growth was severely affected in most of the lines. Three lines, S 17-1, S 25-1, and S 44-1, had comparatively better yields ranging from 3.9 to 5.2 t/ha. Plant survival rate varied from 65 to 73% in these lines. In the check it was 60%. Average bulb weight ranged from 22 to 26.4 g in the selected lines, whereas in the check it was less than 10 g. Individual bulbs with more than 50 g weight were also observed. Plants with better bulb size and plant growth were selected for further studies.

Field evaluation of virus-free lines

Fifteen virus-free lines were evaluated under replicated yield trial during the winter season under net cages. This was the second year of the field evaluation of these lines. During the first year the bulbs were multiplied for trial in net cages. Of these, eight lines had yields ranging from 14.9 to 25.8 t/ha (table 7). Average bulb weight ranged from 97 to 150 g and number of bulblets per plant from 15.2 to 20.6.

Table 7. Performance of promising virus-free shallot lines

Entry	Yield (t/ha)	Avg. bulb wt. (g)	No. of bulblets/plant
S 58	22.2ab	135ab	17.8ab
S 59	19.6ac	132ab	17.0ac
S 60	25.8a	150a	20.6a
S 62	17.8bc	120ab	17.0ac
S 63	16.7bc	150a	20.3a
S 64	15.6bc	140ab	16.2ac
S 65	21.6ac	97b	13.0c
S 70	14.9c	105ab	15.2bc
Mean	19.3	128.6	17.1
CV	14.1	15.9	11.0

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

Host-plant resistance to diseases and insect pests

Screening of *Allium* germplasm for resistance to beet armyworm

Beet armyworm (*Spodoptera exigua*) and common armyworm (*Spodoptera litura*), are serious defoliator pests of onion and shallot in Asia. Adults lay eggs on the *Allium* foliage and neonate larvae either feed on the leaf surface or in most cases bore holes in the leaf cuticle and feed from inside. The latter feeding habit protects larvae from natural mortality factors such as parasite and predators and rainfall as well as from insecticide sprays which are normally applied onto the foliage. Since the host-plant resistance is the best approach to combat these pests, all available nongarlic *Allium* germplasm were screened for resistance to beet armyworm to find sources of resistance which could later be used in breeding *Allium* cultivars resistant to *Spodoptera* species.

Seeds were sown in seedling raising flats for 4 weeks in a greenhouse. A parcel of land was rototilled and worked into 0.75-m beds. These beds were further divided into 2-m-long single bed plots. Four-week-old *Allium* seedlings were transplanted in a single row on the top of individual plots. The planted area was immediately covered at the top and all four sides with 2-m-high fine mesh nylon net. When plants were 4 weeks old in the field, beet armyworm adults were released inside the cage. Insect release was done once a week or whenever a substantial number of adults were available. When the larval feeding damage became visible, each plot was observed and the damage rated on a 0 to 5 scale; 0 = no damage, 1 = 20% leaf area damaged, 2 = 40% leaf area damaged, 3 = 60% leaf area damaged, 4 = 80% leaf area damaged, and 5 = 100% leaf area damaged.

Beet armyworm adults laid eggs on *Allium* foliage where larvae fed on the foliage, in most cases inside the tubular leaves. Intensity of insect feeding increased as the season progressed (table 8). The nine entries belonging to both *A. cepa* and *A. fistulosum* were consistently less damaged than the rest of the accessions and dramatically less than the six susceptible checks.

Table 8. Damage rating of selected *Allium* accessions during three observations, AVRDC, spring 1995

Entry designation[b]	Damage rating[a] in 3 screenings		
	First	Second	Third
AC 029	0.4	0.6	0.9
AC 058	0.3	0.4	0.8
AC 145	0.2	0.3	0.9
AC 465	0.4	0.5	0.8
AF 204	0.4	0.8	1.0
TA 218	1.3	1.5	1.3
TA 243	0.9	1.3	1.4
TA 246	0.9	1.5	1.4
TA 385	1.1	1.2	1.3
TA 174 (S)	1.2	3.3	4.1
TA 200 (S)	0.9	2.6	4.3
TA 228 (S)	1.5	3.8	4.8
TA 241 (S)	2.2	3.9	4.8
TA 392 (S)	2.2	3.4	4.2
TA 395 (S)	2.4	3.4	4.4
Mean (154 entries)	1.2	2.2	3.0

[a] Damage rating: 0 = no damage, 1 = 20% leaf area damaged, 2 = 40% leaf area damaged, 3 = 60% leaf area damaged, 4 = 80% leaf area damaged, and 5 = 100% leaf area damaged

[b] S = susceptible entries

Preference of *Spodoptera litura* and *Spodoptera exigua* for castor and onion

Both *Spodoptera litura* and *Spodoptera exigua* attack large numbers of crop species. Indian scientists have developed an integrated pest management package for *S. litura* in which castor is used as a trap crop to combat this pest. *Spodoptera litura* adults are attracted to the foliage of castor on which the insect lays eggs.

Farmers scout the eggs and destroy them which reduces *S. litura* population build-up and subsequent damage.

Since both *S. litura* and *S. exigua* are key pests of onion, the possibility of using the castor trap crop for reducing damage to onion by these pests was investigated.

Field experiment Two parcels of land, set 37 m apart, were rototilled and after basal fertilizer application, worked into 0.75-m-wide beds. The beds were divided into four 4.5 x 5 m plots. Each plot had six 5-m-long beds. A distance of 6 m was maintained between plots. One-month-old onion seedlings were transplanted on all six beds in each plot. Each bed had 252 onion plants. One month before transplanting, in one parcel a single row of castor seeds was sown on all four sides of each plot. A distance of 0.75 m was kept between onion and castor plants. In the second parcel with four identical size plots, only onions were transplanted. These plots served as checks. Three weeks after transplanting, *S. litura* and *S. exigua* adults were released at the center of castor trap crop plots and check plots. An equal number of insect pairs were used on each side. A total of 132 pairs of *S. exigua* and 26 pairs of *S. litura* were released. Starting 2 days after *Spodoptera* release, 20 onion plants both in the check plots and trap crop plots for *Spodoptera* egg masses were observed once every other day. Twenty castor plants around each plot were also observed for egg masses. *Spodoptera litura* egg masses are white; those of *S. exigua*, a slightly duller color. Both species of *Spodoptera* were released whenever there were extra insects. Total number of insects released was recorded.

In four observations the percentage of onion plants damaged by *S. litura* and *S. exigua* in the onion trap crop and sole onion crop showed no statistically significant difference. However, the percentage of onion plant damage in the castor trap crop was lower over all than the sole onion. The difference was especially conspicuous as the level of damage increased from first to fourth observation. No insect egg masses were found in the field, possibly because of the frequent rains.

Greenhouse experiment Three to four 1-month-old onion seedlings and several castor plants were transplanted into several medium size clay pots. One month after transplanting, two castor and two onion clay pots (with 6 plants) were placed in each of six large cages. Two pairs each of *S. litura* and *S. exigua* adults were released inside each cage. Starting 2 days after insect release, the number of egg masses and number of eggs in each egg mass on onion and castor plants were recorded.

The results suggested that for oviposition *S. litura* prefers castor over onion. Number of egg masses, eggs/egg mass, and total eggs of *S. litura* were substantially more on castor than on onion although there was no statistical difference.

The preference of *S. litura* for oviposition on castor might be due to the fact that the insect larva probably gets more nutrition and protection in castor which leads to better development.

Spodoptera exigua was found not to prefer castor over onion. The number of egg masses, eggs/egg mass, and total eggs are practically identical on both crops. Since total number of eggs is more important in determining insect damage and the fact that total eggs on both crops were identical, castor does not seem to be a good trap crop for *S. exigua*. The oviposition of *S. litura* was earlier than that of *S. exigua*. *S. litura* oviposition probably took too much space on castor foliage so that *S. exigua* just oviposited on onion more than on castor. The total number of eggs of *S. exigua* were also much lower than *S. litura*.

Multiple mating *S. litura* also probably advanced peak oviposition by about 1 to 2 days. The female lays on the average 91% of the total eggs within 6 days after first mating. The eggs obtained during the first and second observations added up to 97.9% of the total number of eggs.

In some areas both *S. litura* and *S. exigua* occur simultaneously. So the two *Spodoptera* species were combined in the same cage in this experiment. Two pairs each of *S. litura* and *S. exigua* were released in the same cage. These two insects probably competed for oviposition, hence, the reduction in total number of eggs of both *Spodoptera* species.

Results showed that *S. litura* indeed preferred castor over onion for oviposition, but it is difficult to determine if *S. exigua* preferred castor or onion for oviposition.

Screening of *Allium* germplasm for resistance to onion thrips

Onion thrips larvae and adults feed on onion foliage by rasping the leaves and sucking the juice oozing from plant parts. As a result of thrips feeding the damaged leaf area discolors and eventually dries up. This insect is especially serious during the dry season and when plants are under drought stress.

Seeds of 153 entries were sown in flats (50 cm long, 20 cm wide, 6 cm high). Each flat had four entries of eight plants each. Plants were maintained in the flats for 3 months in a greenhouse at 27±3°C. At the end of 3 months when thrips damage was high, each entry was evaluated twice within a span of 3 weeks for degree of thrips damage. A scale of 0 to 5 was used where: 0 = no damage, 1 = 20% leaf area damaged, 2 = 40% leaf area damaged, 3 = 60% leaf area damaged, 4 = 80% leaf area damaged, and 5 = 100% leaf area damaged.

All entries were attacked by onion thrips. However, the degree of damage varied considerably in both observations taken during the height of the thrips epidemic. Ratings of least damaged entries selected are summarized in table 9. Ten entries were considered promising with moderate to high levels of resistance to onion thrips. These entries came from both *A. cepa* and *A. fistulosum* species.

Table 9. Damage rating of least damaged entries selected in two evaluations, AVRDC, summer 1995

Entry no.	*Allium* species	Damage rating 1st observn	2nd observn
AF 465	*fistulosum*	2.0	2.4
AC 430	*cepa*	2.2	2.4
AC 448	*cepa*	2.4	2.2
TA 178	*cepa*	2.2	2.4
TA 189	*cepa*	2.4	2.2
AF 204	*fistulosum*	2.4	1.8
TA 210	*cepa*	2.2	2.2
AF 218	*fistulosum*	2.2	2.4
TA 243	*cepa*	2.2	2.4
TA 385	*cepa*	1.2	2.4
TA 254[a]	*cepa*	5.0	5.0
AC 004[a]	*cepa*	5.0	5.0

[a] Susceptible check

Attractiveness of flower scent chemicals to onion thrips

Since onion thrips, *Thrips tabaci* is one of the important constraints to the production of onion in tropical to subtropical Asia, novel methods of reducing pest population to supplement host-plant resistance breeding were explored. Many species of thrips inhabit flowers although not all of them damage that important plant part. It is believed that the unique chemicals present in flowers are responsible for attracting the thrips. Some of these chemicals have been identified. Four of these chemicals were obtained and their effectiveness studied in a greenhouse test.

Chemicals used were p-anisaldehyde, m-anisaldehyde, salicylaldehyde, and anis oil. The chemicals were used without dilution.

Water trough traps consisted of a round 250-mm-diam and 60-mm-deep aluminum container filled with water to about 15 cm below the rim. A small amount of common laundry detergent soap was added to the water. A heavy rubber cork, 50 mm in diameter and

25 mm in height, was placed in the center of the trough. A glass vial tube (50 mm height, 10 mm diam) lined along its inner surface with filter paper was mounted in a hole at the center of the rubber cork. Scent chemical was poured into the vial. A 20-mm-long dental roll wick projecting 10 mm above the top was placed in the top portion of the glass tube. The filter paper acted as a wick between the chemical and dental roll. The chemical moved up by capillary action and evaporated slowly from the 10-mm exposed portion of the dental wick.

Onion was planted in several flats filled with soil. The flats with 3-month-old plants were placed in a greenhouse room (5 x 6 m). All plants were heavily infested with onion thrips. One trap baited with one chemical and one check trap without chemical were placed 2 m apart in the room. The level of exposed dental wick was 10-20 mm above the uneven leaf canopy. After 24 hours the number of larvae and adults in each trap were recorded. Next day a new chemical was tested in a similar manner. The remaining two chemicals were tested, one per day, over the next two days.

Traps baited with each of the four chemicals attracted overwhelmingly more onion thrips than the check traps (fig. 6). Thrips adults probably flew towards traps baited with the chemicals. Large numbers of thrips larvae were observed in scented traps. Larvae apparently crawled from onion plants into the trap. All four chemicals showed considerable influence in attracting onion thrips. The most effective was p-anisaldehyde followed by salicylaldehyde and m-anisaldehyde. Anis oil was the least attractive, possibly due to its low concentration of active anisaldehydes. These chemicals are potentially useful tools in the management of onion thrips.

The scented traps failed to attract *Thrips palmi* when the traps were placed in a greenhouse filled with *T. palmi* -infested eggplant plants.

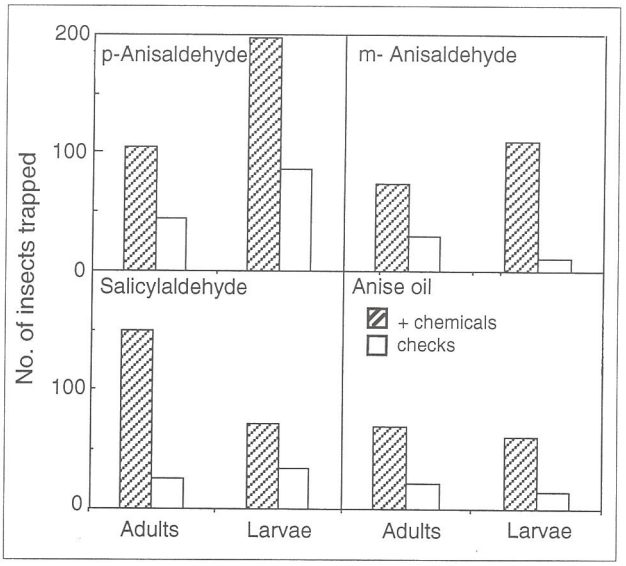


Fig. 6. Effect of four scent chemicals in attracting onion thrips to baited traps

Virus elimination and indexing of garlic and shallot

Routine virus elimination and virus indexing

Routine virus elimination was done. Meristems of 0.3 mm size are first placed on standard MS medium and 10 days later are transferred to MS medium amended with 50 mg/l virazole (MSV medium). After 6 weeks on MSV medium, the new shoot, consisting of the growing point and 0.1-0.2 cm below that, is reexcised and placed on MS medium. Five ELISA tests were conducted using antisera or monoclonal antibodies to seven viruses: onion yellow dwarf virus, garlic common latent virus, shallot latent virus, leek yellow stripe virus, tobacco mosaic virus, mite-borne filamentous virus, and shallot yellow stripe virus. In addition a monoclonal antibody which detects most members of the potyvirus group was also used.

One hundred thirty-one virus-free garlic and 21 virus-free shallot lines have been obtained as of November. Initial virus infection, measured by an ELISA test (E0) before meristeming was high. Of 4144 garlic and 209 shallot cloves tested, 71 and 43%, respectively were virus-infected. Virus elimination was quite effective.

In the first ELISA (E1) test conducted 3 months after meristem excision, virus was detected in only 7% of the tissue cultured garlic and in 4% of the shallot plantlets. In the second ELISA test (E2) conducted on mature plants of the first growth cycle only 3% of the meristem-derived garlic plants, and none of the shallot plants were found to be virus-infected (table 10).

Effect of virazole on virus elimination of shallot and garlic

Since 1994, virazole was routinely added to the tissue culture medium in AVRDC's virus elimination protocol. However, to quantify the effect of virazole on virus elimination, half of the meristems were placed on virazole containing M & S medium and the other half on M & S medium only. The concentration of virazole was 50 mg/l and in previous tests was not found to be phytotoxic to the meristems and/or the young plantlets. ELISA tests were conducted as previously described at various intervals, the last one conducted at the end of the second growth cycle.

The addition of virazole improved virus elimination. In the case of garlic, 20% fewer virus-infected plants were found in the first ELISA test (E1) and 35% fewer in the second ELISA test (E2) (table 11).

Yield comparison of field-derived and meristem-derived garlic lines

Plants of the local cultivar Black Leaf derived from two different meristems (M_1GH_2 and M_2GH_2) were grown for the first time in the field (Chin Jing, Nantou County, Taiwan) in 1994 to investigate virus reinfection and yield of meristem-derived planting material after planting to the field. Cloves were planted in autoclaved soil and emerging plants were covered with a net of 400 mesh/cm^3. Cloves were collected from this first field planting and after storage for 1 month at room temperature and curing for 2 months at 4°C these cloves were subjected to a second field planting in winter 1994-95. Since sufficient bulbs were only harvested from one of the meristem-derived clones $M_2GH_2F_1$, a replicated trial was only conducted with that clone. The other clone ($M_1GH_2F_1$) was planted in a nonreplicated trial.

Table 10. Virus indexing of meristem-derived garlic and shallot plants in 1994 and 1995

	No. of virus positive plantlets/plantlets tested			
Crop / Year	E0	E1	E2	E3
Garlic				
1994	2404/3394 (70.8%)	113/1707 (6.6%)	16/482 (3%)	0/91
1994 + 1995	2945/4144 (71%)	195/2663 (7.3%)	20/1129 (2.7%)	0/459
Shallot				
1994	72/168 (42.9%)	11/273 (4%)	0/111	0/31
1994 + 1995	89/209 (42.6%)	16/401 (4%)	0/120	0/103

E0 = ELISA conducted on cloves before meristem excision
E1 = ELISA conducted on test tube plantlets, shortly before transferring to soil
E2 = ELISA conducted on grown out plants at the end of the first growth cycle
E3 = ELISA conducted on grown out plants at the end of the second growth cycle

Table 11. Effect of virazole in the culture medium on virus elimination of garlic and shallot

ELISA[a]	Treatment	No plants tested[b]	% ELISA positive[c]
Garlic			
E1	No virazole	675 (234)	7.0 (3.6)
	Virazole	466 (193)	5.6 (3.0)
E2	No virazole	354 (111)	2.3 (5.4)
	Virazole	206 (73)	1.5 (1.4)
E3	No virazole	85	0
	Virazole	62	0
Shallot			
E1	No virazole	83	6
	Virazole	33	0
E2	No virazole	25	0
	Virazole	14	0

[a] E1 = conducted on the tissue cultured plantlet, just before transfer to soil
E2 = conducted on mature grown out plantlets (1st growth cycle)
E3 = conducted on mature grown out plantlets (2nd growth cycle)

[b] No. of plants tested in 1994/1995. No. in parentheses represent the 1994 values

[c] No. in parentheses represent the 1994 values

Treatments consisted of covering the plots with a net cage of 400 mesh/cm^2 to exclude infection by insect-transmitted viruses and of planting the cloves into autoclaved soil (to possibly exclude infection by mite-transmitted viruses). In treatments with autoclaved soil the field soil was taken from 30 cm below the surface and autoclaved for 1 h at 100°C (1.5 kg/cm^2). The excavated plot was lined with a perforated black plastic sheet on which a 10-cm layer of autoclaved sand was placed. The remainder of the hole was filled to the top with the autoclaved field soil. Plot size was 192 x 75 cm; plant-to-plant distance was 12 cm and between-plant distance 15 cm. Fifteen cloves were planted per treatment. Plot size of the nonreplicated trial involving $M_1GH_2F_1$ was 72 x 45 cm with 10 cloves per treatment. The experiment was sown in December 1994 in an AVRDC field and harvested in March 1995. Virus infection was measured by DAS-ELISA at regular intervals until harvest. The two inner leaves were used for the ELISA test.

Yields of $M_1GH_2F_1$ and $M_2GH_2F_1$ were 100 and 140% higher than that of a farmers' field-derived clone of the same cultivar, when planted for the second season in the field. Virus reinfection did not take place whether the plants were grown under a protective net cover or in sterilized soil.

Investigation of possible seed transmission of viruses of onion and shallot

Seeds of 9 shallot and 115 onion lines originating from 18 countries were tested by indirect ELISA for the presence of MbFV, LYSV, OYDV, SYSV, GCLV, and SLV. Five seeds of each line were placed in small Eppendorf vials containing extraction buffer (0.05 M Tris-HCl, 0.15 M NaCl, pH 8.0). The vials were sonicated for 20 min in a Cole Palmer sonicator. Both the buffer in which the seeds were shaken, as well as ground up seed were tested for virus presence. Prior to testing, the seeds of each sample were thoroughly rinsed five times in autoclaved distilled water which

was discarded, before they were ground up in 90 µl TBS buffer. Nitrocellulose membranes were spotted with 2 µl of buffer or ground up seed extract. Antisera or monoclonal antibodies to previously mentioned viruses were either those obtained from TARI (GCLV, SLV) or from BBA, Germany [OYDV-AS (#935), MbFV (#994), SYSV-MAB (Mab1H12)] or LYSV antiserum prepared at AVRDC. A polyclonal SYSV antiserum (SYSV 1037), originally prepared by Maat of IPO, Holland, was also obtained from BBA.

Evaluation of bulb *Allium* accessions for resistance to Stemphylium leaf blight, purple blotch, and anthracnose

Seasonal prevalence of fungal foliar diseases

The objective of this study was to determine the occurrence and prevalence of fungal diseases attacking *Allium* throughout the year at AVRDC. Monthly plantings of garlic, onion, shallot, and Welsh onion (*A. fistulosum*) were monitored from November 1994 through October 1995 for fungal foliar diseases. Among diseased leaves examined, 69% were infected by *Stemphylium vesicarium*, 10% by *Colletotrichum gloeosporioides*, 6% by *Alternaria porri*, and 7% by *Puccinia alli*. Stemphylium blight was present throughout the year, but was most prevalent from December to June, occurring on all four crops (fig. 7). Anthracnose and purple blotch were most prevalent from June to October, occurring on all four crops. Rust was present from February to June, but it occurred only on garlic and Welsh onion.

Stemphylium leaf blight

The objectives of this study were to (1) rate the Stemphylium leaf blight reactions of *Allium* lines planted in the field, (2) develop a protocol for laboratory evaluation of onion lines for their

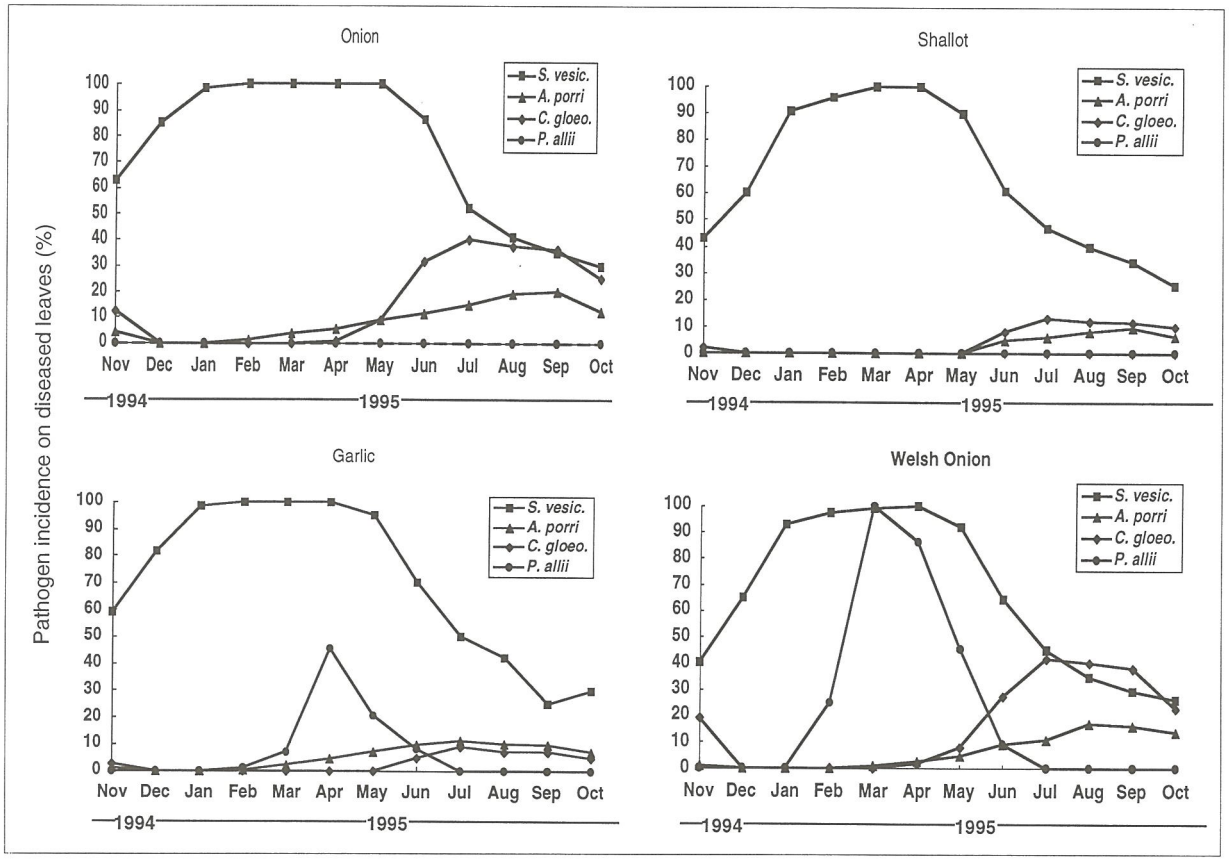


Fig. 7. Incidence of foliar fungal pathogens throughout the year on Allium crops planted at monthly intervals on the AVRDC farm

Stemphylium leaf blight reactions, and (3) determine the efficacy of commonly used fungicides for control of Stemphylium leaf blight of onion.

During the spring of 1995, 1065 *Allium* entries consisting of lines, cultivars, and breeding populations were evaluated for their Stemphylium leaf blight reactions in the field at AVRDC (table 12). Two onion lines, AF 438 self #48 and AC 385-6 self #F, were rated very resistant (no symptoms). Among other onion-related entries, 14 were rated resistant (<5% leaf area affected). Three of these resistant onion entries were derived from interspecific crosses. Two garlic lines, G 57 and G 59, were rated resistant among a total of 142 entries examined.

Table 12. Summary of Stemphylium leaf blight reactions[a] among 1,065 *Allium* lines in AVRDC observation and breeding plots, spring 1995

	Number of entries				
Crop	VR	R	MS	S	VS
Onion	2[b]	14	71	248	445
Shallot	0	0	1	23	119
Garlic	0	2	8	19	113

[a] Disease reactions based on percent leaf area affected: 0% = VR; 0-5% = R; 6-25% = MS; 26-50% = S; and ≥51% = VS

[b] Onion lines 'AF 438 self # GH' and 'AC 385-6 self # F'

The current protocol for evaluation of Stemphylium leaf blight severity on onions is as follows: inoculation of 44-day-old seedlings with a 5 x 10^4 conidia/ml suspension, incubation at 25°C and 100% RH for 48 h, and rating for disease severity 7 days after inoculation. Laboratory evaluations distinguish resistant and susceptible lines, but further refinements in the protocol appear to be necessary to distinguish intermediate levels of disease reactions.

Seven fungicide treatments were evaluated for control of Stemphylium leaf blight in the field (table 13). All treatments significantly suppressed disease development, but the three best treatments were iprodione+mancozeb, iprodione+chlorothalonil, and iprodione alone. Disease control by these three treatments was not significantly different.

Table 13. Fungicidal control of Stemphylium leaf blight of onion[a], AVRDC, 1994-95

Treatment[b]	Yield (t/ha)	AUDPC
Mancozeb + Iprodione	136.1	213.5
Chlorothalonil + Iprodione	122.4	222.3
Iprodione, 23% FP	132.4	224.0
Diphenconazol, 10% WP	127.2	231.0
Chlorothalonil, 75% WP	104.9	269.5
Mancozeb, 80% WP	116.4	280.0
Prochloroz, 50% WP	109.9	280.0
Control	92.5	336.0
LSD (P<0.05)	9.5	12.1

[a] Superex W cultivar

[b] Fungicidal applications made at 2-week intervals

Management of abiotic stresses and other strategic studies

Major abiotic constraints on growth and development of bulb alliums

This study investigated the effect of daylength, temperature, and flooding on the growth and bulbing of selected *Allium cepa* and *A. fistulosum* varieties.

Five onion varieties (AC 324, AC 325, AC 383-2, Granex 429, and TEG 502) and three Welsh onion varieties (TA 105, TA 106, and TA 198) were grown in the experimental field in April (of increasing daylength) and October (of decreasing daylength). An RCBD with four replicates, i.e., 1 x 2 m plot, was employed. Three plants each were randomly sampled

accelerate senescence in AC 324 and AC 325, but delayed senescence in TEG 502 and Granex 429 (table 16).

For the flooding effect study, flooding for 3 days at 45, 60, and 75 days after emergence resulted in reduction in bulb weight and total dry matter accumulation in the April experiment but not in the October experiment. In fact, flooding at 45, 60, and 75 days after emergence in October promoted the overall growth of both *A. cepa* and *A. fistulosum*. The difference in flooding response between April and October experiments could be due to temperature and daylength. High temperature in the April experiment may have aggravated flooding stress. Also an accelerated senescence with an increasing daylength could have made the plants more sensitive to flooding.

In conclusion, undesirable early bulbing which accelerated senescence in *A. cepa* occurred due to increasing daylength in the early growth stage. High temperature regime also caused early bulbing, but to a lesser extent. Flooding has no apparent effect on early senescence. Better performance of AC 324 and AC 325 in the April field planting could be due to less sensitivity to increasing daylength at early growth.

Genetic diversity of garlic germplasm

This study aims to generate RAPD markers for discriminating garlic germplasm and determining their phylogenetic relationship.

Newly expanded leaves of 102 clones were harvested and pooled from 15-20 plants each. Tissue was ground to fine powder in liquid nitrogen, and its genomic DNA extracted. Genomic DNA was run for PCR with 200 10-mer primers. RAPD bands from 9 primers were subjected to principal components and multidimensional scaling (MDS)analyses. Dendrograms were constructed via the unweighted pair-group method. In the subsequent experiment, 14 clones from the Dominican Republic were used to cross-check the established technique.

For each primer assayed, a multiple band (DNA fragment) profile with 6 to 13 major bands, plus a varying number of minor bands, was produced. A considerable degree of polymorphism was detected with most primers tested. Nine of the 200 primers tested generated totally 82 polymorphic, discrete bands ranging from 500 to 2000 bp.

All 102 accessions could be distinguished from every other accession by means of a combination of these 82 bands. The 102 x 102 matrix of genetic similarity measures was subjected to MDS analyses. Inspection of the MDS plot indicated four distinct clusters, with almost no overlap among the four groups (fig. 8), except entry 59 from Argentina which appeared to be an outlier of group III. Dimension 2 in the MDS divides the 102 clones into light- and dark-green leaf types. Dimension 1 can be differentiated by three primers, but the characters involved are not clear.

Other pairs of accessions about which more information is known show interesting similarity relationships. One pair has a similarity of 100% and same leaf color, bulb skin color, clove number, and flowering behavior. The other eight pairs have relatively high similarities, i.e., >96, and same morphologies. All of these pairs also originated from the same countries. In a contrasting situation, a pair has a similarity of 100%, but drastically different morphologies. Both were collected from Taiwan and belong to the dark-green leaf type. Moreover, one pair has a similarity of 100% and same morphologies, but were acquired from different countries. One pair has a similarity of 99% but different leaf color. One pair has a similarity of 98%, but with different bulb skin color and from different countries. These analyses, especially those dealing with the identification of origins of vegetatively-propagated garlic, imply that it is possible to eliminate potential duplicates in germplasm collections.

from each plot at 1-month intervals for the investigation of growth parameters. In a separate experiment, the same entries were grown in the greenhouse. At 40 days after emergence, plants were transplanted and continuously subjected to different daylengths, i.e., 10, 12, 14, and 16 light hours, or different temperatures, i.e., 32/26, 26/20, and 19/13°C, day/night, with 12-hour daylight until the time of investigation or senescence.

For the flooding study, plants were artificially subjected to flooding for 3 days at 45, 60, and 75 days after emergence, and investigated 100 days after emergence in the April planting, or for 5 days at 60, 75, and 95 days after emergence and investigated at 170 days after emergence in the October planting. All treatments had three replicates with three plants per replicate. Growth parameters were measured at the time of harvesting onion bulbs.

Based on the data from the last sampling of the field experiment, the April field planting accelerated the senescence of all *A. cepa* entries. They stopped growing at around 100 days after emergence (table 14). Increasing daylength and temperature in the April planting likely played a role in early bulb formation, thus stopping the overall growth. In the April planting, AC 324 and AC 325 performed much better than the other onion entries in bulb yield (>3 kg/2 m^2 or 15 t/ha) and overall growth. In the October planting, however, TEG 502 and Granex 429 had higher bulb yields (> 20 kg/2 m^2 or 100 t/ha) than the other three AC entries.

All *A. fistulosum* entries have longer growth duration (about 60 days more) than *A. cepa* entries in the April planting, thus resulting in higher dry matter accumulation (table 15). *A. fistulosum* plants tended to have higher growth rates (dry matter accumulation/day) than *A. cepa* plants in the April planting. Despite the nonbulbing nature of *A. fistulosum*, its senescence was also somehow accelerated in the April field planting.

Table 14. Fresh and dry weight accumulation and bulb formation in *Allium cepa* in two seasons

Entry	Yield (kg/m^2)	Bulb FW (g/bulb)	Total FW (g/plant)	Bulb DW (g/bulb)	Total DW (g/plant)	Growing time (days)
April planting						
AC 324	3.26a[a]	50.3a	78.2a	3.88a	6.71a	100
AC 325	3.48a	33.2b	54.5b	3.46a	5.49b	100
AC 383-2	0.26c	15.8c	35.9c	1.87c	3.84c	100
TEG 502	0.75c	32.8b	52.1b	2.35bc	3.98c	100
G 429	2.38b	38.3b	48.5b	2.90ab	3.89c	100
October planting						
AC 324	5.42b	200.1c	486.8b	19.46c	51.41b	220
AC 325	8.93b	323.3ab	544.4a	33.22a	60.48a	220
AC 383-2	7.41b	171.0c	225.5d	22.59b	31.36c	220
TEG 502	20.33a	360.2a	368.7c	25.56b	29.14c	190
G 429	23.65a	327.6b	334.0c	23.48b	26.61c	190

[a] Mean separation within columns of the same planting by DMRT ($P = 0.05$)

Table 15. Fresh and dry weight accumulation in *A. fistulosum* in two seasons

Entry	Total FW (g/plant)	Total DW (g/plant)	Growing time (days)
April planting			
TA 105	106.9b	12.58b	160
TA 106	117.2b	14.59b	160
TA 198	191.7a	23.47a	160
October planting			
TA 105	256.5	20.52	220
TA 106	224.0	18.76	220
TA 198	270.6	22.61	220

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

All *A. cepa* and *A. fistulosum* entries had longer growth duration in the October planting than in the April planting, in total about 220 days for AC 324, AC 325, AC 383-2, TA 105, TA 106, and TA 198, and 190 days for TEG 502 and Granex 429. In the October planting, all *A. cepa* entries had higher growth rates than *A. fistulosum* entries, with higher dry matter in *A. cepa* than in *A. fistulosum*. On the contrary, *A. fistulosum* plants had higher growth rates than *A. cepa* in the April planting.

For the daylength effect study, a 16-h day promoted early bulbing and senescence (table 16) and resulted in little dry matter accumulation in all *A. cepa* entries tested in April and October. A similar trend also occurred in the 14-h day. A 10-h day prevented early bulbing and maturity in the April experiment. AC 324 and AC 325 in April tended to have higher dry matter accumulation than other entries under 10- and 12-h-day conditions. Results supported the early finding that increasing daylength at the early growth stage accelerates bulbing and promotes early growth arrest. Daylength seemed not to have a clear effect on the overall growth of *A. fistulosum* in April and October experiments. However, plants grown in October resulted in higher overall growth than those grown in April, and TA 105 and TA 106 had relatively higher dry matter production.

For the temperature effect study, 32/26°C was detrimental to overall growth in both *A. cepa* and *A. fistulosum*, and bulb growth in *A. cepa* in April and October experiments. A temperature regime of 26/20°C was most favorable for bulb formation in AC 324 and AC 325, and 18/13°C in AC 382-2, TEG 502, and Granex 429 in both April and October experiments. High temperature regime tended to

Table 16. Effects of daylength and temperature on the day to plant senescence[a]

Entry	10-h	12-h	14-h	16-h	19/13°C	26/20°C	32/26°C
April planting							
AC 324	170	170	135	60	170	170	165
AC 325	170	160	120	70	170	170	165
AC 383-2	170	145	145	85	130	130	165
TEG 502	170	160	85	55	130	130	165
G 429	170	165	70	55	130	120	165
October planting							
AC 324	170	170	110	85	170	170	155
AC 325	170	135	90	65	170	170	155
AC 383-2	170	170	170	110	170	170	170
TEG 502	170	85	80	65	115	110	130
G 429	170	110	80	65	115	90	130

[a] Experiments were completed at 170 days after emergence; therefore, number does not indicate real plant senescence

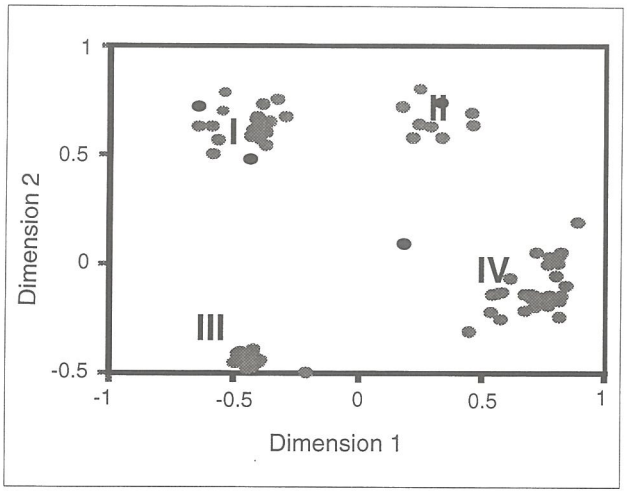


Fig. 8. Multiple dimension scaling analysis of 102 garlic clones

From this study, flowering character seems to be linked with the light-green leaf group, i.e., groups I and II. Among the 29 flowering garlic, only five entries scattered in groups III and IV. Entries in group II are flowering garlic obtained from Japan and are genetically distinct from other flowering garlic. The similarity levels within flowering clones of group I and group II were 65 and 68%, respectively. Some of them appeared to be duplicates. It appears that these flowering garlic may have originated from a narrow geographic region.

Fourteen clones introduced from the Dominican Republic were reported to originate from China, and selected and maintained by different researchers in the Dominican Republic in the past 20 years. With this test, 13 clones are shown to be highly similar (> 96%) and belong to group I, while clone "Qumaido" belongs to group III (fig. 9). The latter can be distinguished from the other 13 clones by 48 tested primers. The results confirmed the applicability of the established RAPD technique for characterizing incoming garlic germplasm.

In conclusion, RAPD marker data that have been collected form a baseline for the assessment of diversity in the current garlic collection and for evaluation of potential new accessions. This contrasts with the difficulties encountered when evaluating accessions for morphological characters, when quantitative measurements of characters are not readily obtained or are subject to varying environmental conditions. Overall, RAPD markers provide a fast, efficient technique for diversity assessment and clonal identification that complements methods currently in use in garlic germplasm management.

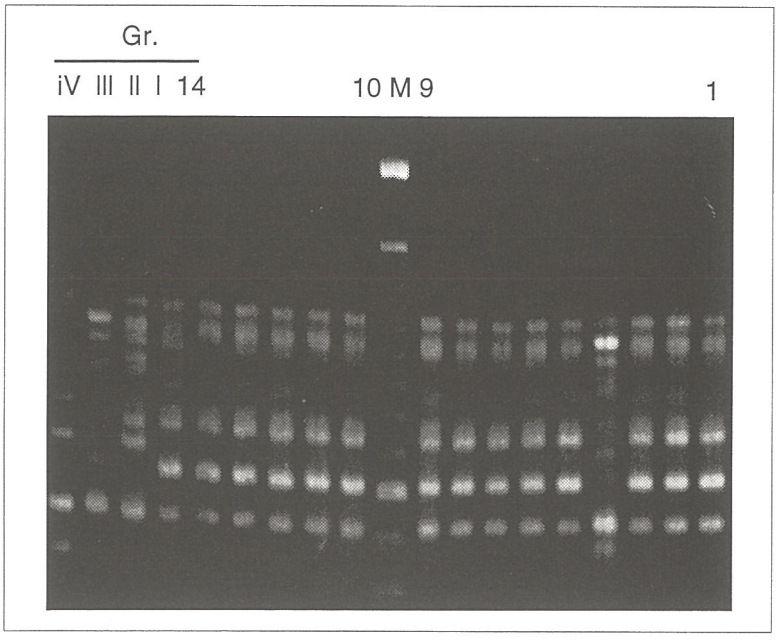


Fig. 9. Comparison of 14 garlic lines from the Dominican Republic with 4 garlic groupings by UBC30 primer

CRUCIFER IMPROVEMENT

The improvement goal for Chinese cabbage (*Brassica rapa* ssp. *pekinensis*) is to develop high yielding, early, and uniform varieties with resistance to major diseases and tolerance to abiotic stresses. During the past two decades, the Center has successfully developed high yielding heat-tolerant Chinese cabbage varieties which are widely adapted in the partner countries. In 1989, the Center decided to scale down the research to a maintenance level and is awaiting new germplasm to tackle other problem diseases such as softrot. Since then, the only active breeding activities were breeding cylindrical head-type Chinese cabbage and incorporation of cytoplasmic male sterility or turnip mosaic virus resistance into advance elite lines.

The development of a few genetically diverse heat-tolerant composites was adopted as a general strategy. Three different methods of generation advancement were applied to develop composite populations: mass selection, bulking selfed seeds, and bulking selfed seeds from selected plants based on progeny testing.

A backcross project was initiated to incorporate cytoplasmic male sterility of radish or mustard origin into heat-tolerant Chinese cabbage lines. Another backcross project was also carried out to incorporate TuMV resistance into elite lines of heat-tolerant Chinese cabbage. AVRDC has identified several lines immune to five known strains of TuMV from several years of screening. Monoclonal antibodies were also developed to identify responsible strain(s) from the individual infected plants. By adopting these selected lines and monoclonal antibodies, the inheritance mode of resistance was studied for three strains of TuMV.

Common cabbage (*B. oleracea* ssp. *capitata*) was added to the Center's mandate crop list in 1992. Cabbage is the only leafy vegetable among the top most important vegetables consumed in the Asian region. Germplasm collection and evaluation, protocol development for flowering and seed production, and defining constraints in production have been the subject of research before launching breeding projects for the development of heat-tolerant and high yielding common cabbage.

To identify the most suitable varieties of common cabbage under hot and wet conditions, 45 varieties collected mostly from private seed companies were tested during summer.

Two activities were designed to assist in the breeding of common cabbage. The project on monthly plantings of common cabbage was carried out to identify the critical factors that affect growing and heading under heat stress conditions while an experiment is being carried out to develop a system for flower induction and seed production under tropical conditions. The development of a feasible system for flower induction and seed production would facilitate the common cabbage breeding program in the tropics.

Genetic resources enhancement and varietal development

Genetic resources activities

The center maintains a *Brassica* germplasm collection for its crop improvement project and for various research purposes. In 1995 a total of 36 accessions of three species were acquired bringing the total in the collection to 1496 (table 1). Five were cauliflowers from SAVERNET, 16 blackrot-resistant common cabbages, and 13 Chinese cabbages from China.

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

Excluding common cabbage, 36 accessions were regenerated in 1995 bringing the total number of accessions of *Brassica* regenerated to 558 (37%).

The common cabbage accessions regenerated in the highlands (>2000 m) included two cytoplasmic male-sterile lines and their corresponding maintainers.

A total of 439 (30%) accessions are now in long-term storage.

In 1995, a total of 918 samples were sent to 32 countries and territories.

Table 1. AVRDC *Brassica* germplasm collection, 1995

Species	No. of accessions
B. juncea	36
B. napus	9
B. oleracea	7
B. oleracea ssp. *alboglabra*	3
B. oleracea ssp. *botrytis*	7
B. oleracea ssp. *capitata*	17
B. oleracea ssp. *gongyloides*	1
B. rapa	866
B. sp.	550
Total	1,496

The seed proteins of 210 accessions of *Brassica* belonging to 4 species and 10 cultivar groups were analyzed using SDS-PAGE (fig. 1). A total of 17 major bands and 35 profiles were observed. The number of bands per accession ranged from 8 to 14. Three bands were always present in all accessions: bands 5, 6, and 10. No single band predominated in any of the groups although some bands were observed only in some accessions. Band 1 was observed only in one of four accessions in ssp. *oleifera* and band 8 only in one of 25 and one of 17 accessions of ssp. *chinensis* and ssp. *parachinensis*, respectively. Band 13 was observed only in one accession of *B. oleracea* ssp. *capitata* and band 16 only in two accessions of ssp. *chinensis*. Band 1 was conspicuously absent in all accessions of *B. rapa*.

Profile 24 was the most dominant occurring in 46% of the accessions observed. The rest occurred in frequencies ranging from 0.48 to 10.48%. The most diverse group was Chinese cabbage which also had the highest number of accessions examined. It exhibited 12 bands and 14 profiles. The five accessions in the ssp. *trilocuris* did not show any variation.

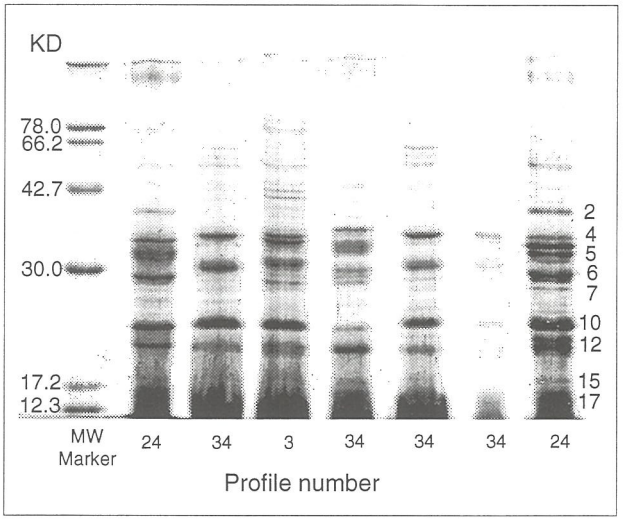


Fig. 1. SDS-PAGE profiles of *Brassica* seed proteins

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

One of the major hindrances in popularizing AVRDC's tropical Chinese cabbage in some countries is its round to near-round head formation. Consumers are more familiar with cultivars with an elongated head shape, particularly 'Wong Bok' which is popular in the tropical highland production regions. The development of heat-tolerant Chinese cabbage with elongated head shape would thus help make this crop more popular in many tropical countries. To develop inbred lines, S4 seeds were produced from 1994 selections and evaluated in mid to late summer to select the most heat-tolerant plants with elongated head type.

The experiment was severely damaged by diamondback moth in the early growth stage and by downy mildew and alternaria leaf spots in the later stage. Also, almost all of the families showed severe tipburn symptoms.

Because of these unexpected problems, many selections were made from the families with the desired head shape (table 2). Plants with medium-long to long head conformation were found in all batches. Plants with many leaves were selected for generation advance. Most of the selected families were medium-early to medium-late maturing with medium-long to long heads. The selections will be taken for intra-family intercrossing as well as selfing to recapture the head conformation of B 61 and the heat tolerance of the tropical parents in the subsequent generation.

Table 2. Selection from families with elongated head shape from segregating populations

Population	Evaluated		Selected	
	Families	Plants	Families	Plants
Batch 1	13	420	6	31
Batch 2	43	1668	28	125
Batch 3	21	871	10	40
Total	77	2,959	44	196

Development of heat-tolerant composite populations of Chinese cabbage

Composite populations were initially made in the 1989-1990 cool season to maintain the heat tolerance gene(s) and to ensure maximum utilization of the heat-tolerant genetic materials. Heat-tolerant lines were grouped into three types, i.e., Chang Puh, ASVEG No.1, and semitropical type, according to head shape, hairiness, and other horticultural characteristics.

The composite populations were further developed by mass selection for seven generations. In addition, two different classes of population were generated after three generations of mass selection either by composite selfed seeds or by composite selfed seeds of selected lines from progeny test.

The populations were further selected in summer. They were sown from June to July and transplanted to the field after 20 days. Each population consisting of 20 plants was rated for heat tolerance, bolting, disease and other horticultural characteristics. ASVEG No.1 served as the check variety for all plantings.

The experiment was severely damaged by insects, mostly by flea beetles and DBM, until mid-growth stage, and the long drought induced incidence of severe tipburn and boron deficiency. Only a few lines showed an acceptable level of heat tolerance. Also, very heat-sensitive lines were not infrequently found.

The large segregation of heat tolerance, which is likely controlled by a major gene, may be due to indirect selection and/or the selection without intervening procedure of intercrossing.

Contrary to the initial objectives and reasoning, the composite populations were subjected to selection under various selection schemes. The composite populations were generated by mixing selfed seeds without employing the intervening procedure of intercrossing. Selections were chosen from the three composites: 43 plants from Composite I, 32 from Composite II, and 25 from Composite III (table 3).

Table 3. Selection from families with heat tolerance from composite populations

Population	Evaluated		Selected	
	Families	Plants	Families	Plants
Composite I	38	760	12	43
Composite II	20	374	8	32
Composite III	21	551	6	25
Total	86	1,685	26	100

A replicated trial was conducted to compare the three different methods of selection and generation of composite population. Seeds were sown on 17 August and transplanted on 7 September. Each plot consisted of two 1.5-m-wide, 4-m-long double-row beds. The spacing was 50 cm between rows and 40 cm between plants.

Differences among composite populations were not significant except that Composite III had a significantly higher head shape index (table 4). All composites from continued bulking outyielded the check variety, ASVEG No. 1.

For the next generation of composites, mass and recurrent selection will be conducted to accumulate favorable alleles in the population. For selection criteria, heat tolerance level will only be considered to generate heat-tolerant populations with diverse genetic makeup.

Table 4. Performance of composites[a] compared to the heat-tolerant check, ASVEG No. 1, at AVRDC, 1995[b]

Entry	Yield (t/ha)	Maturity (DAT)[c]	Harvest rate (%)	Head weight (kg)	Heading efficiency ratio	Head shape index	Solidity (g/cc)	Heading rate (%)	Soft rot (%)
Composite I (B_7)	25.6ab	48c	98a	0.79bc	0.96b	1.9b	0.69cd	98ab	0c
Composite I (B_3S_3/B_1)	21.3cd	55ab	92abc	0.69cd	0.92b	1.7d	0.73abc	97ab	5abc
Composite I (B_3PTS_3/B_1)	20.3cd	59ab	82d	0.75cd	0.94b	1.8bcd	0.65cd	89cd	7a
Composite II (B_7)	22.7bcd	54bc	95ab	0.70cd	1.00b	1.8bcd	0.80ab	97ab	2bc
Composite II (B_3S_3/B_1)	22.3bcd	59ab	91abcd	0.74cd	0.96b	1.8cd	0.82a	94bc	3abc
Composite II (B_3PTS_3/B_1)	19.3de	54bc	91abcd	0.64d	1.04ab	1.9bc	0.70bc	98ab	7ab
Composite III (B_7)	26.6a	60ab	86bcd	0.93a	0.96b	2.3a	0.62cd	87d	1c
Composite III (B_3S_3/B_1)	24.4abc	61a	83cd	0.88ab	0.95b	2.3a	0.67cd	89cd	6ab
Composite III (B_3PTS_3/B_1)	25.1ab	58ab	98a	0.77c	0.99b	2.3a	0.64cd	99ab	1c
ASVEG No.1 (ck)	17.5e	39d	100a	0.53e	1.13a	1.5e	0.58d	100a	0c
CV (%)	8.0	6.3	5.7	7.8	6.9	3.6	8.6	3.4	81.5

[a] Mean separation within columns by DMRT at $P = 5\%$

[b] Sown on 17 August and transplanted on 7 September 1995

[c] Days after transplanting

Incorporation of cytoplasmic male sterility into Chinese cabbage through backcrossing

To develop a simple and stable system of hybrid seed production, two different sources of cytoplasmic male sterility (CMS) found in radish *(Raphanus sativus)* and mustard *(Brassica juncea)* had been repeatedly backcrossed to tropical Chinese cabbage.

In the radish-derived CMS backcross program, 10 lines from three families were sown on 29 August and transplanted on 3 October. A total of 2485 plants in 36 mustard-originated CMS backcross families were also sown on 29 August. The plants were carefully examined for leaf chlorosis level during mid-October and early November. General plant shape as an indicator of advancement from backcrossing was also studied.

Most of the family showed considerable levels of chlorosis. Seventy-four percent of the total radish-derived CMS and more than 90% of mustard-derived CMS plants showed moderate or higher level of chlorosis (fig. 2). Skewed segregation toward severe chlorosis suggests ineffectiveness of backcrossing. Change in chlorosis level of an individual plant between surveys was frequently observed.

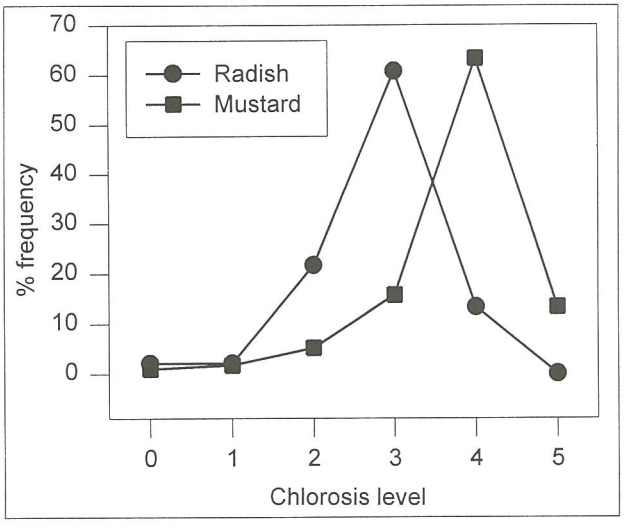


Fig. 2. Frequency distribution for leaf chlorosis level of two different CMS-derived populations (chlorosis level: 0 – 5 = none – very severe)

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

Moderately heat-tolerant common cabbage hybrids have been developed and released to cabbage growers in the tropics by several seed companies. However, the quality tends to be lower than that grown in high elevations or during the cool season in the lowland. The seeds of these hybrids are often inordinately priced.

In an effort to identify the most suitable varieties of common cabbage under hot and wet conditions, 45 varieties collected from commercial seed companies as well as public institutions were grown in the summer to observe their heat tolerance, disease resistance, and general performance.

All of the varieties except one matured from 58 to 80 days after transplanting with a mean of 72 days (fig. 3). Twenty-two varieties had more than 90% heading rate, and only seven entries had less than 50%. In contrast, only four varieties had a harvest rate more than 90%, while 24 varieties had less than 50%. The distribution of head weight revealed that 22 varieties produced heads less than 500 g. The mean head weight was 510 g. The heaviest heads were obtained from 'Southern Cross Star' from Tokita Seeds, Japan with an average head weight of 976 g. Yields ranged from 0 to 17.4 t/ha with a mean of 7.5 t/ha. The best yield was produced by 'Halu' from Evergrow Seeds, Taiwan.

The top five varieties were Halu, Summer Sea YR, Tropicana, JKI, and KK Cross (table 5). They yielded 15-17.4 t/ha and exhibited perfect heading rate and high harvest rate.

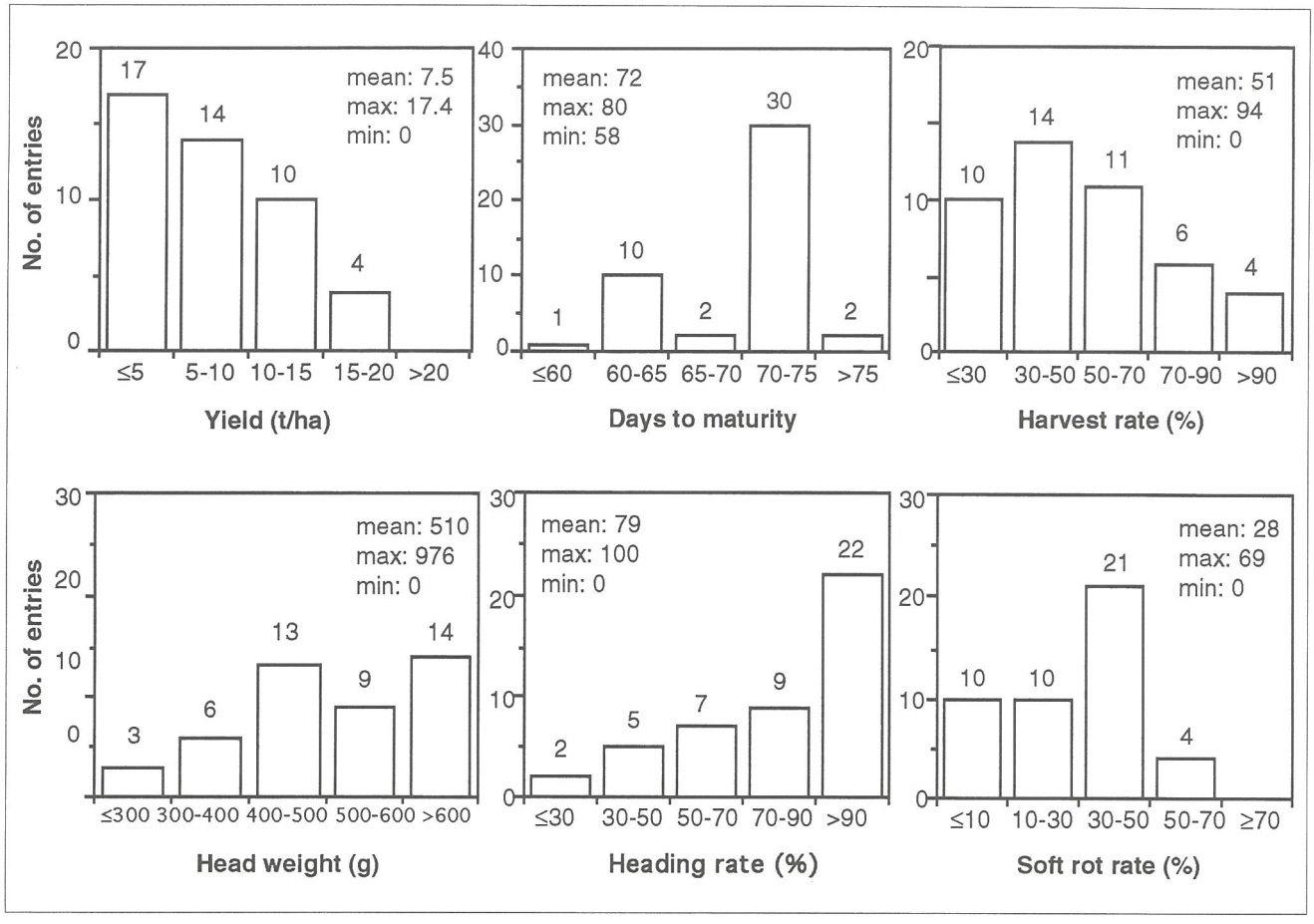


Fig. 3. Distribution of horticultural characteristics among 45 common cabbage accessions in a summer observational trial

Table 5. Yield and head weight of the top 10 varieties of common cabbage in the OT, summer 1995

Variety	Source	Yield (t/ha)	Head weight (g)	DAT[a]	Harvest rate (%)	Percent loss[b]
Halu	Evergrow, Taiwan	17.5	695	75	94	6
Summer Sea YR	Tokita, Japan	16.9	675	62	94	6
Tropicana	Peto, USA	16.4	654	58	94	6
JKI	Northrup King, USA	15.6	624	65	94	6
KK Cross	Takii, Japan	15.0	749	62	75	25
Summer Autumn	Known You, Taiwan	14.5	873	69	63	31
KK Cross Imp.	Tokita, Japan	14.2	655	62	81	19
Shia Fong No.1	Nongsheng, Taiwan	13.1	713	62	69	31
Cheers	Takii, Japan	12.5	626	75	75	19
Yoshin Ball	Tokita, Japan	12.0	554	62	81	12
Mean of 45 entries		7.5	510	72	51	28

[a] DAT = Days after transplanting

[b] Combined percent loss from infections of softrot and *Rhizoctonia solani*

Incorporation of TuMV resistance into inbred lines of Chinese cabbage

To develop heat-tolerant inbred lines with turnip mosaic virus resistance, a backcross program was initiated this year.

Resistance gene(s) in two accessions, which were previously identified by the AVRDC virologist as resistant to all known strains of TuMV, are being incorporated into two heat-tolerant lines, B 18 and E 9. Four BC_1 seeds were sent to the Korean cooperator, Dr. Sang-Gi Suh of the National Agricultural Science and Technology Institute, to make further backcross to recipient inbred lines (table 6). The BC_1 populations were screened against the C4 strain of TuMV, and five resistant plants from each population were finally selected for further backcrossing. Enough seeds were obtained from two backcrosses to B 18, but only a few seeds were recovered from the crosses to E 9. Apparently asynchronous flowering was the problem in producing the latter.

Screening of four F_1 crosses against C5 strain is being carried out under greenhouse conditions at AVRDC.

Table 6. Generation advance at Korea through backcrossing to incorporate TuMV-resistant gene(s) into Chinese cabbage inbreds

Donor	Recipient	Inoculum	No. seeds harvested
Resistant line A	B 18	TuMV-C4	100
Resistant line A	E 9	TuMV-C4	4
Resistant line B	B 18	TuMV-C4	100
Resistant line B	E 9	TuMV-C4	21

Strategic and/or supporting studies

Monthly planting of common cabbage varieties

For breeding common cabbage for the tropics, it is important to define the critical factors that affect the growing and heading of common cabbage under heat stress conditions. A monthly planting experiment was designed, and the biotic and abiotic constraints of growing common cabbage in tropical lowland were observed through the year-round plantings. Five varieties previously rated as moderately heat-resistant and one heat-sensitive variety were sown successively from January to September.

The lowest yield was recorded in planting sown in May for moderately heat-resistant varieties (fig. 4). Small head formation and low harvest rate due to high softrot incidence contributed to yield reduction. Even the most heat-resistant variety, 'KK Cross', produced heads half the size of the normal heads produced in the cool season. Days to maturity was longest in plantings sown in January, May, and June.

In the heat-sensitive variety, the lowest yield was recorded in plantings sown in June and July. The low heading ability along with small head formation contributed to low yield. Unlike the heat-tolerant varieties, the heat-sensitive variety could not form heads under heat stress condition, and almost no plant formed heads in the July planting.

As expected, diamondback moth was one of the most devastating pests during the hot season from August to early October. Cabbage webworm destroyed a considerable portion of the plants. Incidence of blackrot and tipburn was also found as a constraint in the production of common cabbage in hot season.

The recognized constraints for summer common cabbage production are summarized in table 7. It was assumed that the acceptable common cabbage variety

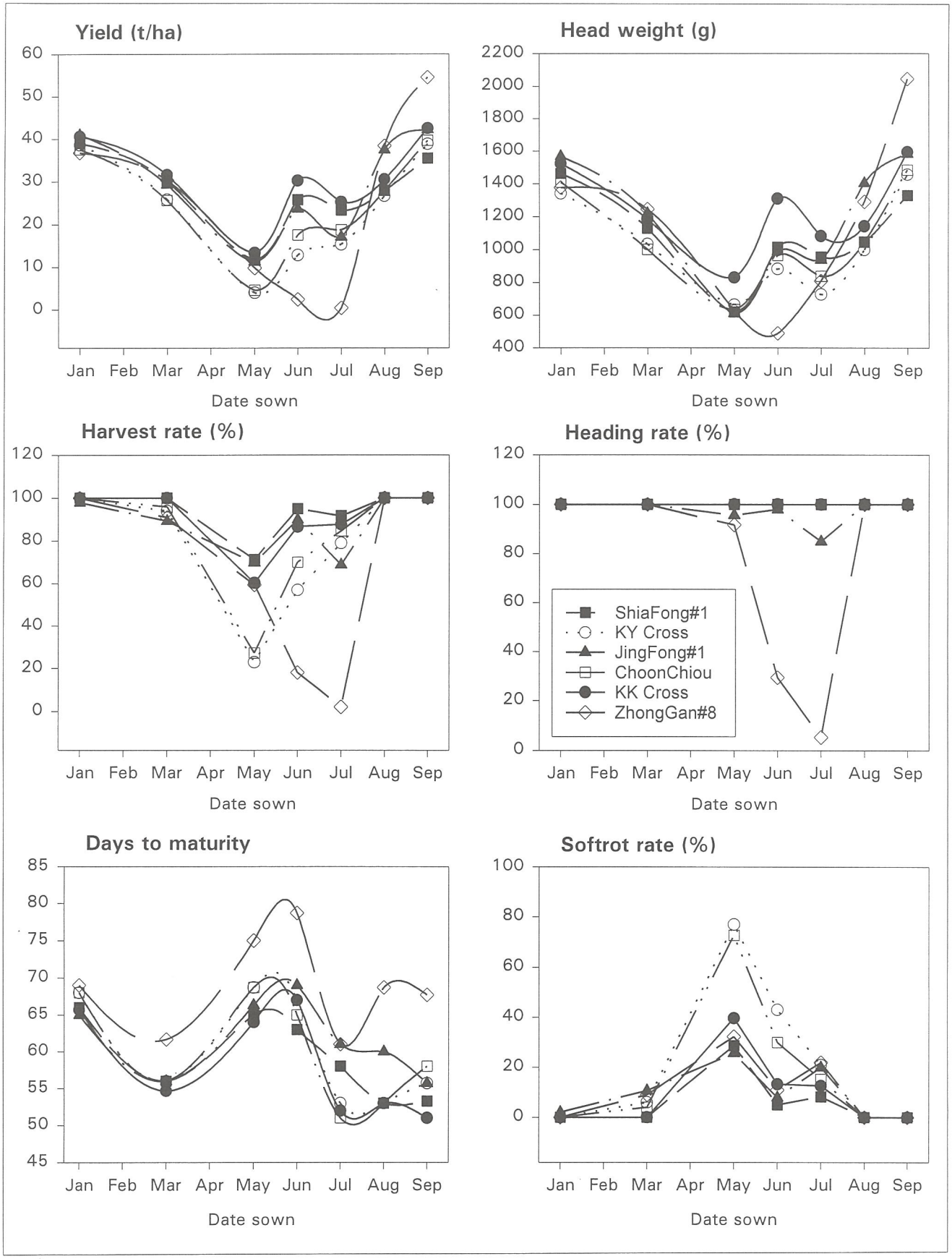


Fig. 4. Horticultural characteristics of common cabbage sown at different times

Table 7. Cultivation schedules and conditions[a] of the experiment and constraints in common cabbage production

Sown	Planted	Harvest	Mean temperature		Precipitation	Constraints[b]
			Max. (°C)	Min. (°C)	(mm)	
19 Jan	20 Feb	24 Apr-1 May	26.9	18.2	87	None
17 Mar	17 Apr	8 Jun-22 Jun	31.4	23.3	266.5	Small head, SR
15 May	14 Jun	11 Aug-28 Aug	32.7	25.2	459.5	Small head, SR, BR, DBM, CW, TB
19 Jun	18 Jul	19 Sep-6 Oct	32.3	24.9	222.5	Small head, SR, BR, DBM, CW, TB
19 Jul	16 Aug	2 Oct-16 Oct	32.0	24.3	96.5	Small head, SR, DBM
17 Aug	7 Sep	30 Oct -16 Nov	30.8	22.0	67.5	Small head, DBM (early)
14 Sep	11 Oct	1 Dec - 4 Jan	27.0	16.4	0	None

[a] Between planting and harvest

[b] SR = Softrot, BR = Blackrot, DBM = Diamondback moth, CW = Cabbage webworm, TB = Tipburn

for summer cultivation in the tropics should have high heading ability, high yielding potential (large head formation), short growing period, and high level of resistance to softrot and blackrot. Combining the first two characters is more important at the beginning. Improvement of populations derived from combinations between high heading rate and high yielding cool season varieties through mass selection or family selection could generate populations with both characteristics. At present, the bottleneck is in flower induction and seed production.

Interactions of strains and inheritance of resistance to TuMV

Turnip mosaic virus is one of the most important viruses in cole crops. It occurs worldwide and causes serious yield losses. In farmers' fields, infection with more than one strain is common. Different modes of inheritance have been proposed for TuMV resistance in Chinese cabbage, such as two dominant genes and two recessive genes. Genetic studies of resistance have usually been based on one strain or isolate because of the difficulty in detecting individual strains when mixtures of strains were inoculated.

In this study the inheritance of resistance to two TuMV strains and their interaction was investigated in five lines, and the interaction of five TuMV strains.

Three Chinese cabbage lines resistant to all five strains of TuMV, BP 58 (58) and BP 79 (79) obtained from China and O-2, an inbred line of AVRDC, and two TuMV-susceptible inbred lines, B 18 (B) and SSD 31 (SS), were used for the inheritance study. The inbred lines 58, 79, O-2, B, SS, their F_1, F_2, and BC were inoculated twice with partially purified TuMV. The first inoculation was on the second and third leaf of plants at the 3-leaf stage; the second inoculation was performed 1 week after the first inoculation on the fourth leaf.

ELISA was used to test for the presence of virus. The monoclonal antibodies, 1A3.7 and 1A9.3 (each specific for TuMV-C1), and 2B4.6 and B16.8 (each specific for TuMV-C2, C3, and C4), were used.

In BP 58 the results of single strain inoculations suggest that two dominant genes and one dominant gene are involved in C1 and C4 resistance, respectively (table 8). In BP 79, resistance to C1 appeared to be controlled by one dominant gene (table 9). Resistance to C4 was controlled by a recessive gene.

Table 8. Summary of genetic study on TuMV resistance

Reaction to	Combination		
	BPI 58 x B 18	BP 79 x B 18	O-2 x SSD 32
C1	DD[a]	D?	DD
C3	-	-	D
C4	D	r	-
Mixture (C1/C3)	-	-	-/?
Mixture (C1/C4)	r/?	?/r?	-

[a] DD = double dominant, D = single dominant, r = recessive, -not tested

Resistance to strains C1 and C3 in the inbred line O-2 was controlled by two dominant genes and one dominant gene, respectively. However, when strain mixtures were used as inoculum, resistance to individual strains seemed to be lower. The F_2 segregating patterns were difficult to interpret and did not fit Mendelian genetics. Interaction between strains may be involved.

Table 9. Inheritance of resistance to TuMV strain C1 and C4 in BP 58 (58) x B 18 (B)

TuMV[a]	MAb[b]	Generation[c]	No. of plants tested	Observed R		Observed S		Expected ratio (R:S)	χ^2
C1	1A9.3	Pr (58)	24	24		0			
		Ps (B)	24	0		24			
		F_1 (Pr x Ps)	25	25		0		1:0	
		F_2 (Ps x Pr) selfed	121	114		7		15:1	0.043
		BC_1F_1 (Ps x Pr) x Ps	48	39		9		3:1	1.000
		BC_1F_1 (Ps x Pr) x Pr	48	48		0		1:0	
C4	B16.8	Pr (58)	24	24		0			
		Ps (B)	23	0		23			
		F_1 (Pr x Ps)	24	24		0		1:0	
		F_2 (Ps x Pr) selfed	124	95		29		3:1	0.172
		BC_1F_1 (Ps x Pr) x Ps	47	23		24		1:1	0.020
		BC_1F_1 (Ps x Pr) x Pr	48	48		0		1:0	
C1.4	1A9.3	Pr (58)	24	24	(24)[d]	0	(0)		
	(B16.8)	Ps (B)	24	0	(0)	24	(24)		
		F_1 (Pr x Ps)	24	23	(19)	1	(5)	1:0	
		F_2 (Ps x Pr) selfed	117	88	(67)	29	(50)	3:1	0.002 (19.627**)
		BC_1F_1 (Ps x Pr) x Ps	52	19	(42)	33	(10)	1:1	3.769 (19.692**)
		BC_1F_1 (Ps x Pr) x Pr	52	52	(51)	0	(1)	1:0	

[a] TuMV strain used for inoculation

[b] 1A9.3 = TuMV-C1 strain-specific; B16.8 = TuMV-C2-C4 strain-specific

[c] Pr: resistant parent; Ps: susceptible parent

[d] Figures in parentheses represent the reactions with respect to the C4 strain

EGGPLANT IMPROVEMENT

Eggplant (*Solanum melongena*) was selected as one of the principal research vegetables at AVRDC in 1992. It is a common vegetable crop grown in nearly all types of gardens and production systems in the tropics. Its growth duration is relatively long, hence it is subject to a number of constraints. The goal of eggplant improvement is to develop stable and high-yielding varieties/lines with improved fruit quality attributes and integrated pest management for bacterial wilt (*Pseudomonas solanacearum*), Phomopsis blight (*Phomopsis vexans*), and fruit and shoot borer (*Leucinodes orbonalis*) with emphasis on varietal resistance/tolerance, and cultural and biological control in the tropics and subtropics.

The eggplant germplasm collection at AVRDC is comprised of 2224 accessions including 1388 accessions of *Solanum melongena* and 42 other *Solanum* species. A worldwide collection of 242 eggplant varieties was also assembled from commercial cultivars and landraces in the past years. The commercial cultivars are predominantly F_1 hybrids. Observation and evaluation of collected commercial cultivars, landraces, and germplasm are aimed at identifying desired genotypes for use in the eggplant breeding program or for recommending to NARS.

Major activities in 1995 focused on (1) germplasm collection, multiplication and characterization, (2) evaluation of germplasm and elite varieties, (3) confirmation of the sources of bacterial wilt resistance and development of bacterial-wilt resistant varieties, (4) development of field screening protocol for bacterial wilt, and (5) development of mass rearing procedure for eggplant fruit and shoot borer.

Genetic resources enhancement and varietal development

Genetic resources activities

AVRDC maintains an eggplant germplasm collection for crop improvement program and various research purposes. In 1995 the center acquired a total of 407 accessions of 12 species bringing the total number of accessions in the eggplant collection to 2224 (table 1).

A total of 111 accessions were planted for seed production in autumn 1994. To date, a total of 357 (16%) accessions have been regenerated.

Wide diversities in fruit color and shape were observed among collected germplasm (fig. 1 and 2). For fruit shape, the range of possible diversity is well covered. However, in terms of fruit color, the collection lack extremely dark colors (e.g., purple black to black fruits) at commercial ripeness. Number of fruit/infructescence range from 1 to 6 and number of fruit/plant from 1 to 120.

Presently, 35 accessions have seeds in long-term storage. This year, a total of 411 samples were sent to 21 countries and territories.

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

Table 1. AVRDC eggplant germplasm collection, 1995

Species	No. of accessions
S. aculeatissimum	39
S. aethiopicum	76
S. americanum	2
S. anguivi	4
S. atropurpureum	1
S. aviculare	2
S. caripense	3
S. capsicoides	2
S. ciliatum	1
S. eleagnifolium	2
S. ferox	1
S. incanum	9
S. indicum	27
S. integrifolium	1
S. juglandifolium	2
S. laciniatum	3
S. linnaeanum	3
S. linociera	11
S. lycopersicoides	5
S. macrocarpon	7
S. melongena	1,388
S. nigrum	18
S. nodiflorum	1
S. ocranthum	1
S. parkinsonii	12
S. petinatum	1
S. pseudocapsicum	3
S. quinquangulare	1
S. rammosum	4
S. regescentoides	1
S. repandum	1
S. rickii	2
S. rostratum	1
S. sepium	1
S. sessiliflorum	1
S. sisymbrifolium	10
S. spinosissimum	1
S. stramonifolium	10
S. suaveolens	4
S. surattense	4
S. torvum	35
S. xanthocarpum	14
S. sp.	509
Total	2,224

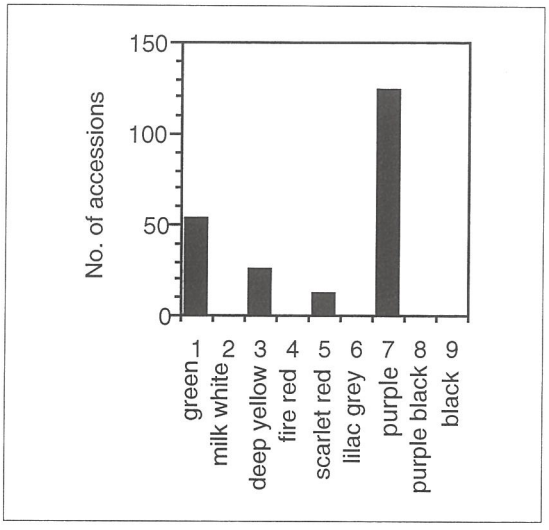


Fig. 1. Eggplant fruit color at commercial ripeness

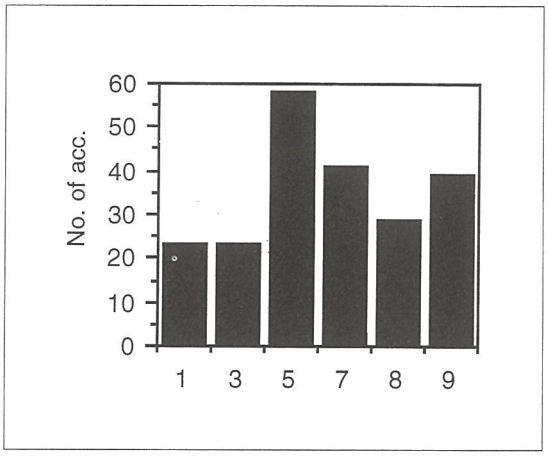


Fig. 2. Fruit shape in eggplant

Evaluation of eggplant cultivars and germplasm

New collections are tested in the field to observe their general performance. Selected promising varieties are then further evaluated in the elite variety trials to confirm their adaptation and yield stability. In the past two years, several observation and evaluation trials were conducted, and a number of desirable genotypes were identified and used.

An observation trial (OT) and two elite variety trials (EVT) were conducted in 1994-95. The OT consisted of 94 entries which were collected mainly from Japan, India, China, and USA and was systematically arranged in the field without replication. Twenty-nine entries each which were grouped into cylindrical and teardrop fruit types were employed in the elite variety trials in autumn 1994 and spring 1995. The experimental design for EVT was RCBD with four replications. For both OT and EVT, the single-row plot size was 9 m^2 (1.5 x 6.0 m) consisting of 12 plants with 1.5 x 0.5 m spacing.

A large diversity in yield, horticultural characteristics, and fruit quality was observed in the OT (fig. 3). Cylindrical fruit type and purple color were the predominant shape and color with 56% and 87%, respectively. The yields of the first 10 harvests ranged from 1.5 to 47.5 t/ha with a mean of 18.1 t/ha. The five top yielders, i.e., PPC, Local-1, Akitawaru, Niha, and White Eggplant, produced yields higher than 42 t/ha. Majority of the entries had 10-20 fruits per plant and fruit weight of 50-100 g, and matured in 90-130 days after transplanting.

Large variations in dry matter, total sugar, and fiber contents were determined among the 90 eggplant entries. The distribution of dry matter, total sugar, and fiber contents ranged from 5.5 to 10.1%, 7.0 to 40.1% and 4.7 to 18.1%, respectively. Dry matter content is positively correlated with fiber content (r = 0.438) but negatively correlated with sugar content (r = -0.710). A negative correlation between sugar and fiber content was also found to be highly significant (r = -0.712).

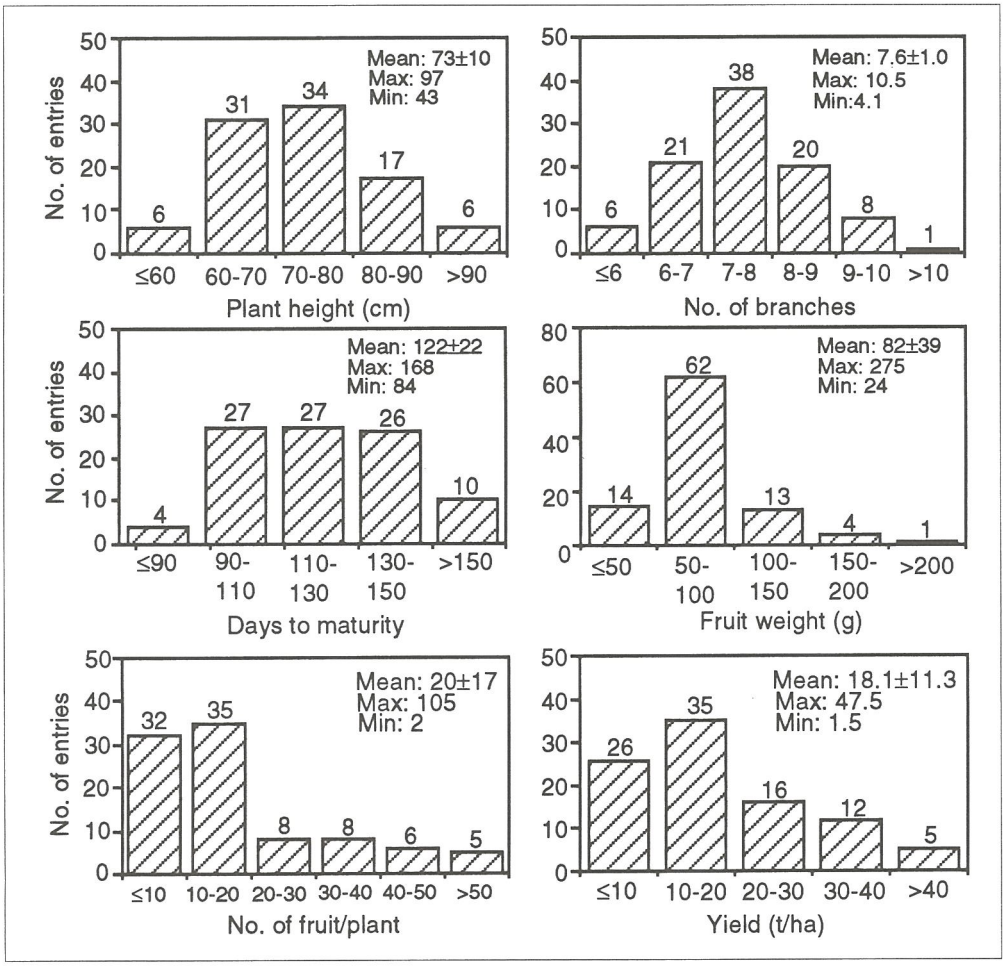


Fig. 3. Distribution of horticultural characteristics among 94 entries of eggplant

Genotypes with promising traits, such as erect plant type, less branches, early maturity, high number of fruit per plant, high yielding potential, and others were identified and further evaluated in EVT.

In the 1994-95 EVTs, the differences in marketable yield among the entries were significant (table 2). For the cylindrical fruit type, the mean yields were 27.2 and 46.6 t/ha, while for the teardrop fruit type, the mean yields were 45.0 and 49.6 t/ha for autumn 1994 and spring 1995, respectively. Generally yield in spring was higher than that in autumn. In each group and trial the best yields were obtained from Pusa Purple Long (36.6 t/ha), Jackpot (55.0 t/ha), Galine F_1 (54.4 t/ha), and Tania F_1 (70.4 t/ha). Four varieties, Sanshi Naga F_1, Farmers Long F_1, Edna F_1, and Tania F_1, performed consistently well with stable high yields in both seasons. Marketable yields were highly associated with the components of fruit weight and number of fruit per plant.

Table 2. Horticultural characters and yield of top 5 eggplant entries in each EVT, 1994-95

Trial/Variety	Plant height (cm)	No. of branches	Days to maturity	Fruit Weight (g)	Fruit L (cm)	Fruit W (cm)	Fruit L/W	No. of fruit/ plant	Yield (t/ha)
1994 autumn[a]									
P.P. Long	93	7.2	88	72	17.2	3.3	5.2	38.9	36.6
Shanshi Naga F_1	100	5.8	84	94	16.2	4.0	4.0	28.4	35.3
Farmers Long F_1	95	5.0	103	63	21.8	2.7	8.3	36.8	31.0
TS 33	99	5.5	100	91	16.2	4.0	4.1	24.0	29.0
Daikokuden F_1	91	5.4	88	101	12.0	4.6	2.7	20.9	28.1
Mean of 16 var.	99	5.6	95	85	17.6	3.6	5.1	24.7	27.2
Galine F_1	116	6.4	97	227	9.9	6.1	1.7	18.3	54.4
Agora F_1	97	5.5	101	235	12.0	5.8	2.1	16.9	52.6
Soma F_1	100	5.3	100	301	10.7	6.8	1.6	13.2	52.5
Tania F_1	101	5.9	103	251	11.3	6.6	1.7	15.7	52.2
Edna F_1	103	5.9	102	231	12.5	6.2	2.0	16.5	50.7
Mean of 13 var.	107	5.7	102	230	11.9	6.2	2.0	15.3	45.0
1995 spring[b]									
Jackpot	115	6.3	81	107	17.7	3.3	5.4	38.8	55.0
Ichiban PS F_1	106	6.3	80	89	14.4	3.4	4.2	45.7	53.9
Sanshi Naga F_1	89	6.2	71	87	14.7	3.5	4.2	46.4	53.7
Farmers Long F_1	108	5.6	82	71	21.6	2.9	7.4	55.3	52.1
Kopek	121	6.3	80	117	14.8	3.8	3.9	33.2	51.5
Mean of 14 var.	111	6.0	81	98	16.1	3.8	4.4	20.5	46.5
Tania F_1	120	5.6	81	241	10.2	7.2	1.4	22.1	70.4
Tasca F_1	144	6.8	82	243	9.9	7.7	1.3	19.8	63.6
Othello F_1	113	5.7	83	276	9.9	7.2	1.4	16.8	61.6
Pusa Kranti	123	7.1	82	129	11.7	5.8	2.0	35.7	61.1
Edna F_1	127	6.2	80	205	10.8	6.9	1.6	20.7	56.7
Mean of 15 var.	125	6.0	81	204	10.3	6.5	1.6	19.2	49.6

[a] Sowing date: 12 September; transplanting date: 7 October 1994

[b] Sowing date: 17 April; transplanting date: 11 May 1995

Evaluation of germplasm for resistance to bacterial wilt

More than 200 accessions of eggplant were screened for resistance to bacterial wilt in the past two years. Among these, 38 accessions were identified to have a high level of resistance.

These 38 resistant accessions were reexamined under both greenhouse and field conditions. Inoculation was done by combining root wounding and soil drenching in the greenhouse. Seedlings were planted 3 days after inoculation in a noninfected field for field screening. The bacterial wilt infection was satisfactory in both greenhouse and field inoculations. Disease reading was undertaken up to 30 days after inoculation in the greenhouse and up to 60 days after transplanting in the field.

Among the 38 accessions only six showed consistent resistance with disease indices less than 10% in both greenhouse and field. They were TS 3, TS 43, and TS 47A from Malaysia; and TS 69, TS 87, and TS 90 from Indonesia. Four of them, i.e., TS 3, TS 43, TS 47A, and TS 90, exhibited excellent stability in resistance to bacterial wilt throughout all screening trials in 1994-95. Moreover, seven accessions showed a consistent disease reaction but with moderate resistance under both greenhouse and field conditions. In addition, different disease reactions were observed between greenhouse and field screenings in 17 accessions.

In general, the disease indices were higher in the field than in the greenhouse screening probably due to the different observation periods. Based on the disease indices of 38 accessions, a significant correlation ($r = 0.614$) was found between field and greenhouse screening results. On the other hand, inconsistent bacterial wilt reactions of an eggplant accession might be attributed to environmental changes between trials, growth differences of plants, and genotypic differences or seed impurity within the accession. These differences might have influenced the degree of susceptibility of the accession between screening trials.

In addition, 37 new accessions of the different sources were screened for resistance to bacterial wilt in the greenhouse. Six accessions, all wild types collected from Malaysia, were identified to be resistant: TS 16, TS 18, TS 29, TS 40, TS 42, and TS 51.

Sixteen F_2 populations of the crosses made for bacterial wilt resistance development were screened for resistance at seedling stage in the greenhouse. A total of 1548 resistant plants were selected and transplanted in the field for further evaluation of horticultural traits such as earliness, plant type, fruit appearance, yield potential, and others. About 104 individual plants were selected for advancement to F_3 generation.

To improve the bacterial wilt resistance of three landrace varieties, Pingtung Long, Pusa Purple Long, and Uttara, crosses were made between them and Slim Jim, a resistant variety. Two backcrossings were made to their respective recurrent parents. Another 40 new crosses were made between parents with desirable horticultural traits and bacterial wilt resistance. These hybrids are being evaluated for bacterial wilt resistance and yield potential.

Information on the mode of inheritance of bacterial wilt disease would facilitate the development of resistant eggplant varieties. Three resistant varieties, S 56B, EG 014, and EG 190, and three susceptible varieties, EG 120, EG 048, and S 112, were selected for studying the genetics of bacterial wilt resistance. All possible cross combinations of F_1, F_2, and backcrosses were developed. Evaluation of bacterial wilt resistance for F_1, F_2, and backcrosses will be done in the greenhouse by using the soil drench and root-severing method of inoculation.

Major diseases and insect pests

Development of field screening protocol for eggplant bacterial wilt

A field trial was conducted using a factorial design from June to August to develop a field screening protocol for bacterial wilt resistance. Treatments used include inoculating seedlings 3 days before transplanting and preparing a disease nursery.

Results indicated that wilt % of resistant (R, TS 56B), moderately resistant (MR, Pingtung Long), and susceptible (S, Bonne) varieties in each treatment at the end of the trial were significantly different (fig . 4). However, a significant difference on disease progress (area under disease progress curve) was observed only in the treatment with inoculated seedlings in the noninfested field. Planting inoculated seedlings or in the disease nursery did not increase the final wilt % of Bonne but it did speed up the disease progress significantly. Inoculated seedlings can increase the final wilt % but not the disease nursery in the MR and R varieties. A repeat trial is ongoing with plants transplanted in October. Although the disease pressure in this trial is lower than the June trial, obvious differences among the three test varieties can still be observed. Symptoms other than wilting were observed in the R and MR

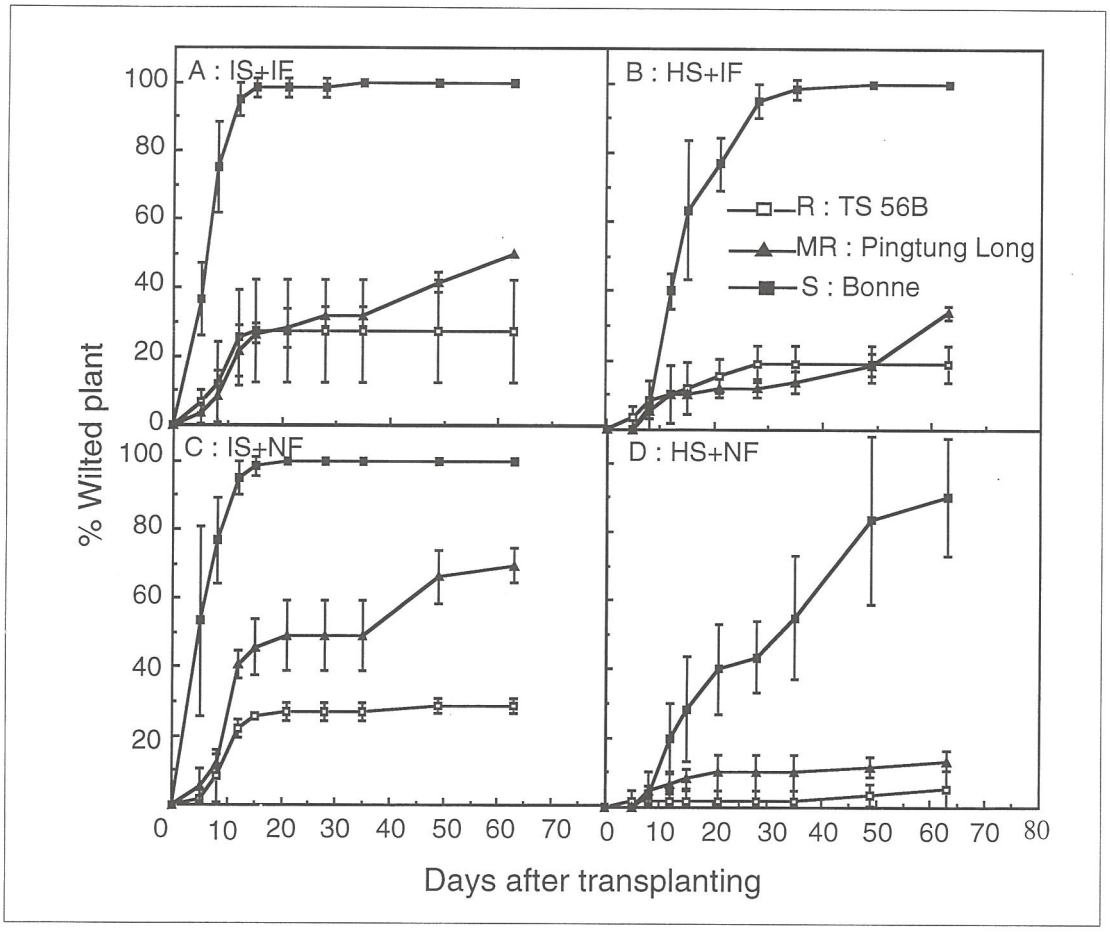


Fig. 4. Disease progress of eggplant bacterial wilt in the field

The experiment followed a factorial design with two factors: inoculated seedlings (IS) or healthy seedlings (HS) and infested field (IF) or noninfested field (NF). Within each combination, 3 varieties were planted, i.e., TS 56B (resistant), Pingtung Long (moderately resistant) and Bonne (susceptible)

varieties. Some plants exhibited stunting and lower leaves gradually turned brown and defoliated. Results of isolation indicated that these symptoms were due to latent infection of the pathogen.

The protocol of planting inoculated seedlings in noninfested fields was adopted for field screening and a trial was conducted in August. Results indicated that significant differences in final wilt and disease progress can still be observed among the R, MR, and S varieties.

Correlation between field screening by planting inoculated seedlings in noninfested field and seedling screening by soil drenching method with root wounding was analyzed. The data included two control varieties (resistant and susceptible) and 38 varieties which previously showed high levels of resistance in the seedling screening. Results indicated that the field and seedling screening were highly correlated ($r = 0.71$) when data of disease index were compared and 0.61 when data of survival % were compared.

Rearing of eggplant fruit and shoot borer on artificial diet

Although eggplant fruit and shoot borer is the most destructive pest of eggplant in Southeast Asia, the damage by this insect in Taiwan is sporadic. Because of the economic and social importance of eggplant in Asia and the fact that eggplant fruit and shoot borer is the most important biotic constraint in the production of this vegetable, AVRDC is looking for ways to combat this pest on a sustainable basis. Research on the rearing procedure of this insect in the laboratory and its diet is ongoing.

Larvae and pupae of fruit and shoot borer were collected from an eggplant field in AVRDC's experiment station. They were maintained on fresh eggplant fruits until adult emergence in the laboratory. Upon emergence the adult insects were kept in a 14-cm-diam, 35-cm-tall acrylic cylinder. A fine nylon net-lined cylinder served as oviposition site. The cylinder was covered with thick black paper on the outside. Both open ends of the cylinder were also covered with black cloth. A 10% honey solution placed in a small bottle served as food source. This solution was made available to the insect by the capillary action of a 15-cm-long dental cotton wick dipped in the solution. Adults laid eggs in the nylon net and black cloth. Eggs were removed and placed on the artificial diet for hatching and subsequent larval feeding.

A semisynthetic diet developed earlier at AVRDC is now being evaluated in the laboratory for the mass production of eggplant fruit and shoot borer. The composition of the diet is as follows:

BioServe beet armyworm diet	140 g
Dry eggplant powder	14 g
Agar	19.8 g
Water (distilled)	820 ml

Agar was dissolved in 820 ml of distilled water and boiled with constant stirring. The other ingredients were mixed in a separate container. When agar was completely dissolved and the temperature had cooled down to between 50 to 60°C, the agar solution was slowly poured into the blender containing the other ingredients and stirred for 1 min. The mixture was then poured into plastic containers to a depth of 2 cm and allowed to cool and settle for at least 4 h. A small hole in the plastic lid of this container when covered with tissue paper was enough to maintain optimum relative humidity. Fifteen to 20 newly hatched larvae were maintained in each container. After 3 to 4 days the diet was replaced with a new one to minimize fungal growth on the diet.

Frequent replacement of the diet every 3 to 4 days to overcome fungal contamination rendered the artificial diet unsuitable for the mass production of eggplant fruit and shoot borer. So far three different treatments to improve the diet are now being evaluated in the laboratory. Treatments include the addition of aureomycin, exposure to ultraviolet light, and autoclaving the diet.

Fully mature larvae left the food and moved toward the tissue paper that lined the cover and pupated on the periphery of the plastic containers or on the side of the plastic cover. Adults emerged from the pupal case within 8 to 10 days. Adults were then transferred to a new cage for egg laying.

Studies on the variation of flower types in eggplant

Eggplant bears both long-styled (the stigma is either above or on the same level as the stamen) and short-styled (the stigma is below the stamen) flowers on the same plant. The short-styled flower has a rudimentary ovary which does not develop into a fruit. Selection of a genotype with stable and high numbers of long-styled flowers may increase fruit setting and yield. An investigation was conducted in the field to observe variations in the proportion of different flower types among the selected genotypes.

Four samplings each were taken from 10 genotypes randomly selected from the field to investigate the variation in the proportion of long- and short-styled flowers. A large variation was found among the genotypes in terms of percentages of long- and short-styled flowers. The mean percentages of long-styled flowers ranged from 30 to 94.9%, while the short-styled flowers ranged from 5.1 to 70%. An Indian variety, BB 49, showed consistently high percentages of long-styled flowers over the sampling dates. Pingtung Long, a local commercial variety, and New Hsin, a Chinese variety, also exhibited a high percentage of long-styled flowers. In contrast, two Indian varieties, Pusa Kranti and EP 57, had a high percentage of short-styled flowers. The proportion of long- and short-styled flowers varied with dates of sampling in each genotype. Apparently, there are some factors which are related to the occurrence of different flower types.

PEPPER IMPROVEMENT

Hot and sweet peppers (*Capsicum* spp.) are grown throughout the tropics, although the hot varieties, because of their culinary significance and wide consumption, are far more important. Peppers are rich in vitamins A and C. Used in both fresh and processed form, they generally have a longer storage life and better transportability than most of the other fruit vegetables.

The center added peppers to its list of principal crops in 1986. The goals of the pepper improvement project are to: (1) develop varieties that are resistant to a complex of viruses, such as cucumber mosaic virus; anthracnose, Phytophthora blight; and bacterial spot and bacterial wilt; (2) improve heat tolerance and yield in the tropics; (3) alter the crop duration and harvest index to suit various cropping systems; and (4) develop a series of market types for the fresh market, for processing, and dried spice.

At the initial stage of the project, the center established the international hot pepper trial network (INTHOPE) to foster exchange and evaluation of hot pepper landraces and promising breeding lines in diverse geographic regions, and employed the method of pureline selection in existing varieties.

With support from the Japanese government, AVRDC works closely with national partners in the Philippines and Thailand on the regeneration and characterization of pepper germplasm. The center also collaborates with other NARS in Southeast Asia and South Asia, through the Asian Development Bank-funded regional networks AVNET and SAVERNET, in conducting studies and surveys on pepper viruses. These are geared towards identifying constraints in production and exchange of high yielding, and pest and disease-resistant varieties.

Genetic resources enhancement and varietal improvement

Genetic resources activities

The center maintains a pepper germplasm collection for use in its crop improvement progam and for various research purposes. In 1995 a total of 206 accessions of five species were acquired bringing the total number of accessions in the pepper collection to 6835 (table 1). More than 50% of the collection is now in long-term storage.

A total of 286 accessions majority of which originate from China, Korea, and Iran were regenerated at headquarters. Another 400 accessions were sent to NPGRL in the Philippines for characterization and regeneration. Characterization data for 298 accessions were received from Kasetsart University, Thailand.

Characterization of germplasm was done based on a standard set of descriptors. Registration, passport, distribution, and seed inventory are regularly updated.

Karyotype analysis on five species was done. Cold treatment induced banding in somatic chromosomes.

Table 1. AVRDC pepper germplasm collection, 1995

Species	No. of accessions
C. annuum	4,089
C. baccatum	356
C. chacoense	30
C. chinense	378
C. eximium	4
C. frutescens	365
C. praetermissum	4
C. pubescens	30
C. sp.	1,579
Total	6,835

The banding patterns were consistent and useful in identifying chromosomes and characterizing karyotype of *Capsicum* spp. The different species had distinct karyotype based on relative length, arm ratio, presence of satellite, and banding pattern.

Differences in karyotypes suggest that species differentiation involved a series of structural changes in their chromosomes. Five trisomics (Brun, Noir, Vert, Pourpre, Rouge) were recovered from the complete set sent by INRA. In one of the trisomics (Pourpre), the chromosome involved was that carrying the nucleolus organizing region. The trisomics were characterized chromosomally and morphologically.

A total of 4150 samples were sent to 49 countries and territories (table 2).

Table 2. Distribution of pepper germplasm in 1995

Country	No. of samples
India	360
Japan	113
Korea	131
Philippines	749
Taiwan	512
Tanzania	86
Thailand	671
USA	320
Vietnam	91
Zimbabwe	78
Others[a]	1,039
Total	4,150

[a] Albania, Bangladesh, Barbados, Bhutan, Botswana, Cambodia, Cayman Is., China, Costa Rica, Egypt, Ethiopia, Ghana, Hungary, Indonesia, Israel, Italy, Lao PDR, Malawi, Malaysia, Marshall Is., Mauritius, Mexico, Mozambique, Namibia, Nepal, Netherlands, Nigeria, Pakistan, Panama, Seychelles, Sierra Leone, Singapore, Republic of South Africa, Sri Lanka, St. Vincent and Grenadine, Swaziland, Uganda, U.K., Zambia

Seed production, observation, and evaluation trials of new and advanced germplasm

Three field experiments were conducted to observe a total of 394 *Capsicum* accessions (landraces and inbred lines) and to increase their seed supply. They consisted of 139 accessions frequently requested because of their disease resistance, nonpungency, or heat tolerance; 112 accessions that were low on seed quantity; and 143 new accessions. Data was collected on plant and fruit traits to categorize the pepper germplasm collection. The seed will be used to fill seed requests, to serve as parents in new crosses, and to plant an observation trial during the 1996 hot, rainy season.

Hybridization and selection of new genotypes with combined disease resistance, quality, and regional adaptation

A total of 238 sweet pepper and 115 hot pepper F_2 populations were planted in April-May to undergo selection during the hot, rainy season at AVRDC. Twenty-nine populations were screened at the seedling stage for the presence of *Bs2* (a dominant qualitative gene conferring resistance to bacterial spot), 18 for quantitative resistance to bacterial spot, 57 for quantitative resistance to *Phytophthora capsici*, 19 for chili veinal mottle virus resistance, and the rest

were transplanted without seedling screening. Sixteen hot pepper F_6 lines and two checks were planted in a randomized complete block design with three replications. Another six F_6 lines were planted in a single replication trial. In the CVMV backcrossing project, a total of 132 backcross lines (6 plants/line) were screened for resistance to CVMV. Resistant plants were backcrossed to their recurrent parents (23 parental types, average of 6 BC lines/parent).

Sweet pepper F_2 population selection

Because there were no typhoons during the hot, rainy season, survival of the sweet pepper populations was good. There was enough disease and insect pressure to provide a good selection differential and allow superior genotypes to be identified. About 500 plants with good heat tolerance and disease resistance were identified. These were tested by ELISA for the presence of CMV and CVMV. Plants that tested negative for the presence of both viruses were selected, along with several other plants with good fruit traits, for selfing. A total of 250 F_2 plants were selfed. Forty virus-negative plants were crossed to one of four sweet peppers (Jupiter, PM4, Paprika Murgi, and Paprika Rossita) to generate new populations segregating for heat tolerance, disease resistance, and fruit type.

Hot pepper F_2 population selection

Preliminary selections identified 363 plants with good heat tolerance and disease resistance. An additional 24 plants were selected based on their stem morphology (strong, upright stem with multiple branches). The 363 primary selections were selfed using net bags on individual branches to obtain F_3 seed. The 24 additional selections were harvested as open-pollinated seed, which will be treated as F_1 seed. No new crosses were made with these materials.

F_6 hot pepper yield trial

Some segregation for plant type, fruit type, and disease resistance was observed in several of the lines. This was not unexpected, since each line had been harvested in bulk from F_4 open-pollinated plants. Single plant selections were made for desirable plant type, fruit type, and disease resistance in each line to purify them. Table 3 shows the mean and range for nine traits measured in the hot pepper yield trial, along with the means for each check and entry 3, the highest yielding entry in the trial.

The analysis of variance detected significant differences between genotypes for all traits (table 3). Replication effects were significant only for yield and fruit number, which probably contributed to their relatively high coefficients of variation.

Table 3. Mean and range for nine traits measured in the hot pepper yield trial

	Marketable yield (t/ha)	Anthesis date (das)	Fruit length (cm)	Fruit width (cm)	Fruit no. plant	Fruit weight (g)	Fruit dry matter (%)	Harvest index (%)	Culls (%)
Mean	11.6	79	9.0	1.3	111	3.7	15.8	26	11
Range	6.8-15.4	76-85	7.7-10.6	1.0-1.6	58-172	2.6-5.1	13.7-19.1	11-33	5-26
PBC 385 (ck)	11.1	85	10.6	1.4	92	4.1	15.3	27	8
PBC 208 (ck)	7.8	78	10.5	1.1	58	4.6	19.1	31	26
Entry 3	15.4	79	7.9	1.5	172	3.1	14.8	33	9
DMRT	3.3	4	0.9	0.2	37	0.7	2.0	11	7
CV (%)	15.4	2	5.2	7.5	17	10.0	6.6	21	36

Harvest began 121 days after sowing

CVMV backcrossing program

One hundred thirty-two $BCNF_1$ plants (where N=1, 2, or 3) in various stages of backcrossing CVMV resistance from nine different sources into 23 diverse recurrent parents were screened for CVMV resistance. Forty-two of the lines did not show any resistant plants (0 out of 6 screened), so an additional 48 plants were screened from each of these lines. All 48 plants in all 42 susceptible lines were susceptible, confirming that they had lost their resistance. Resistance to CVMV had been shown in a related genetic study to be due to a single dominant gene in PSP-11, and two genes (one dominant, one recessive) in Perennial HDV. The remaining 90 lines were backcrossed to their respective recurrent parents.

Collection, evaluation, multiplication, and distribution of INTHOPE #5 entries

Seeds of the INTHOPE #5 trial were sent to 32 recipients in more than 17 countries for testing at 67 sites. The INTHOPE #5 trial was tested for 10 pepper diseases: bacterial spot, bacterial wilt, anthracnose, Phytophthora root rot, cucumber mosaic virus, chili veinal mottle virus, potato virus Y, tobacco mosaic virus, tomato mosaic virus, and pepper mild mottle virus. The INTHOPE #5 trial was evaluated for field performance and quality traits at AVRDC in summer 1994 and fall-winter 1994-95. An RCBD with three replications was employed. The summer planting involved two experiments, one transplanted on 1.0-m beds and the other on 1.5-m beds, with population densities of 44,444 and 29,630 plants/ha, respectively. The fall trial was on 1.5-m beds with 29,630 plants.

The INTHOPE #5 trial was sent to 32 different recipients; no feedback has been received to date. Results obtained during the cool, dry season are not highly correlated with results obtained during the hot, rainy season. Growth conditions were favorable for the cool, dry season INTHOPE #5 yield trial. Harvest began from 123-158 days after sowing, depending on the maturity of individual lines.

The analysis of variance detected significant differences between genotypes for all traits except fruit dry matter. Replication effects were significant only for yield and fruit number, which probably contributed to their relatively high coefficients of variation.

Genetics of resistance to major pepper diseases

A genetic study on the inheritance of resistance to CVMV and PVMV was conducted. It involved one susceptible parent, Cheongryong (S), and two resistant parents, Perennial HDV (R1) and PSP-11 (R2), and the F_1, F_2, BCR and BCS populations derived from the crosses SxR1 and SxR2. Population sizes were 24, 24, 24, 240, 48, and 120 for the S, R, F_1, F_2, BCR, and BCS populations, respectively. Separate sets of populations were inoculated with CVMV and PVMV. Plants were inoculated at the 3-4-true leaf stage and again a week later. Resistance or susceptibility was measured by ELISA. Data was combined with similar data obtained in 1994 to determine inheritance and number of genes involved.

There were no reciprocal differences between F_1 combinations for either CMV or PVMV, indicating that cytoplasmic effects were not important, hence no cytoplasmic effects were considered thereafter. Based on disease reactions for CVMV, Chi-square tests indicated that one dominant and one recessive gene conferred resistance in R1, and one dominant gene conferred resistance to CVMV in R2. The F_2 segregation ratios tested were 13:3 (R:S) ($\chi^2 = 2.26$, $P = 0.21$) and 3:1 (R:S) ($\chi^2 = 0.13$, $P = 0.61$) for R1 and R2, respectively. The BCS segregation ratio tested was 1:1 (R:S) ($\chi^2 = 0.13$, $P = 0.61$ for R1, $\chi^2 = 164.8$, $P < 0.0001$ for R2). One of the segregating backcrosses significantly deviated from expected ratios ($P < 0.0001$). This may be due to linkage of resistance genes, differences in gametic viability, or gene(s) with minor effects that affect virus movement in the plant.

Further testing of F_3 families or other segregating progeny is needed to confirm the inheritance results.

Based on disease reactions for PVMV, Chi-square tests indicated that two recessive loci conferred resistance to PVMV in both resistant parents. The F_2 segregation ratio tested was 15:1 (R:S) ($\chi^2 = 5.05$, $P = 0.04$ for R1, $\chi^2 = 0.001$, $P = 0.98$ for R2), and the BCR segregation ratio tested was 1:3 (R:S) ($\chi^2 = 190.4$, $P < 0.0001$ for R1, $\chi^2 = 3.83$, $P = 0.08$ for R2). One of the segregating backcrosses significantly deviated from expected ratios ($P < 0.0001$). This may be due to linkage of resistance genes, differences in gametic viability, or gene(s) with minor effects that affect virus movement in the plant. Further testing of F_3 families or other segregating progeny is needed to confirm the inheritance results.

The genes for resistance to CVMV in R1 and R2 appear to be allelic, since 36/36 F_1 and 77/80 F_2 plants from the cross R1xR2 were resistant. The genes for resistance to PVMV in R1 and R2 also appear to be allelic, since 35/35 F_1 and 298/305 F_2 plants from the cross R1xR2 were resistant. Therefore, the proposed genotype for Perennial HDV is *Prc1Prc1 prc2prc2, prp1prp1 prp2prp2*. The proposed genotype for PSP-11 is *Prc1Prc1 Prc2Prc2, prp1prp1 prp2prp2*. The genotype of the susceptible parent, Cheongryong, would be *prc1prc1 Prc2Prc2, Prp1Prp1 Prp2Prp2*. *Prc* and *Prp* are proposed gene symbols derived from "potyvirus resistance CVMV" and "potyvirus resistance PVMV", respectively.

Management of major insect pests and diseases

Screening for virus resistance

Many sources of resistance have been identified among cultivated and wild *Capsicum* species for PVY, TMV, and ToMV. Also several *C. annuum* lines have been found to have resistance to CVMV and CMV. However, some of these CMV and CVMV-resistant lines were found susceptible to local isolates in Malaysia and Thailand. Therefore, more lines were screened to identify additional and possibly different sources of resistance to CVMV and CMV, as well as resistance to PMMV, because so far PMMV resistance was only found in a few *C. chacoense* accessions. Some lines were also screened for resistance to watermelon silver mottle virus, which is reported to cause serious damage on tomatoes and possibly peppers in Asia.

Resistance screening was done by mechanical inoculation. Twenty-four plants per accession per virus were inoculated and kept in an insect-proof screenhouse for symptom observation and subsequent testing by ELISA (table 4). Two ELISA tests were conducted at 10 and 21 days after inoculation and ELISA-negative plants were transplanted to the field for exposure to natural infection. A last ELISA test was conducted shortly before harvest and seeds were collected from ELISA-negative plants. A confirmation screening is usually done on selfed seeds of resistant plants.

Of the 15 lines from India tested for all viruses, nine were immune to CVMV, while three had more than 50% CVMV-resistant individuals. Five lines had more than 50% PVY-resistant individuals. One line had more than 90% CMV-resistant individuals by both cotyledon and third leaf inoculation. PMMV resistance was not found.

Table 4. Reaction of selected pepper lines previously found resistant or moderately resistant to CMV

Line/Selection	% resistant plants			
	1st screening[a]	2nd screening[b]		3rd screening[c]
PBC 370-2	96 (c)[d]	92 (c)	100 (3)	93 (c, 3)
				100 (c, 3)
VC 41a-3-1	95 (3)	100 (c)	100 (3)	100 (c, 3)
				100 (c, 3)
PBC 549-3	85 (3)	100 (c)	100 (3)	92 (c, 3)
				100 (c, 3)
VC 223-1-4	83 (3)	87 (c)	83 (3)	92 (c, 3)
VC 16a-1-4	79 (3)	100 (c)	100 (3)	95 (c, 3)
				100 (c, 3)
PBC 521-2	78 (c)	96 (c)	100 (3)	100 (c, 3)
				96 (c, 3)
VC 16a-2-4	75 (c)	100 (c)	100 (3)	100 (c, 3)
				100 (c, 3)
VC 41a-3-1	69 (c)	88 (c)	100 (3)	100 (c, 3)
				100 (c, 3)
VC 16a-5-1	67 (c)	100 (c)	100 (3)	100 (c, 3)
				96 (c, 3)
VC 10a (S ck)	0 (c)	0 (c)	0 (3)	0 (c, 3)
Avg. (without S ck)	81	96	98	98

[a] First screening was done in 1992/93 by two inoculation methods. Rating was by ELISA, conducted 4 weeks after inoculation. Resistant plants were transplanted to the field and seed were collected from selfed resistant plants

[b] Second screening was in 1994, using seed of the resistant plants of the first screening. Two inoculation methods were used (cotyledon and third leaf). Rating was by two quantitative ELISA tests, conducted 2 and 4 weeks after inoculation. Resistant plants from the cotyledon inoculation were transplanted to the field. One more ELISA test was conducted before harvest

[c] Third screening was in 1995 using seed of selfed resistant plants of the second screening (cotyledon inoculation). Inoculation was on the cotyledon followed by another inoculation on the third leaf. Rating was by 3 ELISA tests, conducted at 25, 57, and 96 days after the first inoculation; all plants were negative in the second ELISA test and were transplanted to the field at 62 days after the first inoculation

[d] c = inoculated on the cotyledon; 3 = inoculated on the third leaf (of five-leaf stage plants decapitated above the fourth leaf)

Of the 276 lines mainly screened for CMV (at the cotyledon and third leaf), CVMV, and PMMV, three lines had more than 50% CVMV-resistant individuals and four lines had between 50 and 100% CMV-resistant individuals (when inoculated on the third leaf). PMMV resistance was not found.

Of the 44 PBC lines tested for all viruses, 5 were found with resistance to both TMV and ToMV, 14 with resistance to PVY, 3 with resistance to CVMV, and 3 with resistance to CMV (when inoculated on the third leaf). Three and five lines were identified with more than 70% CMV-resistant individuals when inoculated on the cotyledon and on the third leaf, respectively. Six and eight lines with more than 70% CVMV-resistant and PVY-resistant individuals, respectively, were also identified.

Cloning of the PMMV 54 K gene

The widespread planting of peppers with resistance to common strains of TMV and ToMV has given rise to resistance breaking tobamoviruses. These have been differentiated by breeders as pathotypes P1, P1.2, and P1.2.3, based upon their ability to overcome the TMV/ToMV resistance conferred by an allelic series of genes known as L1, L2, and L3, respectively.

Some of these new pathotypes particularly P1.2.3, also called pepper mild mottle virus, are responsible for significant economic losses in pepper crops worldwide. In this activity, transgenic expression of either intact replicase genes or derivatives including modifications or deletions of a few nucleotides was attempted to develop replicase-mediated resistance for PMMV. This type of resistance is known to be unaffected by inoculum dose and temperature. The gene encoding the 183 KDa protein has been implicated in the replication process of several viruses including tobamoviruses. Within this region is a 54-KDa noncoding gene. The first step in this activity is to clone this noncoding gene.

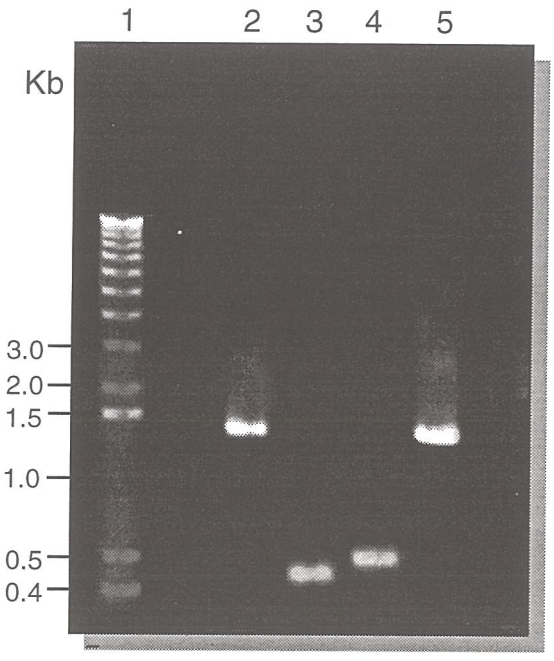
A pepper mild mottle virus isolated from a farmer's field in Taiwan was used for cloning the 54 K gene. The virus was purified from PMMV inoculated in *N. debneyi*.

RNA was precipitated from purified virus by sodium acetate and ethanol at -80°C/3 h. The RNA pellet was washed twice with 70% ethanol and resuspended in tris EDTA (TE) buffer. The RNA concentration was analyzed by 0.7% 0.5x TBE agarose gel electrophoresis.

Two primers, 54 K(-) 4895 and 54 K(+) 3492 annealing to the 54 K region were designed according to the sequence data reported for the Spanish PMMV. Primers were synthesized by the Protech Technology Enterprise Co., Taiwan. The oligo-nucleotide 54 K(-) 4895 (5'AAGGATCCTTACTCCAAAAAGC) complementary to nucleotides 4922 to 4895 from the 3'end of the Spanish PMMV sequence was used for priming the first strand synthesis.

Double stranded DNA (corresponding to the size of the 54 KDa protein gene) obtained by PCR was digested with *Xba*I and *Bam*HI and DNA fragments were cloned into pBluescript II KS (+). Four clones were obtained (fig. 1), but only two of the clones were 1.4 kb in size.

Partial sequence of the 1.4 kb clone was homologous with the corresponding parts of the published 54 K DNA sequence of the Spanish PMMV. Full length sequence analysis showed 100% identity with the 54 K sequence of the Spanish PMMV.



Lane 1: 1 Kb ladder marker
Lane 2: 1.4 Kb inserted fragment
Lane 3: 0.4 Kb inserted fragment
Lane 4: 0.5 Kb inserted fragment
Lane 5: 1.4 Kb inserted fragment

* Recombinant vectors 54K-1.4 a, 54K-0.4, 54K-0.5 and 54K-1.4 b were primed using 54 (+) 3492 and 54 (-) 4895 primers

Fig. 1. TBE electrophoresis of PCR-amplified recombinant vectors

Evaluation of *Capsicum* accessions for resistance to anthracnose and Phytophthora blight

Anthracnose (Colletotrichum capsici *and* C. gloeosporioides)

Twenty entries in INTHOPE #5 were evaluated for their anthracnose reactions (table 5). Percentage of fruit with anthracnose lesions ranged from 9.8 to 93.7% among the entries. Incidences of fruit infection in Tabasco L-167 (PBC 559) at 9.8% and Chinda 2 (PBC 743) at 30.9% were significantly ($P<0.01$) lower than all other entries.

Eighteen F_6 hot pepper lines were evaluated for their anthracnose reactions. Incidence of fruit infection ranged from 12.0 to 43.7% among the entries tested. Incidence of fruit infection averaged <20% for the eight CCA lines suggesting they possess some degree of resistance to anthracnose.

Development of anthracnose inoculation techniques to evaluate fruit reactions of pepper lines in the laboratory is in progress.

Phytophthora blight (Phytophthora capsici)

This study assessed the Phytophthora blight reactions of entries in INTHOPE #5 and among sweet pepper breeding populations and (2) evaluated *P. capsici* isolates for the occurrence of pathotypes.

Evaluation of Phytophthora blight reactions was done in the greenhouse following inoculation of individual plants with 5 ml of a zoospore suspension ($3x10^4$/ml; isolate Pc-17). Disease reactions of the INTHOPE entries were based on the percentage of plant survival and disease severity ratings, but the breeding population reactions were based only on percentage of plant survival. Isolates of *P. capsici* were evaluated for their virulence and differential behavior on a sweet pepper variety, Blue Star, and a hot pepper line, PBC 137, following inoculation of individual plants with 5 ml of a zoospore suspension ($3x10^4$/ml) from the various isolates. Individual plants were scored on a disease severity rating scale (0 = no symptoms and 4 = dead plant) and the mean values used to estimate the disease reaction for each treatment.

Twenty pepper entries in INTHOPE #5 were evaluated in the greenhouse for their reactions to Phytophthora blight. PBC 602 was highly resistant with 83% survival. Three lines expressed intermediate levels of resistance: Szechwan 8, Szechwan 921207, and PI 244670 with 54, 52, and 47% survival, respectively. The reactions of the other 16 lines ranged from 0 to 27% survival.

Table 5. Incidence of anthracnose-infected[a] pepper fruit among entries in the INTHOPE #5 field trial at AVRDC, summer 1995

Entry	Name/Origin	Fruit with symptoms (%)[b]		
		Harvest	Postharvest[c]	Total
PBC 636	Galkunda Miris 01146/Sri Lanka	92.9	0.8	93.7
PBC 450	Cayenne Cajun 1/USA	82.4	9.7	92.1
PBC 602	Szechwan type/Taiwan	81.0	8.9	89.9
PBC 583	Ruhunu Miris/Sri Lanka	73.3	15.2	88.5
PBC 717	Sheetal-51/India	83.0	4.0	87.0
PBC 715	Jwalla/India	80.7	5.6	86.3
PBC 619	PI 244670/Korea	79.1	6.2	85.3
VC 44a	PI 163201/India	77.0	3.0	80.0
PBC 142	Pant C-1/India	71.8	7.3	79.1
PBC 549	Lv. 2722/Indonesia	71.0	6.1	77.1
PBC 074	Szechwan 8/Taiwan	70.0	6.8	76.8
PBC 137	CNPH 703/India/Brazil	70.8	5.2	76.0
VC 19a	Serrano 1534/P.Smith USA	66.1	9.0	75.1
PBC 075	Szechwan 921207/Taiwan	66.7	7.8	74.5
PBC 065	Szechwan 921203/Taiwan	66.1	7.8	73.9
PBC 584	??/Thailand-KKU	52.1	9.0	61.1
PBC 711	Dedo de moca/Brazil	44.8	15.3	60.1
PBC 593	??/Thailand	44.3	7.6	51.9
PBC 743	Chinda 2/Thailand	13.7	17.2	30.9
PBC 559	Tabasco L-167/USA	1.4	8.4	9.8
LSD (P <0.01)		15.0	8.7	15.2

[a] Inoculated once with *Colletotrichum gloeosporioides* 2 weeks prior to the first harvest

[b] Mean of three harvests; four replications of 12 plants each

[c] Symptom development during 2 weeks postharvest storage at 25°C and 95±2% RH

Fifty-one sweet pepper BC_1F_2 families of about 200 plants each and six BC_1F_3 families of 50 to 100 plants each were screened for their Phytophthora blight reactions. Known sources of resistance in their backgrounds included CNPH 1149, HDA 248, and Adra. Plant survival among families ranged from 1 to 88%.

Fourteen stock cultures of *P. capsici* were tested for their virulence to pepper lines Blue Star and PBC 137. The percentage of Blue Star and PBC 137 plants killed by the various isolates ranged from 0 to 94% and 0 to 73%, respectively. From host plants, four isolates were reisolated and from them single spore colonies were derived. The single zoospore isolates varied greatly in their virulence to Blue Star and PBC 137. Furthermore, some isolates were pathogenic only to Blue Star and others to both Blue Star and PBC 137, suggesting the occurrence of pathotypes among isolates of *P. capsici*.

Application of DNA probes and primers for detection of *Xanthomonas campestris* pv. *vesicatoria*

Based on DNA homology, *Xanthomonas campestris* pv. *vesicatoria* (Xcv) can be divided into three groups, i.e., groups A, B, and C. Primers derived from the sequence of *hrp* cluster of Xcv and PCR program of each primer pair specific to groups A, B, and C have been developed through a collaborative project with Dr. R.E. Stall of the University of Florida, USA.

Primers RST 9 and RST 10 can amplify a 355 bp DNA fragment specific for the group A strains which are predominant in the world. Protocols for PCR and seed detection were developed for detecting Xcv from tomato and pepper seeds (fig. 2).

Both primers were used to detect Xcv from seeds using three steps: (a) removing bacteria from seeds; (b) partially purifying bacteria from seed extract; and (c) amplifying specific DNA fragment by PCR.

Several seed lots of tomato and pepper were prepared from fruits showing bacterial spot symptoms in the field. The efficiency and sensitivity of PCR detection method and direct plating on semiselective media for detecting Xcv were compared.

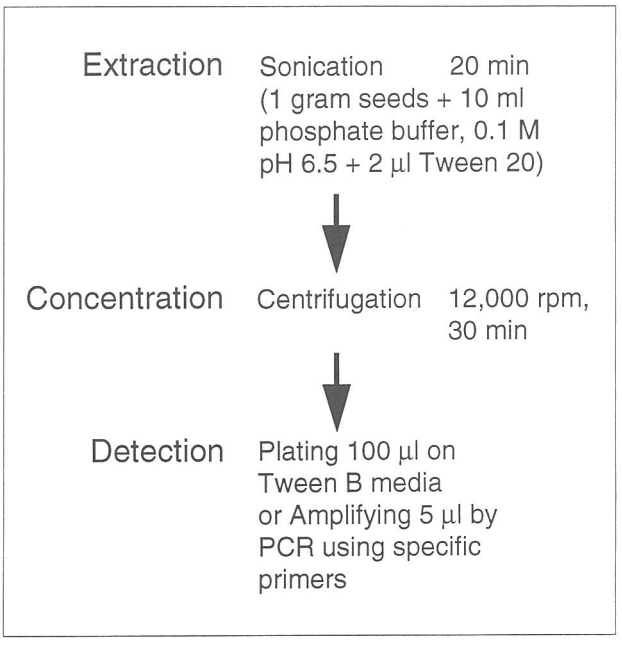


Fig. 2. Flow chart showing procedures used in detecting *Xanthomonas campestris* pv. *vesicatoria* from tomato and pepper seeds

Pepper seed lots contaminated with Xcv in different degrees were used (fig. 3). Seeds were sown individually in speeding trays and kept under favorable conditions for bacterial spot development. Seedlings prepared from the contaminated seed lots were also transplanted to the field. Incidence of bacterial spot was observed.

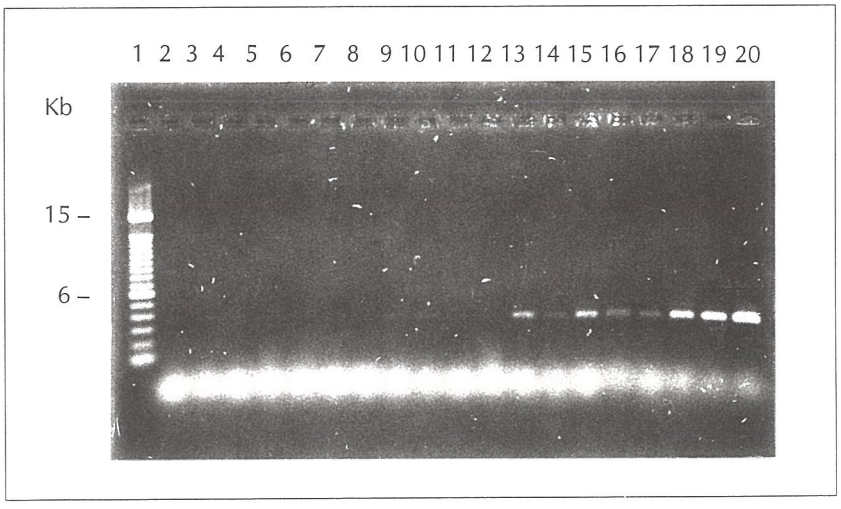


Fig. 3. PCR products from pepper seeds (artificially coated by different concentrations of *X. campestris* pv. *vesicatoria* suspension) of Early Calwonder by RST 9 and RST 10 primers

The percentage of positive detection of Xcv from 27 tomato and pepper seed lots from diseased fruits was 45% by PCR method and 0% by plating on Tween B media. Results suggest that the PCR method is more sensitive, specific, and time saving than the plating method. Symptoms developed on cotyledons when sowing the PCR-positive seed lots in vermiculite and kept at 28°C with overhead sprinkling for 30 sec every 30 min. However, when seedlings prepared from PCR-positive seed lots were transplanted into the field on 9 June, plants encountered several heavy rains but no symptoms were observed until 16 August.

Development of molecular markers for CVMV resistance

This study aims to develop sequence-characterized amplified region (SCAR) markers for CVMV resistance.

Two hundred primers, including 100 simple sequence repeat-targeted primers and five Operon primer sets, were run for RAPD across two resistant parents (VC 16a and VC 160) and one susceptible parent (PBC 186). Primers which produced polymorphic bands between resistant and susceptible parents were used to screen across 80 F_2 individuals. Segregation of these polymorphic bands in the F_2 generation and CVMV scores were analyzed for correlation. Markers which showed high correlation with resistance scorings were selected as potential candidates for developing SCAR markers.

The linked RAPD products were purified and reamplified using the same primer that identified the RAPD polymorphism. After reamplification, products were resolved by gel electrophoresis, excised from the gel, purified, and then blunt-end ligated into the pBluescript II KS vector (Strategene) that has been previously linearized with *Eco*RV.

In this study, 15 RAPD bands for CVMV resistance derived from eight random primers were analyzed for their correlation with CVMV scores in the F_2 segregating population. Five RAPDs showed negative correlation with disease symptoms or ELISA reactions (table 6).

Table 6. Correlation of five RAPDs with CVMV symptom development and ELISA test results

Primer	RAPD band (bp)	Resistant parent	Symptom correlated with RAPD bands (< 5%)
UBC813	2000	VC 16a / VC 160	N[a], R, Mos, E / N, R, Mos, Mot, E
OPU12	480	VC 16a	Mot, E
OPV01	750	VC 16a	N, R, Mos, E
OPV02	1000	VC 160	N, R, Mos, Mot, E
OPV15	1050	VC 16a	Mot

[a] N = necrosis, R = ring, Mos = mosaic, Mot = mottle, E = ELISA

Five RAPD products listed in table 6 were isolated and cloned. The identity of the cloned RAPD products was confirmed by hybridization of the cloned fragments to Southern blot of F_2 individuals that segregated for the progenitor RAPD marker (fig. 4 and 5). Three clones, i.e., UBC813 (2.0 kb), OPU12 (480 bp), and OPV01 (750 bp), were confirmed to be derived from the targeted RAPD band and showed strong signal in the F_2 individuals that carried RAPD products. OPV15 (1050 bp), unlike the RAPD profile, showed a signal in all individuals. However, OPV02 showed a weak signal.

Genetic transformation for CMV resistance

This study aims to develop CMV-resistant tomatoes and peppers using *Agrobacterium*-mediated transformation with truncated CMV RNA-2 replicase and CMV coat protein genes.

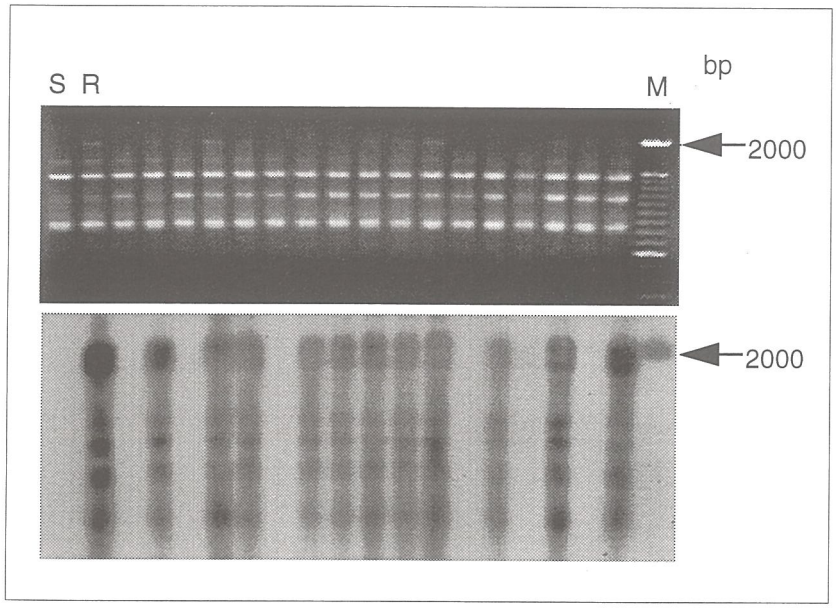


Fig. 4. Identity confirmation in a Southern blot of F_2 [(VC 16a (resistant) x PBC 186 (susceptible)] individuals
Top: RAPD products derived from genomic DNA of F_2 individuals with primer, UBC81; Bottom: Hybridization of the cloned product of UBC813, 2.0 kb, to a Southern blot of the above RAPD profile

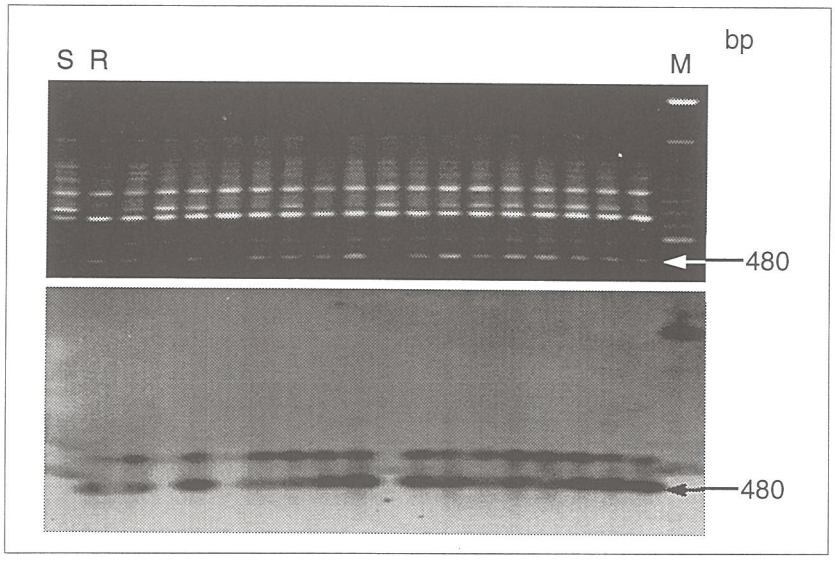


Fig. 5. Identity confirmation of the cloned UBC813 2.0 kb product in a Southern blot of F_2 [VC 16a (resistant) x PBC 186 (susceptible)] individuals
Top: RAPD products derived from genomic DNA of F_2 individuals with primer, OPU12; Bottom: Hybridization of the cloned product of OPU12, 480 bp, to a Southern blot of the above RAPD profile

Cotyledon explants of tomato (L 4783), sweet pepper (C 00157D), and hot pepper (Szechwan) were used for cocultivation with *Agrobacterium tumefaciens* LBA4404 harboring the truncated CMV RNA-2 replicase gene or CMV coat protein gene. The regenerated plants derived from the shoots were selected in the medium containing kanamycin.

The transformed plants were assayed by dot-blot analysis and tested against CMV-P522 (isolated from the diseased pepper plant). Four fully expanded leaves of R_1 seedlings derived from the self-pollinated transformed plants were also tested against the virus.

Nine transformed pepper plants (R_0), including three hot peppers (HP1, HP2, and HP5) and six sweet peppers (SP1, SP2, SP3, SP4, SP6, and SP7), were generated and established in the greenhouse. Dot-blot analysis confirmed that these plants contained the introduced truncated CMV RNA-2 replicase gene. When transformed plants were inoculated with CMV-P522 and tested with ELISA, results showed that HP1 and HP2 were resistant to the virus without any symptom after three virus inoculations (fig. 6). However, HP5, SP1, SP2, SP3, and SP4 developed symptoms 4-12 days later than the control, after the second virus inoculation.

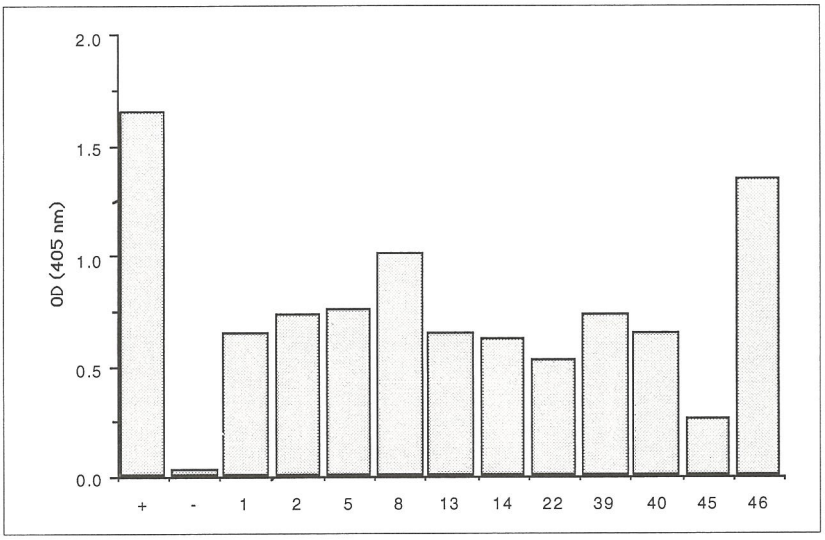


Fig. 6. OD (at 405 nm) values of ELISA tested at 18 days after CMV-P522 inoculation on R_1 HP2 plants
+ = total leaf extract of the diseased plant; - = total leaf extract of the healthy plant; numerical numbers = plant no.

When R_1 plants were inoculated with CMV-P522, results showed that only one of 47 R_1 plants derived from HP2 did not develop any symptom 15 days after the virus inoculation. With ELISA, most of these R_1 plants tended to have lower virus titers than the diseased control plant. Unexpected symptom development on most of the HP2 R_1 plants may be likely due to the higher concentrations of the virus used in the inoculation or the instability of the introduced gene.

In the tomato experiment, 12 plants were regenerated from cotyledonary explants of L 4783 cocultivated with *Agrobacterium tumefaciens* LBA4404 harboring the CMV-T coat protein gene. These plants are still being established in the soil for further virus testing.

Strategic and/or supporting studies

AVNET Support

Determination of presence of minor viruses

The presence of CVMV, CMV, PVY, and the tobamoviruses ToMV, TMV, PMMV (in order of importance on peppers in Asian countries) has been established in previous surveys. However, not much information is available for other viruses such as tobacco etch virus, pepper mottle virus, tospoviruses and leaf curl virus, which are serious on peppers in the Western Hemisphere. Therefore, as part of AVNET an attempt was made to survey peppers for these viruses, using ELISA and polyclonal antibodies for the two potyviruses and the tospovirus, and nucleic acid hybridization tests for the detection of leaf curl viruses.

Each AVNET member country was asked to prepare leaf squashes of pepper plants showing symptoms typical of virus infection on nitrocellulose membranes for testing for TEV, PeMV, and WSMV, which are considered of minor importance in Asia.

In addition, samples showing symptoms typical of geminivirus infection such as yellowing, leaf curling, and stunting were squashed on nylon membranes. These were sent to AVRDC for testing. The following nucleic acid probes were used: the M3 probe, a narrow range probe known to react with the monopartite Taiwan, Indian, and Egyptian leaf curl virus and the TYLCV-Thai probe, a wide range probe prepared against the bipartite Thailand tomato yellow leaf curl virus, which reacts with a wide variety of geminiviruses in various crops.

TEV was detected in a small percentage (<7%) of samples from Thailand and Indonesia, whereas PeMV was detected in <5% of the samples from Thailand and the Philippines. However, the presence of these viruses has not yet been confirmed by the virus isolation and characterization. A geminivirus causing leaf curling was found in 22% of samples from Thailand and 6% of the samples from the Philippines. This virus should be considered of major importance.

Detection of strains of chili veinal mottle virus and cucumber mosaic virus

Knowledge of strains of a virus is important for resistance breeding. So far, no information is available on pepper strains of CVMV and CMV. Therefore AVNET cooperators were asked to collect isolates of the two viruses during their surveys and test these on selected differential hosts.

Several lines found resistant to either CVMV or CMV, or to both viruses at AVRDC or at one of the four AVNET member countries were selected for seed multiplication and testing with different local isolates. Seed multiplication was done by Dr. Chew Boon Hock of MARDI, Malaysia.

Mechanical inoculations were done with the local isolates of CMV or CVMV. Twenty plants or more were inoculated and kept in an insect-proof screenhouse. The reactions were assessed either visually or by ELISA 40 days after the inoculation.

Based on the reactions on 12 selected lines 7 CVMV strains could be identified in Malaysia and 5 in Thailand. Two lines (VC 160a and VC 16a) were identified with high levels of resistance to all CVMV isolates of the five countries. Although several lines were resistant to all CVMV strains in Malaysia, only one line, Toom, was found resistant to all five strains in Thailand.

Five CMV strains exist in Thailand and Malaysia which seem to be different. VC 17a was resistant to five CMV strains in Malaysia but susceptible to four strains in Thailand. Four lines were identified with high levels of resistance to all five strains in Thailand.

Seed treatments for the elimination of seed-borne PMMV

Since networking involves the movement of pepper seed across borders, the absence of seedborne viruses, particularly PMMV, needs to be ensured. Therefore, seed treatments were tried for the elimination of this virus from contaminated seed.

Four seed treatments, HCl (4-h soak in 1:19 HCl, followed by 4 h rinse in running tapwater; heat (76°C for 3 days); Na_3PO_4 (2-h soak in 10% Na_3PO_4, followed by 45-min rinse in running tapwater); and NaOH (10-min soak in 2% NaOH, followed by 1-h rinse in running tapwater) were tested on seed collected from mechanically inoculated plants of two cultivars each of hot pepper (Passion, Szechwan) and sweet pepper (Yolo Wonder VC10a, Blue Star). Seeds were treated in batches of four, each batch containing 30 seeds. After the treatments, each batch was tested for PMMV contamination of the seedcoat and embryo. To check for virus on the seedcoat the seed batches were shaken for 2 days in 3 ml extraction buffer which was then directly used for the ELISA and infectivity tests on *N. glutinosa*. To test for virus inside the embryo, the seed batches were rinsed for 1 h in running tapwater, and after the removal of water ground in 3-ml sodium phosphate buffer (pH 7.0). The resulting seed extract was used for ELISA and infectivity tests. A germination test on moist filter paper was conducted on separate batches which had undergone the same treatments.

Among four seed treatments the NaOH treatment appeared most promising.

TOMATO IMPROVEMENT

Tomato (*Lycopersicon esculentum*) is one of the most economically important vegetables in Asia, with approximately 25 million metric tons produced yearly on about 1 million hectares. Tomato production in the tropics tends to be seasonal. Peak production occurs in the dry season when slightly lower temperatures and moderate rainfall favor tomato growth in the lowlands (<200 m asl). Most tomato production shifts to the highlands (>700 m asl) in the summer after hot, wet conditions prevail in the lowlands. Dwindling tomato supply to markets in the summer results in drastic price increases. Expanded lowland summer tomato production may help reduce summer tomato prices and alleviate pressure to open highland areas to vegetables.

The goal of the tomato improvement project is to develop tomato germplasm adapted to summer production in the lowland tropics. Consequently, heat tolerance, resistances to bacterial wilt, tomato yellow leaf curl virus, tomato mosaic virus, and tomato fruitworm, as well as good horticultural characteristics are important selection criteria. The project develops improved varieties of fresh market, processing, and cherry types. Processing types are exclusively of determinate growth habit while both determinate and indeterminate fresh market and cherry types are bred. Most research is conducted on the fresh market and processing types. Major emphasis is given to breeding of improved inbred lines for all market classes, although fresh market and cherry hybrids have also been developed.

Genetic resources enhancement and varietal development

Genetic resources activities

Forty-two accessions were acquired in 1995 bringing the total number of accessions in the tomato collection to 6906 (table 1). Four accessions from India were sent in exchange and 10 came from the Philippines. Eighteen of the new accessions are known to carry resistances to late blight and wilt.

A total of 58 accessions were regenerated: 49 accessions from Peru and 9 accessions from Ecuador. Characterization was done following the tomato descriptor.

Characterization of seed protein by SDS-PAGE was done on 180 accessions. A total of 29 bands and 12 profiles were noted. Of the 29 bands 16 were constantly observed in all accessions. Some bands and profiles were observed only in certain species: bands 3, 4, and 19 in *L. chilense*, 5 in *L. pimpinellifolium*, and 9 and 10 in *L. esculentum*; profiles 5 and 10 in *L. hirsutum*, 6 in *L. peruvianum*, 8 and 11 in *L. chilense*, 9 in *L. pimpinellifolium*, and 12 in *L. esculentum*.

The center sent 4779 germplasm samples to 66 countries and territories (table 2).

Registration, passport, distribution, and seed inventory databases are regularly updated.

Table 1. AVRDC tomato germplasm collection, 1995

Species	No. of accessions
L. cheesmanii	26
L. chemielewskii	10
L. chilense	30
L. esculentum	5,025
L. glandulosum	11
L. hirsutum	65
L. parviflorum	12
L. peruvianum	124
L. pennelii	57
L. pimpinellifolium	306
L. sp.	1,240
Total	6,906

Table 2. Distribution of tomato germplasm in 1995

Country	No. of samples
France	149
India	579
Japan	125
Malawi	165
Nepal	121
Philippines	416
Tanzania	193
Thailand	1,035
USA	143
Zimbabwe	319
Others[a]	1664
Total	4,779

[a] Australia, Bangladesh, Barbados, Brazil, Cambodia, Cayman Is., China, Costa Rica, Denmark, Egypt, England, Ethiopia, Fiji Is., Ghana, Grenada, Greece, Guyana, Indonesia, Israel, Ivory Coast, Jamaica, Kiribati, Laos, Liberia, Malaysia, Marshall Is., Mauritius, Netherlands, Nicaragua, Nigeria, Niue Is., Oman, Pakistan, Panama, Puerto Rico, Samoa, Saudi Arabia, Senegal, Sierra Leone, Singapore, Solomon Is., Republic of South Africa, Spain, Sri Lanka, St. Kitts, St. Vincent and Grenadine, Suriname, Swaziland, Taiwan, Togo, Tonga, Tuvalu, Uganda, Vanuatu, Vietnam, Zaire

Genetic improvement of fresh market tomato

The fresh market (FM) tomato is the most important market class in tropical countries and it is eaten raw or cooked. Important characters for a tropically-adapted FM tomato variety include high temperature fruit-set and good yield, fruit firmness, good taste, and bacterial wilt (BW) resistance.

This activity aims to develop horticulturally acceptable fresh market determinate tomato lines and indeterminate hybrids suitable for summer production in the lowland tropics. Towards this end, AVRDC screens varieties to identify lines adapted to tropical conditions.

Preliminary yield trials were arranged in RCBD with two replications. Plots consisted of two 4.8-m-long rows on raised beds; between and within row spacings were 60 cm and 40 cm, respectively. Beds were spaced 1.5 m apart and covered with gray plastic; a layer of rice straw was placed over the plastic. Plants were pruned to two branches. Fruit were harvested from the inner 4 m of each row and yield per plot was determined from a 6-m^2 area. Prior to bed construction, 2000 kg/ha organic compost, 5 kg/ha borax, and 40-80-60 kg/ha of N-P_2O_5-K_2O were broadcast in the field. Plots of April-July PYTs were sidedressed at 10 days (20-0-30 N-P-K), 21 days (60-20-60), 42 days (60-20-30 N-P-K), and 63 days (60-20-30 N-P-K) after transplanting. The November-April PYT received these fertilizer amounts plus additional sidedressings of 60-20-30 N-P-K at 84 and 105 days after transplanting.

PYT I and II included 14 determinate and indeterminate inbred entries, respectively. PYT III (25 entries) and IV (16 entries) included indeterminate F_1 hybrids. PYT I-IV were sown on 14 March and transplanted 13 April. Fruit were harvested on 16 June -12 July. Mean max./min. temperatures during the

trial were 31.9/23.6°C. Most fruit-set occurred in May when mean max./min. temperatures were 30.4/22.7°C. Total rainfall during PYT I-IV was 464.5 mm.

Evaluations of PYT I-VI entries for bacterial wilt reaction were conducted in a separate plastic house experiment. Plants of each entry were grown individually in plastic pots containing about 120 g of a 1 sand: 3 soil: 1 rice husk: 1 compost mixture. Experimental units consisting of 24 plants and entries were replicated twice and arranged in RCBD. About 25 days after sowing (5-true leaf stage), 20 ml of 10^8 cells/ml inoculum of *Pseudomonas solanacearum* strain PSS4 was poured into each pot. Plants were observed weekly for wilting until 4 weeks after inoculation.

Horticultural characters of superior entries and checks for PYT I-IV are presented in table 3. Mean marketable yields (MY) were high in summer PYT I-IV, ranging from 37.9 to 52.1 t/ha. Tropical storms and subsequent flooding did not occur during the trials so excessive moisture was not a yield constraint. Most entries were infected by whitefly-vectored geminivirus although infection resulted mostly after fruit-set. Mean fruit color values were well below 2.0 because high temperatures during fruit ripening impeded normal lycopene formation. Mean BW survival of entries in PYT I-IV trials were moderately low, ranging from 21.3 to 36.4%. However, some entries showed BW survival ≥50%. Several determinate entries including CLN 1464-111-30-2-0-0 and CLN 1462-220-110-10-0-0-3 in PYT I achieved yields comparable to the heat-tolerant check, CL 5915-93D4-1-0-3, and mean fruit sizes were almost three times greater than the check. Marketable yields of the best indeterminate lines in PYT II were significantly less than fresh market hybrid check FMTT 22; solids content of FMTT 22 was superior to that of most lines. Marketable yields of the indeterminate hybrids in PYT III and IV were high and similar to the heat-tolerant hybrid FMTT 22 but five times greater than the heat-sensitive hybrid, KY 301. Experimental hybrids FMTT 586, 608, and 599 will be evaluated in future tests.

Genetic improvement of cherry tomato

Cherry tomato (*L. esculentum* var. *cerasiforme*) is a relatively new or unknown crop in many tropical countries although it has become very popular in Japan, Korea, and Taiwan. In Taiwan and Japan, it is regarded more as a fruit rather than a vegetable. High fruit solids content and good taste, high temperature fruit-set, and resistance to BW are desirable characteristics in a cherry tomato for the tropics.

Three preliminary yield trials were established at AVRDC during 1994-1995. PYT I was sown on 13 September 1994, transplanted 12 October, and harvested 20 December 1994 - 17 January 1995. PYT II was sown on 20 October 1994, transplanted 16 November, and harvested on 24 January - 31 March 1995. PYT III was sown 15 March, transplanted 13 April, and harvested 16 June - 10 July. Plot sizes, spacing, and fertilizer applications were identical to those described previously for fresh market tomato PYT.

Evaluation of PYT III entries for bacterial wilt reaction was conducted in a separate plastic house experiment. Plants of each entry were grown individually in plastic pots containing about 120 g (dry weight basis) of a 1 sand: 3 soil: 1 rice husk: 1 compost mixture. Experimental units consisting of 24 plants and entries were replicated twice and arranged in RCBD. About 25 days after sowing (5-true leaf stage), 20 ml of 10^8 cells/ml inoculum of *P. solanacearum* strain PSS4 was poured into each pot. Plants were observed weekly for wilting until 4 weeks after inoculation.

In PYT I, hybrid check CHT 264 yielded 106.4 t/ha (table 4), significantly greater than the other entries and two times larger than the trial mean for marketable yield (50.8 t/ha). Three lines (CLN 1560-4-3-16-3-10, CLN 1560-4-3-16-3-6, and CLN 1561-128-37-11-11-9G) yielded significantly more than the commercial hybrid 'Santa'. The solids content of Santa

Table 3. Horticultural and quality characteristics of selected entries from fresh market PYT I-VI, AVRDC, 1994-1995

PYT	Entry	MY (t/ha)	Fruit size (g)	Brix°	Acid (%)	Color (a/b)	BW survival (%)
I	CLN 1464-111-30-2-0-0	50.5a	110a	4.20a	0.39b	0.76b	43.8a
	CLN 1466-65-40-15-0-12	43.6a	120a	4.40a	0.39b	1.00ab	43.7a
	CLN 1463-245-14-0-0-0	43.4a	112a	4.65a	0.52a	1.32a	57.6a
	CL 5915-93D4-1-0-3 (ck)	50.9a	39b	4.30a	0.43b	1.23a	27.1a
	Mean of all entries	40.5	102	4.45	0.38	1.12	28.4a
	CV (%)	11.7	6.6	5.7	8.5	14.1	68.3
II	CLN 1466-65-40-25-8-1	55.9b	141a	4.20c	0.37a	0.99a	60.5a
	CLN 1463-160-40-60-0-0	44.2b	127a	4.40bc	0.38a	0.98a	47.9a
	CLN 1466-65-40-25-8-12	43.3b	147a	4.50abc	0.48a	0.97a	47.9a
	CLN 1460-20-2-1-0-1	42.4b	132a	5.20ab	0.43a	1.21a	40.2a
	FMTT 22 (hybrid ck)	78.1a	135a	5.40a	0.38a	1.30a	12.5a
	Mean of all entries	40.5	103	4.70	0.31	1.17	35.6
	CV (%)	14.2	6.6	8.1	13.5	2.0	61.5
III	FMTT 586	67.4a	167a	4.05b	0.45ab	1.43a	52.1ab
	FMTT 608	63.4a	127bc	4.70a	0.39ab	1.34a	31.3bc
	FMTT 571	62.8a	149ab	4.60ab	0.37b	1.50a	29.2bc
	FMTT 584	62.5a	153a	4.50ab	0.46ab	1.47a	80.9a
	FMTT 22 (ck)	56.3a	122c	5.05a	0.48a	1.23a	15.0c
	Mean of all entries	52.1	136	4.69	0.43	1.44	36.4
	CV (%)	22.4	6.2	4.8	9.6	11.1	49.9
IV	FMTT 599	60.6a	127a	4.90a	0.49a	1.47a	22.9ab
	FMTT 593	46.0a	125a	4.75a	0.47a	1.38ab	37.5a
	FMTT 552	42.1a	114a	5.15a	0.52a	1.43a	22.9ab
	FMTT 591	40.4a	137a	4.75a	0.51a	1.06b	12.5b
	FMTT 22 (ck)	48.5b	113a	4.75a	0.47a	1.48a	14.6b
	Mean of all entries	37.9	124	5.00	0.51	1.35	21.3
	CV (%)	22.9	11.4	4.4	6.8	10.7	39.7
V	FMTT 602	163.5a	140b	4.65a	0.40a	1.93a	10.4a
	FMTT 591	150.3a	178a	4.70a	0.44a	1.88a	12.5a
	FMTT 599	149.3a	140b	4.65a	0.43a	1.94a	22.9a
	FMTT 556	129.2b	145b	4.70a	0.46a	1.93a	10.8a
	FMTT 22 (ck)	151.9a	141b	4.95a	0.47a	1.94a	14.6a
	Mean of all entries	140.7	149	4.73	0.48	1.96	21.3
	CV (%)	5.2	3.9	3.2	39.1	2.9	39.7
VI	FMTT 612	172.0a	156b	3.90b	0.37a	1.84b	15.2b
	FMTT 618	170.0a	133c	4.40ab	0.38a	1.94ab	46.0a
	FMTT 583	160.0a	179ab	4.40ab	0.37a	2.13a	81.3a
	FMTT 586	152.0a	175ab	4.40ab	0.39a	1.89ab	52.1ab
	FMTT 22 (ck)	168.0a	133c	4.90a	0.46a	1.90ab	15.0b
	Mean of all entries	143.0	156	4.50	0.40a	1.98	36.4
	CV (%)	13.2	4.5	4.6	12.5	4.1	49.9

Means within columns within PYTs followed by the same letter are not significantly different at the 5% level according to DMRT

Table 4. Horticultural and quality characteristics of selected entries from cherry tomato PYT I-III, AVRDC, 1994-1995

PYT	Entry	MY (t/ha)	Fruit size (g)	Brix°	Acid (%)	Color (a/b)	BW survival (%)
I	CLN 1560-4-3-16-3-10	60.0b	12.0a	6.45b	0.35e	2.00a	-[a]
	CLN 1560-4-3-16-3-6	54.7c	10.0b	7.10b	0.44cd	1.97a	
	CLN 1561-128-37-11-11-9G	45.0d	12.0a	6.70b	0.41de	1.82bc	
	CLN 1555-105-6-6-3-9	31.6e	12.0a	7.25b	0.47bc	1.65c	
	CH 264 (ck)	106.4a	10.0b	6.95b	0.51ab	1.86abc	
	Santa (ck)	37.7e	9.0c	8.35a	0.52a	1.55d	
	Mean of all entries	50.8	11.0	6.99	0.41	1.92	
	CV (%)	10.6	3.0	3.0	5.0	3.7	
II	SN-60-7-0-12	48.9b	8.9ab	6.90ab	0.73a	1.42a	-[a]
	SN-60-7-0-34	47.9bc	10.8a	7.10a	0.70ab	1.18a	
	SN-60-7-0-24	43.4cd	9.1ab	7.00a	0.73a	1.26a	
	SN-60-7-0-2	38.4d	8.7b	7.20a	0.70ab	1.45a	
	CH 154 (ck)	56.8a	8.7b	6.30b	0.64b	1.47a	
	Santa (ck)	25.5e	12.2a	6.70ab	0.69ab	1.63a	
	Mean of all entries	42.5	9.4	6.84	0.71	1.42	
	CV (%)	3.8	5.9	0.5	4.7	13.9	
III	CLN 1560-4-20-6-3-4	34.0a	12.0b	5.10b	0.36b	1.33a	6.3b
	CLN 1555-105-6-6-11-10	16.5b	18.0a	6.50a	0.46a	1.11a	37.5a
	CLN 1555-4-105-6-6-11-9	14.2b	15.0ab	6.00a	0.52a	1.17a	4.2b
	CLN 1555-105-6-6-3-7	11.9b	13.0b	5.60ab	0.53a	1.43a	23.0a
	CH 154 (ck)	13.9b	7.0c	5.10b	0.41b	1.26a	8.6ab
	Mean of all entries	9.3	10.0	6.10	0.50	0.98	18.5
	CV (%)	30.6	11.4	6.90	8.0	20.1	54.4

Means within columns within PYTs followed by the same letter are not significantly different at the 5% level according to DMRT

[a] Entries in PYT II and III were not evaluated for bacterial wilt reaction

(8.35) was significantly greater than other entries although the trial mean for brix was high (6.99). Most entries showed no fruit cracking and developed good color.

Nine entries in PYT II significantly outyielded Santa and produced a solids content equal to that of Santa. However, check CH 154 yielded significantly more than the other entries. Trial means for marketable yield and brix were 42.5 t/ha and 6.840, respectively. Mean max./min. temperatures during the trial (transplanting-final harvest) were 25.7/15.9°C.

CLN 1560-4-20-6-3-4 was the notable entry in PYT III, significantly outyielding the other entries by two to three times. The trial mean for marketable yield was only 9.3 t/ha. Low yields resulted from poor fruit-set from high temperatures during the trial (mean max./min. temperatures = 30.4/22.7°C). Most entries produced brix >6.0 but showed poor color development and some cracking. BW reactions of entries ranged from 4.2 to 37.5% survival.

Genetic improvement of processing tomato

High fruit solids content (brix°), low fruit pH, deep-red color, and firmness are important characteristics of a good processing tomato (PT) variety. Concentrated fruit-set, a compact vine, and a jointless pedicel facilitate machine harvest. In many tropical countries, PT varieties are commonly sold in the fresh market in addition to use in processing.

Research on PT focuses on developing tropically-adapted, firm fruited tomato inbreds with good processing qualities.

One preliminary yield trial was conducted during 1994-95. The PYT included 27 entries and was arranged in RCBD with two replications. Plots consisted of two, 4.8-m-long rows on a raised bed; between and within row spacings were 60 cm and 40 cm, respectively. Beds were 1.5 m apart and covered with gray plastic. Plants were staked and pruned. Fruit was harvested from the inner 4 m of each row and yield per plot determined from a 6-m^2 area. Prior to bed construction, 2000 kg/ha organic compost, 5 kg/ha borax, and 40-80-60 kg/ha of N-P_2O_5-K_2O were broadcast in the field. A sidedressing of 20-0-30 kg/ha N-P_2O_5-K_2O was applied 10 days after transplanting, and further sidedressings of 60-20-60 kg/ha N-P_2O_5-K_2O were applied 21, 42, and 63 days after transplanting. Mean max./min. temperatures during the trial were 31.8/23.8°C. Total rainfall during the trial was 464.5 mm.

Most entries in the trial lacked significant levels of heat tolerance and consequently the trial mean for marketable yield was only 9.0 t/ha (table 5). Three entries (PT 4664BC_1F_3-3-0-1, CLN 1355-23TC_1F_5-1, and PT 4664BC_1F_3-1-0-8) produced marketable yields not significantly different from the heat-tolerant check, CL 5915-93D4-1-0-3. Fruit sizes of the three entries were about three times larger than CL 5915-93D4-1-0-3. Generally, BW resistance of entries (evaluated in a separate greenhouse trial) was low although PT 4664BC_1F_3-3-0-1 showed moderate resistance.

Seasonal variation of tomato marketable fruit yields in the Philippines and Thailand

Although AVRDC and its national partners in several Southeast Asian countries focus on development of varieties adapted to lowland summer conditions, it would be advantageous if "summer" tomato varieties also performed relatively well in the dry season. The objectives of this study were to determine genotype rank correlations between seasons for marketable yield, and to estimate the heritability of marketable yield.

Table 5. Horticultural and quality characteristics of selected processing tomato lines and checks in the PYT, AVRDC, April-July, 1995

	MY (t/ha)	Fruit size (g)	Fruit-set (%)	BW survival (%)	Pedicel type[b]
PT 4664BC_1F_3-3-0-1	20.6a	102b	44a	45.8a	J
CLN 1355-23TC_1F_5-1	17.4a	147a	34a	-[a]	J
PT 4664BC_1F_3-1-0-8	16.0a	95b	34a	35.4a	N
PT 4671BC_1F_3-18-0-1	11.8b	104b	38a	30.4a	N
CL 5915-93D4-1-0-3 (ck)	22.7a	36c	42a	-[a]	N
Mean of all entries	9.0	81	29	19.9	–
CV (%)	43.1	20.2	29.6	110.6	–

Means within columns followed by the same letter are not significantly different at the 5% level according to DMRT

[a] entry not tested for bacterial wilt reaction

[b] N = normal, J = jointless

Twenty-two determinate tomato inbreds representing varieties grown in lowland and mid-elevation areas of Southeast Asia were grown during one summer and one dry season each at Los Baños, the Philippines, and Kamphaengsaen, Thailand. Entries in each trial were replicated three times and blocks were arranged in RCBD. Marketable yield was recorded for each plot.

Analyses of variance were performed for each location-season, and over locations within seasons. Because of error variance heterogeneity between dry and summer trials, a combined analysis of variance over seasons and locations was not possible. Environmental variance, genotype x location variance, and genetic variance were estimated by s^2/rl, s^2gl/l, and s^2g, respectively where r = replication number and l = number of locations. Broad-sense heritability for marketable yield on an entry mean basis was estimated by genetic variance/(genetic variance + genotype x location variance + environmental variance).

The analyses of variance over locations within seasons revealed significant mean squares for genotypes and the genotype x location interaction in both seasons (table 6). The mean dry season marketable yield (table 7) over locations (20.1 t/ha) was about three times greater than the mean summer MY over locations (6.8 t/ha). Mean dry season MY over locations ranged from 10.5 to 34.8 t/ha, and mean summer MY ranged from 1.0 to 16.6 t/ha. Many entries yielded poorly in the summer trials, probably due to low fruit-set caused by high temperatures.

Broad-sense heritabilities determined on an entry mean basis were 0.56 and 0.70 respectively, for dry and summer seasons. This suggests that selection for marketable yield in the summer would be more effective than in the dry season. The Spearman rank correlation of entries between seasons was 0.63** indicating that the relative performance of entries was consistent over seasons. Development of tomato varieties suitable for the dry season and summer tomato production should be possible.

Several entries, notably MT 1, Mapula, and CL 5915-93D4-1-0-3, performed relatively well in both seasons, although they are small-fruited. 'Marikit', the highest yielding entry over locations in the dry season ranked among the lowest yielding entries in the summer trials.

Table 6. Mean squares and contrasts from the ANOVA of marketable yield measured on 22 tomato determinate lines grown in summer and dry seasons in the Philippines and Thailand

Source	df	Dry season MS	Summer MS
Location (L)	1	4368.9	183.4
Rep (L)	4	614.0	65.0
Genotypes (G)	21	281.4*	142.4**
G x L	21	122.8**	42.4**
Error	84	56.3	12.2

* significant at 5% level
**significant at 1% level

Tomato fruitworm host-plant resistance

Screening and selection of Lycopersicon hirsutum*-based resistance breeding progeny*

Lycopersicon hirsutum f. *typicum* accession LA 1777 has shown resistance to a wide variety of insect pests including tomato fruitworm (TFW), *Helicoverpa armigera*, in the United States and Israel. Research at Cornell University is using this accession as a parent in an insect pest resistance breeding program and AVRDC screens its progenies for resistance to TFW. In one field experiment conducted in autumn-winter 1994-95 season 124 families each consisting of about 20 plants were screened for resistance to TFW and desirable horticultural characters.

Table 7. Marketable tomato yields (t/ha) of selected varieties evaluated in summer and dry seasons in the Philippines and Thailand

Entry	Origin	Dry season			Summer		
		Thai	Phil.	$\bar{X}$	Thai	Phil.	$\bar{X}$
Marikit	Philippines	38.6	30.9	34.8	6.1	3.7	4.9
MT 1	Malaysia	28.7	33.2	31.0	15.1	5.4	10.3
Maigaya	Philippines	19.1	35.6	27.4	4.6	11.8	8.2
CLN 698BC$_1$F$_2$-358-4-13	AVRDC	27.7	25.5	26.6	12.8	5.6	9.2
Mapula	Philippines	19.7	33.5	26.6	7.7	9.1	8.4
CL 5915-93D4-1-0-3	AVRDC	16.8	30.0	23.4	20.9	11.4	16.2
Seedathip 1	Thailand	15.5	29.9	22.7	16.8	11.0	13.9
VF 134-1-2	USA	9.6	17.6	13.6	1.4	1.0	1.2
Walter	USA	7.6	18.7	13.2	0.7	1.9	1.3
LSD (P = 0.05)	–	15.1	8.9	13.3	7.1	4.0	7.8
Trial mean	–	14.3	25.8	20.1	8.0	5.6	6.8
CV (%)	–	63.8	20.9		54.1	43.4	

One-month-old seedlings of each progeny were raised in the greenhouse and transplanted in a single row on the top of each 1.5-wide-bed on 3 November 1994. A distance of 1.5 m was maintained between two adjacent plants. On all four sides of the field, a row of TFW-susceptible TK 70 was transplanted.

TFW were raised in the laboratory on a commercially available artificial diet. Newly emerged adults were introduced in the tomato field to augment the native TFW population to ensure uniform infestation. Insects were released once a week starting from the first week of December 1994 to the second week of February 1995.

Once when tomato fruits started ripening and once 5 weeks later at harvest in mid-February 1995, each plant was observed in the field; the total number of tomato fruit and TFW damaged ones were recorded, and percentages of fruits damaged for each plant calculated.

The percentage of fruits damaged varied from 0 to 100%. Plants with less than 5% fruits damaged and yield of at least 50 fruits per plant were selected.

In the first and second observation, only 72 plants had less than 5% fruits damaged and more than 40 fruits in both observations. Seeds of these plants were extracted for further improvement.

Screening of selected tomato germplasm for resistance to tomato fruitworm

One accession each of *Lycopersicon pennellii* and *L. hirsutum* are already being used as resistance sources in the TFW resistance breeding activity. Recent reports indicated that certain cultivars and two *L. esculentum* var. *cerasiforme* accessions are resistant to beet armyworm (*Spodoptera exigua*) in the United States. These accessions were screened for resistance to TFW to identify additional sources of resistance.

One-month-old seedlings of two *L. esculentum* var. *cerasiforme* accessions, LA 1310 and LA 1320, one commercial cultivar Tiny Tim, one processing line UC 204A, and one AVRDC heat-tolerant breeding line CL 5915, were transplanted in a single line on the top of 1.5-m wide beds. Each entry was planted in eight randomly selected plots, each plot being one replicate.

Beginning with first flowering, TFW adults from a laboratory-reared colony were introduced to increase insect population and TFW infestation. When fruits in most entries were developed and ready for harvest, the total number of fruits and TFW-damaged ones on each plant were counted. The percentage damaged fruits were calculated and compared in the five entries.

LA 1310 and LA 1320 were the least damaged entries (table 8). LA 1320 was significantly less damaged than susceptible CL 5915 and UC 204A. Tiny Tim, reported to be resistant to beet armyworm, is susceptible to TFW. CL 5915 was significantly less damaged than the susceptible UC 204A and Tiny Tim.

Insect resistance did not have any relationship with fruit size. This is in contrast to findings of several past studies which showed that the smaller the fruit the lesser was the insect damage. The smallest fruited entry, Tiny Tim, had the highest insect damage and the biggest fruited the next highest. LA 1320 which had the lowest insect damage had fruits seven times larger than LA 1310. The insect resistance of LA 1320 seems to be genetic and related to high concentrations of glycoalkaloids.

Table 8. Infestation of fruits of selected tomato accessions by tomato fruitworm, AVRDC, spring 1995

Accession	Damaged fruits (%)	Fruit size (g)
Tiny Tim	25.61	6.1
UC 204A	17.10	97.6
CL 5915	8.02	37.7
LA 1310	5.08	2.1
LA 1320	2.02	15.5
LSD (P = 5%)	4.80	

Management of abiotic stresses

Physiology of flooding stress at high temperature

Eight tomato accessions collected near Ayacucho, Peru, where flooding is common, and obtained from the University of California-Davis, and 11 other accessions, which have been previously determined as either flooding-tolerant or flooding-sensitive, were studied for their flooding tolerance under greenhouse conditions.

Six each of 4-week or 6-week-old seedlings were subjected to 5-day flooding in August. Mean max./min. temperatures during flooding for 4 and 6-week-old seedlings were 34.0/23.6 and 33.2/25.0°C, respectively. Two weeks after the completion of flooding treatment, seedlings were investigated for their survival rates and growth responses.

Flooding caused substantial reduction in growth of all entries (more than 50% reduction in total fresh weight), and in some cases, death of certain entries. Surviving plants appeared to produce adventitious roots. Results of exposing 4 or 6-week-old seedlings to flooding were comparable.

L 123 had been previously identified to have some level of flooding tolerance. In this experiment, L 123 maintained 100% survival and relatively higher root growth after 5 days of flooding. None of the newly acquired accessions, *L. esculentum* var. *cerasiforme*, performed better than L 123 under artificial flooding conditions.

Development of molecular markers for virus resistance

Tomato leaf curl virus, cucumber mosaic virus, potato virus Y, and watermelon silver mottle virus are the most widespread and devastating viruses of tomato in the tropics and subtropics. Resistance to three of the viruses (PVY, CMV, LCV) has been identified in *L. chilense* (TLCV and CMV) and *L. hirsutum* (PVY). Introgression of resistance genes from wild tomato into *L. esculentum* and the development of horticulturally suitable lines involve backcrossing to *L. esculentum* and concomitant multivirus resistance screening. This process is not only labor-intensive and time-consuming but also meets with difficulties due to the differences in transmission and symptom expression of the three viruses involved. To facilitate and accelerate the introgression process, molecular markers are being developed for marker-assisted breeding.

Segregating mapping populations for TLCV resistance

Three *L. chilense* accessions (LA 1969, LA 1932, and LA 2737) were used as resistance sources and heat-tolerant CL5915-93D4-1-0-3 as the recurrent parent.

Virus screening, crossing, and seed production were done in the greenhouse. Seeds were sown in AVRDC compost mix in 72 plastic planting trays. At the 2-3-true leaf stage seedlings were exposed to viruliferous *Bemisia tabaci*. BL 983 was used as the susceptible cultivar. Plants were observed for leaf curl virus symptoms throughout their growth period. Symptomless plants were tested by nucleic acid hybridization, using a DIG-labeled 1.4 kb probe (M3) of the Taiwan TLCV cloned in pBluescript II KS (+).

Plants which remained symptomless longest and in which absence of virus was confirmed by the nucleic acid squash blot test were chosen for further crosses to produce BC_2F_2 populations for mapping purposes.

Large segregating populations (>150 plants) of BC_1, BC_2, and one BC_3 of several *L. chilense*-derived populations were screened in the screenhouse. Pollen was collected from those plants that remained virus-free longest and were negative by DNA hybridization tests. It was bulked and crossed to the recurrent parent CL 5915-93D4-1-0-3. BC_1F_2 plants for RFLP mapping were obtained and evaluated from one population (CLN 1966) (table 9). DNA from resistant and susceptible plants will be extracted for RFLP mapping of the TLCV tolerance/resistance genes with the assistance of Dr. S. Tanksley of Cornell University, USA.

Segregating mapping populations for PVY and CMV resistance

L. hirsutum L 111-2 and *L. chilense* accessions LA 1969-9 and LA 1969-11 were used as resistance sources for PVY and CMV, respectively. CLN 65-349D5-2-0, which possesses bacterial wilt resistance and moderate heat tolerance was used as the recurrent parent for the PVY crosses, while CL5915-93D4-1-0-3 was used for CMV crosses. Plants were raised in the greenhouse and mechanically inoculated at the 2-leaf stage with CMV isolates, 'NT9' and 'Peet', which had been previously isolated from tomato. The first inoculation was done at the 2-leaf stage with the 'Peet' isolate, the second 1 week later with 'NT9'.

PVY inoculations were done at 25 and 32 days after sowing using the local tomato isolate T-1103. ELISA tests were done at 2 and 3, 5 and 6 weeks after the last inoculation to test for absence of virus.

The PVY resistance of L 111-2 was confirmed by a cooperator in California using a locally prevalent strain. Eight BC_4F_5 lines have been developed from *L. hirsutum* L 111-2 (PI 247087) which is resistant to the common PVY strain (0). All plants were found resistant in a first screening (one mechanical

Table 9. Introgression of leaf curl virus resistance into tropical tomato

L. chilense acc.	Cross no.	F_1 plants	No. of resistant plants/total no. screened[b]			
			BC_1F_1	BC_2F_1	BC_3F_1	BC_4F_1
LA 1969 I6[a]	CLN 1740	61	14/159	29/533[c]	0[d]/313	b
					0[d]/62	b
LA 1969 I4	CLN 1741	16	1/58	1/19	6/144	b
LA 1969 H1	CLN 1742	9	2/26	1/125	b	
LA 1932	CLN 1962[e]	23	13/22	2/143	b	
					17/242	b
LA 2737	CLN 1966[e]	33	7/17	7/144	b	
LA 1961	CLN 1964	7	5/13	e		
LA 1968	CLN 1965	10	4/11	d		
LA 2952	CLN 1959	5	3/5	e		
LA 1960	CLN 1975	5	4/5	e		
LA 3113	CLN 1961	1	4/26	d		
LA 2981 A	CLN 1948	3	8/49	d		
LA 2765	CLN 1957	8	2/15	d		

[a] LA 1969 (85L8760) received from C. Rick, University of California (original CMV screening: 13/13 resistant plants; screening with seed from resistant plants: 1969-8 = 4/7; 1969-4 = 29/45; 1969-11 = 46/46 resistant plants)
I4 and I6 = CMV-resistant plant No. 8, and No. 11 respectively from original CMV resistance screening

[b] b = screening for resistance in progress; c = seed produced or seed production in progress, but not yet screened for TLCV resistance; d = B_1F_2 seed produced and in storage; e = B_2F_1 seed produced and in storage

[c] CMV screening: 56/56

[d] some virus-positive but symptomless plants within this population

[e] used for RFLP studies

inoculation at 24 days after sowing, followed by an ELISA test 16 days after inoculation) but not in a second, more severe screening (2 mechanical inoculations at 28 and 67 days after sowing, followed by 4 ELISA tests). In the second screening CLN 808 had 0, 31, 54, 96% virus-infected plants at 17, 51, 66, and 91 days after sowing, respectively (fig. 1). However, the susceptible check (TK 70) already had 100% virus-infected plants by the time of the first ELISA test. Three of these PVY-resistant BC_4F_6 (CLN 808BC_4-5-16-1-12, CLN 808BC_4-2-22-1-32, CLN 808BC_4-2-22-1-28) lines were sent to Cornell University for identification of common *L. hirsutum* introgressions in the BC_4F_6 lines which probably condition PVY resistance.

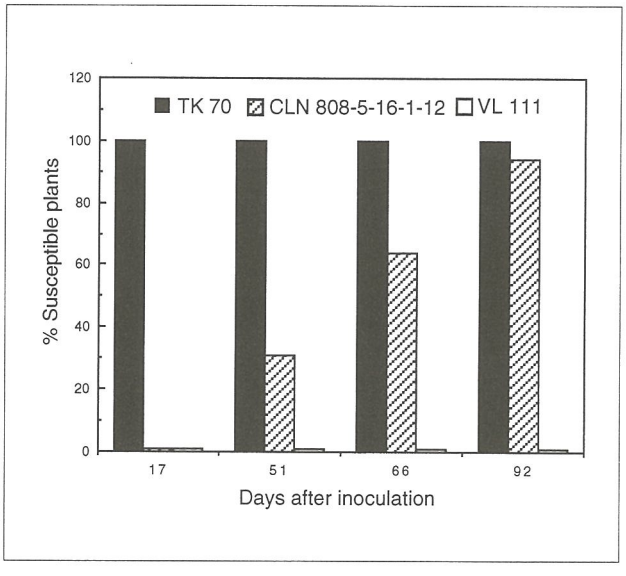


Fig. 1. PVY resistance in BC_4F_5 of CLN 808 crosses

Agrotransformation for WSMV resistance

Two clones (pWN11, pWN12) of the nucleocapsid (N) protein gene of WSMV in *Agrobacterium tumefaciens* were provided by Dr. S.D. Yeh of National Chung Hsing University in Taiwan.

Leaf disk transformation was done with five AVRDC lines. Strong growing shoots developing from positive transformants were selected and transferred to vermiculite and then into AVRDC soil mix. Western blots were conducted on agrotransformed plantlets at the 6-7-leaf stage. The protein bands obtained after PAGE were transferred on nitrocellulose membrane. Immunostaining was done by chemiluminescence using peroxidose conjugate and by color reaction using alkaline phosphatase conjugate. Seeds were collected from all transformed plants.

Twenty-six kanamycin-resistant shoots (5 from pWN11 and 21 from pWN12) were obtained after 6 months of cultivation.

Thirteen plantlets (11 from pWN12 and 2 from pWN-11) were rooted and grown in the greenhouse for seed collection. N-protein expression in transformed plants was analyzed. Out of 11 individual plants, two (4183-PWN12-2 and 4783 PWN12-7) expressed a protein which reacted with the WMSV-N protein antiserum against the alkaline phosphatase detection system. Using the horseradish peroxidase detection system four plants (4783 PWN12-2, 4783 PWN12-7, 4783 PWN12-5, 4783 PWV1-8) gave a reaction. It thus appears that the horseradish peroxidase detection system is more sensitive. These results are being confirmed.

Studies on leaf curl virus and SAVERNET, CONVERDS, and AVNET support

Survey for geminiviruses of tomato and pepper

One of the major objectives of AVRDC's networks, SAVERNET and CONVERDS, are to determine the occurrence and importance of geminiviruses on tomato and pepper.

Samples were collected from tomato and pepper showing symptoms typical of geminivirus infection, such as yellowing, leaf curling, and reduced leaf size and stunting. These were processed and tested using three probes: TYLCV-Egypt, TLCV-India (Bangalore isolate), and TYLCV-Thai. The former two are narrow range probes, whereas TYLCV-Thai is a wide range probe that is known to react with a number of geminiviruses from different hosts. Of some samples, which gave no or only a very weak reaction by DNA hybridization, PCR was conducted as follows: leaves were homogenized using the AC1v 1978 and AV1c 715 primers. The presence of a geminivirus was evidenced by the presence of an amplified 1.4 kb DNA fragment on the agarose gel.

The presence of a geminivirus on tomato was confirmed in Tanzania with 8% of the 390 samples tested. In Nepal, Pakistan, and Thailand the presence of a geminivirus on pepper and tomato was also confirmed whereas in India the presence of a geminivirus was only detected on tomato. A geminivirus could not be detected in any of the tomato and pepper samples received from Bhutan, Bangladesh, Sri Lanka, and the Philippines.

Of 127 tomato samples collected in southern India, 46% reacted with the geminivirus probe and of 120 samples collected from Nepal, 33% reacted with the geminivirus probe. Only 1.4% of the 278 samples from Pakistan reacted with the TLCV-India probe. Of 133 tomato samples collected in Tanzania 44% reacted with the geminivirus probe. Of five samples sent from Tanzania in November 1994 none reacted positively

with the two probes used. However, when these five samples were subjected to PCR, two were found to contain a geminivirus. Similarly of five samples sent from the Philippines, only four reacted very weakly with the TYLCV-Thai probe. PCR was done on these samples to confirm the presence of geminivirus. A band of 1.4 kb was detected in all five samples, confirming the presence of a geminivirus (fig. 2).

Further characterization of the Taiwan TLCV

An extensive host range study which included 25 varieties of 17 species was conducted with a pure TLCV isolate maintained in tomato at AVRDC. Transmission was by grafting 10 test plants with TLCV-infected scions as well as by whitefly transmission, exposing 24 test plants to viruliferous *B. tabaci* for 48 h. Infection was checked by visual observation when symptoms were clear and by DNA hybridization when symptoms were weak or absent.

The following varieties and species were not infected: *Abelmoschus esculentus, Cucurbita pepo* 'Phoenix', 'Zucchini', *Cucumis sativus* 'Delikatess Robusta', *C. melo* 'Charentais', *Capsicum annuum* (11 varieties), *C. chinense* 'Miscucho', *C. frutescens* 'Tobasco', *Gossypium hirsutum, Phaseolus vulgaris, Sesamum indicum, Solanum nigrum,* and *Vigna unguiculata. N. benthamiana, N. tabacum* 'Xanthi', and 'Samsun' were the only hosts that could be artificially infected in this study.

It thus appears that TLCV-Tai has a narrow host range, confined to *L. esculentum, N. benthamiana, N. tabacum* and, as previously reported, *Datura stramonium* and *Petunia hybrida. Capsicum annuum* does not appear to be a natural host of the virus.

Screening for TLCV resistance

Several lines with reported resistance to tomato yellow leaf curl virus were screened by either grafting or by whitefly inoculation. Similarly, some lines which were found to be resistant or having a high percentage of resistant individuals were rescreened, using seed of previously resistant plants. For grafting a 10-cm scion was cut from each of 10 or more plants of each line to be tested. These scions were then wedge grafted to TLCV-infected tomato plants. For whitefly

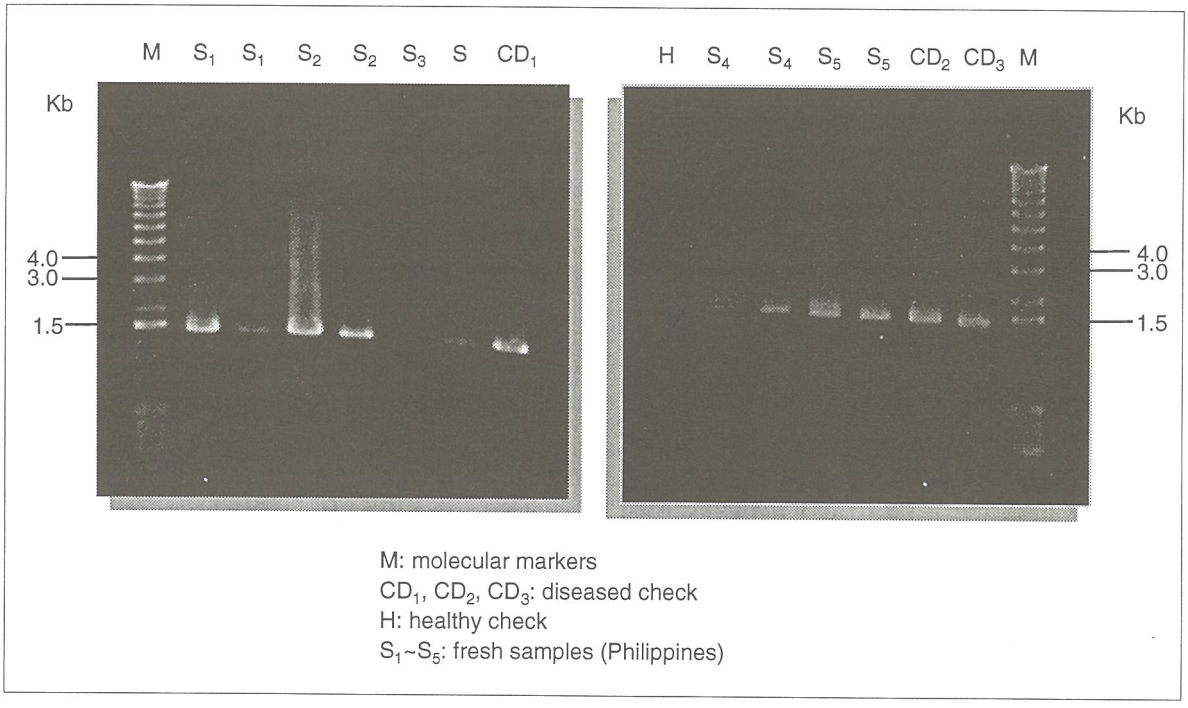


Fig. 2. TBE electrophoresis of PCR-amplified DNA from tomato samples (Philippines)

transmission, 10 or more seedlings at the 3-leaf stage were exposed to viruliferous whiteflies in the greenhouse. The plants were observed for 50 days for the development of symptoms typical of geminivirus infection. Rating was done visually or by nucleic acid hybridization in cases where no or very weak symptoms were observed.

TyKing, a commercial F_1 hybrid previously found resistant showed a high level of resistance in plants from selfed seed after exposure to viruliferous whiteflies. None of the other lines tested [SARIA (Peto), TOP-2-1] was found resistant. However, one line (CL x 3752) had 60% resistant plants by whitefly screening and another line, L 4848, 96% resistant plants by grafting. Previously a high percentage (~50%) of resistant plants was found in three *L. hirsutum* L 3683. However, when seed of resistant individuals were subjected to confirmation screening by viruliferous whiteflies, the average percentage of resistant individuals was only 35%. One line (L 3683-3-2-14) had 60% resistant individuals. Seeds have been collected from resistant plants for confirmation screening by whiteflies.

Artificial inoculation by grafting seems less effective (70-79% infection) than using viruliferous whiteflies in which almost 100% infection can be achieved.

Application of DNA probes and primers for the detection of *Pseudomonas solanacearum*

Species-specific primers, AU 759 and 760, of *Pseudomonas solanacearum* were identified in 1994. According to past studies, the sensitivity of this primer set can be as low as 1 to 20 cells. Protocols for applying this primer set to detect Ps from plant tissues have been developed. For detecting Ps from tomato stem pieces by PCR, different methods of preparing DNA templates were tested: maceration, extraction by incubating stem tissues at 18°C for 8 h used directly for PCR, and different concentrations of the plant extracts for PCR.

Selected highly resistant tomato lines were inoculated in the seedling stage using the soil drenching method. The percentage of wilt, colonization frequency of Ps, and internal Ps population were determined (table 10). Detection of Ps in the collar region of symptomless plants remaining at the end of trial was done by PCR as well as plating onto selective media.

Table 10. Percentage of wilt and colonization of *Pseudomonas solanacearum* in tomatoes

Variety	% Wilt[a]	Collar colonization		Collar Ps
		PCR[b]	TZC[c]	population[e]
R 3034	0	6/36[d]	12/36[d]	0.82
L 180	0	28/36	20/36	2.01
L 285	2.8	19/35	25/35	3.21
L 390	52.8	13/17	17/17	6.44

[a] Means of percentages of wilted plants of three replications
[b] Detection by PCR using AU 759 and AU 760 primers
[c] Detection by plating on selective medium (tetrazolium chloride medium, TZC)
[d] Number of plants in which Ps was detected / number of total tested symptomless plants
[e] Averages of Ps population in the collar regions of all tested symptomless plants in the unit of LOG (cfu/g fresh tissue)

Direct maceration of stem tissues released too much PCR inhibitors and no amplification product can be observed. When Ps cells were extracted by incubating stem tissues in sterile water at 20°C for 8 h, significant PCR products can be observed. However, the sensitivity of this protocol is poorer than the traditional plating method using selective media. Preliminary experiments indicated that colonization frequency and Ps population in the collar part may be used as indicators of stability of resistant lines. R 3034 and L 180 both showed 0% wilt in the greenhouse but the average Ps populations in the collar region were 0.82 and 2.01 cfu/g fresh tissue in these two lines,

respectively. The colonization frequency in R 3034 was also lower than L 180 (33.3 vs. 55.6% based on plating results or 16.7 vs. 77.8% based on PCR results).

References on the detection of microorganisms in soils by PCR were collected and studied. Different methods of preparing DNA templates from Ps-infested soils were tested to develop an efficient and sensitive PCR protocol for soil samples.

Cell extraction followed by DNA extraction was tested. Bacterial cells were extracted from soils using a sucrose gradient under low speed centrifugation (750 *g*, 10 min) and concentrated by high speed centrifugation (12,000 *g*, 20 min). The cell extracts were used for PCR directly. The detection limit was 1,000 cells/g soil under this condition. The recovery rate of Ps cells from the infested soils of the present protocol ranged from 0.1 to 50% and should be improved further.

Identification and characterization of bacterial wilt resistance in tomato

A set of of 36 resistance sources or breeding lines of tomato to bacterial wilt has been collected from eight countries and their seeds increased. Multilocation trials were conducted to evaluate this set in naturally infested fields in different countries. In 1995, this set was evaluated in the greenhouse by the soil drenching method, in the disease nursery at AVRDC, and in naturally infested soil at Taiwan Seed Service (TSS). Combined analysis was conducted to determine the location effect as well as to identify the most stable resistance sources worldwide.

As of November 1995, 23 collaborators in 19 countries have requested the set. Results of field evaluations have been received from seven countries. Trial means for survival % of each location were 95.1 in Australia; 82.6 in Brazil; 77.4 in Florida, USA; 73.3 in India; 33.7 in Japan; 68.4 in Guadeloupe; 80.6 in the Philippines; 86.5 in TSS Taiwan; 39.7 at AVRDC field; and 72.7 at the AVRDC greenhouse. Data sets from Australia and Florida were not included in the combined analysis due to low disease pressure and large variation between replications.

Results indicated that Location, Entry, and Location x Entry effects were highly significant ($P = 0.0001$). Hawaii 7996 had the highest survival % over locations. Fla 7421, a line with bacterial wilt resistance derived from Hawaii 7997, showed significantly less resistance than Hawaii 7997. This indicated that not all the BW resistance genes in Hawaii 7997 were incorporated into Fla 7421, or Hawaii 7997-derived BW resistance is reduced in a different genetic background. AVRDC lines CLN 1463 and CLN 1464, derived from crosses between an AVRDC tropical line and CRA 84-26, were not more resistant than AVRDC tropical lines CL 5915 and CLN 65. Thus, testing general combining capability should be studied before selecting additional resistance sources. Entries with resistance level similar to L 285 and with unknown resistance sources include 4 lines from the University of the Philippines Los Baños (UPLB), 1 from the Malaysian Agricultural Research and Development Institute (MARDI), 1 from Lembang Horticultural Research Institute (LEHRI), and 2 from the University of Florida.

Host resistance of black leaf mold, late blight, Fusarium wilt, and gray leaf spot of tomato

*Black leaf mold (*Pseudocercospora fuligena*)*

The objectives of this study were to (1) identify additional black leaf mold (BLM)-resistant sources among *Lycopersicon* spp. and (2) determine seasonal severity of BLM and associated environmental factors that affect disease development.

A total of 717 tomato accessions were scored for their BLM reactions in the laboratory following foliage inoculation. Two accessions, L 5368 and L 5996, both *L. hirsutum*, were identified as BLM-resistant (<10% leaf area affected). Four accessions were moderately

resistant (11-20% leaf area affected). Year-round studies on BLM have shown that the disease is most severe from September to March. A study of factors involved in disease development showed that (1) the number of days of dew formation is positively correlated with BLM severity while rainfall is negatively correlated; (2) most *P. fuligena* conidia germinate during the first 6 h after hydration; (3) stomatal penetration by germ tubes occurs over a period of more than 120 h after inoculation; and (4) some conidia remain viable for more than 18 months.

Late blight (Phytophthora infestans)

This study (1) tested the durability of four previously identified sources of late blight resistance and (2) determined the inheritance of resistance in *L. hirsutum* accessions L 3684 and *L. pimpinellifolium* accession L 3708.

Late blight-resistant *L. hirsutum* accessions L 3683 and L 3684, and *L. pimpinellifolium* accessions L 3707 and L 3708 were evaluated in the field during 1995 in Taiwan, Tanzania, and Thailand. They were also subjected in laboratory inoculations to *P. infestans* isolates from Taiwan, the Philippines, and USA. To date none of the *P. infestans* populations to which they have been subjected in the field or in seedling inoculations have been able to overcome their resistance. To study inheritance of late blight resistance from L 3684 and L 3708, susceptible x resistant crosses (MoneyMaker x L 3684) and (CLN 657BC_1F_2-274-0-15-4 x L 3708) were used to generate F_1 plants, F_2 populations, and backcross populations. The responses of these populations to laboratory inoculations show that resistance is a partially dominant trait and suggest that it is monogenic in both resistant accessions. The level of late blight resistance is higher in L 3708 (table 11).

Fusarium wilt (Fusarium oxysporum *f. sp.* lycopersici)

The objectives of this activity were to (1) assay AVRDC tomato lines and commercial varieties frequently grown in Taiwan for their reactions to race 1 and 2 of Fusarium wilt, and (2) to determine the prevalence of Fusarium wilt races 1 and 2 in Taiwan tomato growing areas.

Fifty-seven AVRDC tomato lines and 20 commercial cultivars were assayed for their reactions to races 1 and 2 (table 12). Among the AVRDC entries, 14 were susceptible, 20 resistant to race 1, and 23 resistant to

Table 11. Late blight reactions of tomato populations to support a monogenic control of a partially dominant trait hypothesis for inheritance of resistance from accession L 3708

Populations	No. plants	Presumed genotype	Mean disease severity reaction[a]	
			Expected[b]	Actual
L 3708 (R parent)	24	RR		1.13
CLN 657 (S parent)	24	rr		6.00
F_1	24	Rr		3.13
F_2	719	1 RR : 2 Rr : 1 rr	3.35	3.65
BC_1F_1	119	1 Rr : 1 rr	4.57	4.86
BC_1F_2				
19 families	24 each	1 RR : 2 Rr : 1 rr	3.35	3.8 - 5.0
20 families	24 each	rr	6.00	5.7 - 6.0

[a] Mean reactions of all plants in each population; 0 = no symptoms and 6 = dead plant

[b] Expected values are calculated from actual values of presumed genotypes

races 1 and 2. Among the commercial cultivars, none were susceptible, 16 were resistant to race 1, and 4 resistant to races 1 and 2.

A total of 23 *F. oxysporum* isolates were obtained from tomatoes in Taiwan during 1995 (table 13). Assays showed that 20 of the isolates were race 2 types and that the other 3 were avirulent. No race 1 isolates were identified, but most varieties being grown are resistant to race 1.

Table 12. Fusarium wilt reactions of tomato lines and cultivars — 1995 summary

Tomato entries	No. of entries		
Source/number	Susceptible	R1 res.	R 1&2 res.
AVRDC, 57	14	20[a]	23[a]
Commercial, 20	0	16	4
Total, 77	14	36	27

[a] One line was segregating for resistance to both race 1 and race 2

Table 13. Race determination[a] and virulence of *Fusarium oxysporum* isolates from tomato in Taiwan - 1995 survey

	No. of isolates			
Location	Total	Avirulent	Race 1	Race 2
Chusan	2	2	0	0
Kuantien	2	0	0	2
Tungsan	2	0	0	2
Likang	1	0	0	1
Chinliao	4	1	0	3
Shihu	4	0	0	4
AVRDC	3	0	0	3
Chutzuhu	5	0	0	5
Total	23	3	0	20

[a] Based on inoculation of tomato host differentials

Cloning of the chitinase gene from fungi-inhibiting bacteria

This study aims to clone the chitinase gene from fungi inhibitory bacteria.

Four strains of *Serratia marcescens* were isolated from shrimp shell-enriched soil and identified by the Analytical Profile Index (API) system. Using the modified mycelium extension-inhibition assay, all *S. marcescens* strains were tested against *Fusarium oxysporum* f. sp. *lycopersici* (*Fol*) and other fungal pathogens.

S. marcescens inhibited most of the tested fungal pathogens when the pathogens were cultured in the media containing 1% chitin (table 14), indicating that chitinase could be the major inhibitor of fungal growth.

In the subsequent experiments, chitinase was purified from *S. marcescens* extracellular filtrate by the chitin affinity method and examined by sodium dodecyl sulfate-polyacrylamide gel electrophoresis.

Table 14. Response of phytopathogenic fungi to the chitinolytic bacteria, *Serratia marcescens*

Fungi	PDA with 1% chitin	PDA w/o chitin
Fusarium oxysporum	+	-
Rhizoctonia solani	+	-
Stemphylium lycopersici	+	+
Alternaria solani	+	•[a]
Sclerotium rolfsii	±	-
Phytophthora capsici[b]	±	+

[a] Radial growth was limited but not inhibited

[b] Reported to have no chitin in the cell wall

Based on the published DNA sequence of bacterial chitinase genes, two oligonucleotides, i.e., 5'-GTTGCATGCGCAAATTTAATAAACC-3' and 5'-GCAGGTACCGATTGTTGAACGCC-3', were designed and used as primers for PCR-based gene cloning. PCR products from an *S. marcescens* genomic DNA were ligated to pQE vectors and expressed in *Escherichia coli* M15 [pREP4] of the QIA*express* system. Colonies of *E. coli* containing plasmids encoding the chitinase gene were identified on the chitin agar plates by the presence of clear zones, indicating that the chitin had been digested by chitinase.

SDS-PAGE of purified chitinase from four strains of *S. marcescens* revealed that all of them have three distinct polypeptides of 44, 46, and 57 kD (fig. 3).

With the PCR reaction, three DNA fragments, i.e., 1.0, 1.4, and 1.7 kb, were obtained from *S. marcescens* genomic DNA (fig. 4). These PCR products closely corresponded with the predicted DNA molecular weights based on polypeptides derived from SDS-PAGE. One of three DNA fragments, i.e., 1.7 kb, carrying the chitinase gene was cloned.

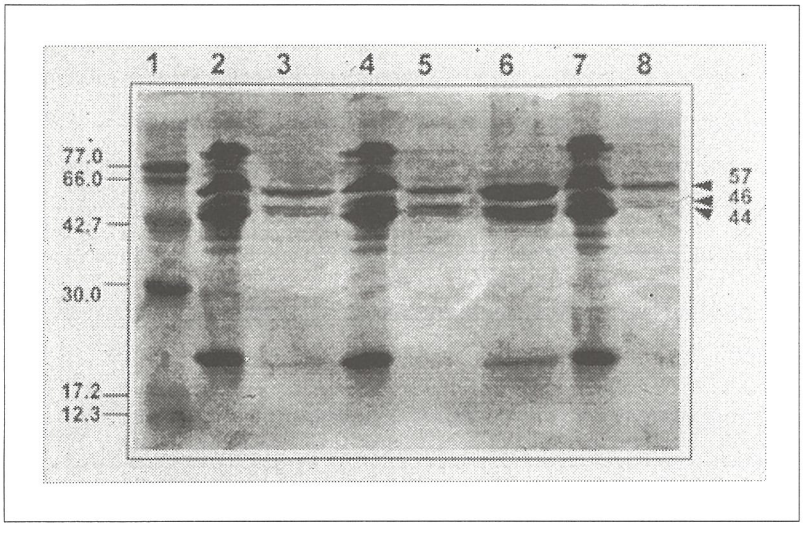


Fig. 3. SDS-PAGE of chitinases secreted from various *S. marcescens* strains
Lanes 2, 4, and 7, crude proteins; lanes 3, 5, 6, and 8, partially purified proteins; and lane 1, mol. wt. markers. Arrows indicate the position of chitinases

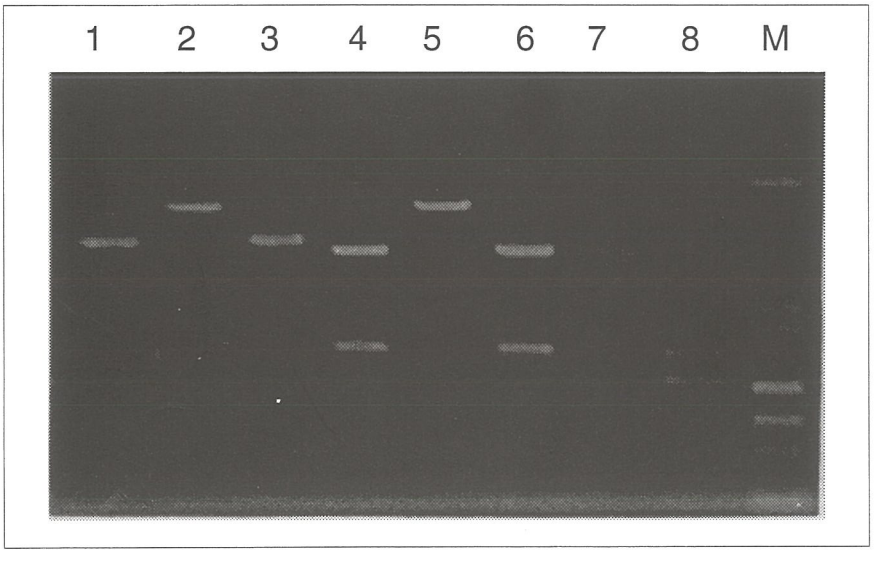


Fig. 4. Gel analysis of recombinant plasmids carrying chitinase gene and PCR products from *S. marcescens* genomic DNA
Lanes 1 and 3, circular cloned plasmids; lanes 2 and 5, linear cloned plasmids (*Kpn* I digested); lanes 4 and 6, linear pQE vector and inserted DNA fragment (cloned plasmids digested with *Kpn* I and *Sph* I); lane 7, linear pQE vector (*Kpn* I digested); lane 8, PCR products; lane M, λ/*Hind*III DNA size markers and ϕX174/*Hae* III DNA size markers

LEGUME IMPROVEMENT

The legume improvement project works on two commodities: mungbean (*Vigna radiata*) and soybean (*Glycine max*). It aims to develop high yielding lines with resistance to pests and diseases, early uniform maturity, resistance to shattering, improved seed quality, and suitable for the tropics and subtropics. Regeneration of soybean germplasm and mungbean research, including the coordination of three international mungbean nurseries and the distribution of improved germplasm are done at the AVRDC Asian Regional Center based in Thailand (see page 154 for details).

At headquarters, activities on mungbean were undertaken to screen germplasm for resistance to *Maruca* podborer, develop a reliable screening method for mungbean yellow mosaic virus, and distribute germplasm. The bean podborer, *Maruca testulalis* Geyer, is the most destructive pest of mungbean, cowpea and yard-long bean in Asia. Insect larvae bore in flowers and pods and feed while remaining concealed, resulting in considerable yield reduction. Moderate resistance to the bean podborer was confirmed in 20 accessions.

A commercial preparation containing *Bacillus thuringiensis* (Bt) strain aizawai, as compared to strain kurstaki, was found more effective in controlling podborer.

Soybean activities aim to select for appropriate vegetable and grain soybean, incorporate the *lx lx* gene in elite lines, and distribute germplasm. Significant results include the development of new breeding lines with graded pod yield of up to 16 t/ha and with 88 g/100-seed weight.

AVRDC hopes to improve the quality and graded pod yield of vegetable soybeans and develop disease-resistant varieties to reduce chemical and labor costs for pesticide application, develop varieties for whole pod and shelled bean for domestic use, and evaluate the sustainability aspects of vegetable soybean production.

Three AVRDC soybean breeding lines have contributed to the development of one recommended variety each in three countries. For vegetable soybean, two breeding lines are popularly used in five countries.

Meanwhile, the collaborative effort with Korea to advance their early generation materials at AVRDC has continued into its 21st year.

Transformation systems for mungbean and vegetable soybean are being developed to lay the foundation to introduce the sulfur-rich protein gene from paradise nut via chimeric gene constructed at the University of Hawaii at Manoa.

Genetic resources activities

A total of 86 mungbean and 2233 soybean samples were sent to 9 and 24 countries and territories, respectively in 1995 (table 1).

Table 1. Distribution of legume germplasm in 1995

Country	No. of samples		Purpose
	mungbean	soybean	
Argentina	10	-	evaluation trial
Bangladesh	-	12	evaluation trial
Canada	9	-	phylogenetic studies
India	1	91	part of virus tester set evaluation trial, AVSET
Italy	2	-	
Korea	-	63	
Malaysia	-	30	
Mauritius	-	25	evaluation trial, AVSET
Pakistan	22	-	special types (MB)
Philippines	-	100	evaluation trial
Sri Lanka	1	-	evaluation trial
Taiwan		1573	joint multiplication project
Tanzania	-	40	
Thailand	-	40	evaluation trial, AVSET, *G. soja*
U.K.	37	-	RAPD analysis, in vitro transformation, mapping CL-resistant genes, evaluation trial
USA	1	28	regeneration, transformation
Vietnam	3	40	evaluation trial (MB)
Others	-	191[a]	evaluation trial, AVSET, genetics of beanfly resistance, SB cyst nematode race determination
Total	86	2233	

[a] Chile, Germany, Ghana, Indonesia, Iran, Malawi, Marshall Is., Nepal, Nigeria, Sierra Leone, Singapore, Solomon Is., Swaziland

Development of a reliable screening method for mungbean yellow mosaic virus

MYMV, a whitefly-transmitted geminivirus, causes one of the most serious diseases of mungbean in all of South Asia. The virus also affects other leguminous crops such as soybean, blackgram, and cowpea. For the last few decades national programs, particularly in India and Pakistan, have studied the biological characterization of the virus-vector relationship, epidemiology and disease control by chemical means, and resistance breeding. Despite nearly 25 years of resistance breeding efforts and the release of tolerant lines, the disease still poses a major problem to economic production of mungbean on the Indian subcontinent. This has been attributed to various factors, including increase in whitefly populations and unstable levels of resistance.

AVRDC has, therefore, accorded high priority to this virus. One of the various recommendations drawn up at the international workshop on MYMV in 1991 was to study the variability of MYMV and improve resistance-breeding strategies. Sensitive diagnostic tools are a prerequisite for these studies. Polyclonal antisera as well as monoclonal antibodies are highly unspecific and were not useful for these studies. The development of virus-specific DNA probes was, therefore, attempted because they were considered the most effective for exact diagnosis.

Samples were collected in South Asian countries from mungbean and other leguminous crops showing typical yellow mosaic symptoms. The samples were air-dried. DNA was extracted and amplified by polymerase chain reaction using three primer pairs. One primer pair was designed from the top half and another pair from the bottom half of the DNA-A sequences of known whitefly-transmitted geminiviruses and a third pair was designed from the top half of known DNA-B sequences. PCR-derived DNA fragments were digested with *Pst*1 restriction enzyme.

The whole DNA-A was split into three DNA fragments and the top of DNA-B into one DNA fragment. The different individual DNA fragments and the *Pst*1-digested plasmid bluescript II KS(+) were ligated and transformed separately into competent *Escherichia coli*. Selection for inserted plasmids was on TY agarose medium, contaning IPTG, X-gal, and the antibiotics ampicillin and tetracyline.

Four MYMV-specific clones, pIM5, pIM13, pIM20 (specific for DNA-A), and pIM9 (specific for DNA-B), were selected and identified by DNA sequencing. It was shown that MYMV from India had 95% DNA sequence homology with the MYMV from Thailand (table 2). Inserted DNA-A and DNA-B were used as templates to synthesize MYMV-specific probes by digoxygenin labeling. Positive signals were obtained from yellow mosaic-diseased mungbean in North and South India and cowpea and soybean from North India and from mungbean and blackgram in Pakistan (table 3).

Table 2. Comparison of MYMV-IND (common region) with other geminiviruses

Virus[a]	% sequence homology
MYMV-Thai	93%
TLCV-IND	44%
ICMV	41%
Croton virus (Ac region)	56%

[a] MYMV-Thai = MYMV from Thailand
TLCV-IND = tomato leaf curl virus from India
ICMV = Indian cassava mosaic virus

The probe, however, did not react with any of the mungbean, soybean, cowpea, and rice bean samples collected from Nepal and showing typical yellowing symptoms. This suggests that they may have been infected with different strains of MYMV, with a different geminivirus, or with another virus causing similar yellowing symptoms. This will be the subject of further investigation. The new probe is thus useful for resistance screening and epidemiological studies in Pakistan and South India.

Table 3. MYMV survey in leguminous crops on the Indian subcontinent

Country	Crop	No. of samples tested[a]	No. of samples positive (%)
India			
North	mungbean	51	1(2)
	blackgram	1	0
	cowpea	7	1 (14)
	soybean	8	1 (13)
South	mungbean	37	19 (51)
	soybean	30	0
	cowpea	8	0
	rice bean	1	0
Nepal	mungbean	13	0
	soybean	30	0
	cowpea	8	0
	rice pea	1	0
Pakistan	mungbean	46	12 (26)
	cowpea	2	0
	blackgram	5	2 (40)

[a] DNA hybridization using the MYMV-India probe mixture of pIM5 and pIM9 was used for the test

Breeding appropriate vegetable soybean

Vegetable soybean varieties from Japan and improved selections from the center are used as base materials to develop improved soybeans. Crosses are made between tropically adapted AGS grain soybean lines with potentially useful vegetable soybeans. The F_1s are backcrossed to vegetable soybean two to four times depending on the seed size of the nonrecurrent parent. Backcross inbred generations are evaluated in Pingtung, Taiwan, and Chiang Mai and Kamphaengsaen, Thailand. Selections are based on total pod yield, consumer quality, and shelled bean. Selections for Taiwan focus on suitability for

mechanical harvesting and improved quality. From the total biomass, NPK contents of stem, leaves, and shells are estimated to determine the contribution of vegetable soybean to soil sustainability.

A total of 33 crosses have been made to combine large pod and seed size, lipoxygenase *(lx)* null and good appearance to selected breeding lines with good yield. In 1994, observational, advanced, and intermediate yield trials were conducted in spring, summer, and autumn. A combined analysis of three-season data revealed the predominant influence of seasons on yield, seed size, and pod size. There was no interaction for summer and autumn, but there was for all others: spring and summer; spring and autumn; and spring, summer, and autumn. Therefore, selection should be specific for spring season. Autumn was the best season with 8.4 t/ha followed by spring and summer with 5.6 t/ha and ~4.0 t/ha graded pods, respectively (table 4). Sugar content was also higher in autumn.

A number of new breeding lines gave significantly higher graded pod yield than the check varieties, KS 1, KS 2, and KS 3. One entry, GC 91025-123-1, gave up to 16 t/ha graded pod yield with 88 g for 100 seeds in 98 days while the check had only 8 t/ha in 98 days in spring 1995. Three entries in 1994 had a 100-seed weight of more than 100 g: GC 89008-S-1-2-1W (106 g), GC 89017-1-1 (102 g), and GC 89008-S-1-2-1 (110 g). They matured in 76 days in autumn. The check varieties had a 100-seed weight of 73 to 87 g and matured in 72 to 76 days in the same season. The best entries from the 1994 AYT are given in table 5.

Table 4. Influence of season on pod yield and other attributes in AYT, 1994

Season	Pod yield (t/ha)		100-seed	Sugar
	Graded	Total	weight (g)	(%)
94 spring	5.62	11.28	60.8	10.46
94 summer	3.96	7.20	59.0	10.70
94 autumn	8.41	10.88	69.1	11.67

Table 5. Promising selections from AYT vegetable soybean, autumn 1994

Entry	Pod yield (t/ha)		Harvest index (%)	Graded pod harvest index (%)	Days to maturity	Pod length/ 2 seeds	Pod width/ 2 seeds	100-seed wt. (g)	No. of graded pod/ 500 g
	graded	total							
GC 87012-10-B-6	10.1	11.8	55	48	70	5.2	1.3	75.4	168
GC 87012-10-B-4	9.6	11.7	52	43	72	5.0	1.3	76.0	169
GC 87012-20-B-2-1	9.4	13.3	58	41	76	5.0	1.3	78.7	175
GC 87012-20-B-2-2	9.3	13.1	59	42	76	5.0	1.3	77.7	177
GC 87012-10-B-4-2	9.2	11.7	53	41	72	5.1	1.3	72.4	179
GC 87020-20S-B-5	8.2	10.0	55	46	69	5.0	1.3	74.3	171
KS 3 (ck)	7.9	10.7	52	38	76	4.8	1.3	67.5	182
KS 2 (ck)	7.8	10.7	54	40	76	4.7	1.3	61.7	217
KS 1 (ck)	7.1	9.0	54	36	66	5.1	1.2	64.3	201
Means of 20 entries	8.4	10.9	55	43	71.0	5.0	1.3	69.1	183
CV (%)	8.35	6.52	2.65	5.32	0	3.37	2.96	4.13	3.84
LSD (0.05)	0.99	1.0	2.07	3.22	0	0.24	0.05	4.04	9.96

AVRDC soybean evaluation trial

Advanced breeding lines from AVRDC and promising lines or improved varieties from partner countries are included in the AVRDC Soybean Evaluation Trial (ASET).

In 1995 three ASETs, 55 AVRDC *Glycine* selections (AGS), 64 pedigree selections, and 73 selected accessions were distributed to 22 cooperators in 17 countries. Results of eight trials from six cooperators were received. Vietnam has released AVRDC's AGS 327 as 'HL 92'. AGS 327 was selected from a rigorous selection of PYT (3 crops), standard yield trial (SYT) (4 crops), and on-farm trials in 34 farmers' fields. It is early maturing (70-78 days), adapted to corn-soybean-tobacco cropping system in red soil, has a 100-seed weight of 12-14 g, with low soybean rust incidence and pod decay disease. HL 92 has a yield potential of 1.1 to 2.0 t/ha. It gave 22 to 35% higher yield than the local variety Namrang. It is planted to 500 ha in the autumn in Dongnai province.

Zimbabwe has released a new variety called 'Nyala'. It is a cross between (Oribi x GC 30229-8) x (21/6/23 x 31/6/31). Its narrow leaflet, early maturity, and high yield are derived from AVRDC's GC 30229-8.

Nepal has released a variety called 'Seti Bhatta'. It is an AVRDC selection from the cross KS 419 x KS 525.

A complete list of varieties released so far are shown in table 6.

AVRDC vegetable soybean evaluation trial

Promising vegetable soybean introductions and improved breeding lines from AVRDC and from other partner countries are utilized.

A total of 11 AVRDC Vegetable Soybean Evaluation Trials (AVSET), 89 AGS, 20 selected breeding lines, and 11 promising accessions were distributed to 24 cooperators in 17 countries (table 7).

Plenty of Canada is distributing AVRDC's AGS 190 to farmers in Sri Lanka. It is used to make soy nuts, soy milk, and ice cream. Pakistan has released AGS 190 as 'Rawal-1'. Malaysia has released AGS 190 as 'MKS 1' in 1995. AGS 292 (KS 1) is planted to about 3,000 ha in China by the Taiwan Frozen Food Association members who also have freezing plants there. The frozen product is exported to Japan. AGS 192 is also becoming popular in Vietnam. In Indonesia, 'Ryokkoh', introduced by AVRDC, is planted to about 200 ha for export to Japan.

The list of vegetable soybean varieties released from AVRDC increased from 5 to 7 countries (table 8).

Results of 12 trials were returned by 10 cooperators from 9 countries. Newer breeding lines gave higher graded pod yields in different countries, as much as 26 t/ha and a total pod yield of 33 t/ha in the dry season (table 9).

In the Philippines, AGS 292 gave a graded pod yield of 14 t/ha while in Grenada, AGS 328 and 331 gave 12 t/ha graded pods.

Seed multiplication of elite lines and Korean breeding line

Elite breeding lines and introduced improved varieties are planted to produce sufficient seed for distribution.

Promising entries in the advanced yield trial were multiplied in the field. The multiplied entries are being prepared for 25 new AVSET and 10 ASETS.

Sufficient seeds of 10 promising vegetable soybean entries in the advanced yield trial have been multiplied. Enough seeds are available for preparing 20 AVSETs.

The collaboration with Korea on soybean breeding continues, cutting the time taken to release the variety in Korea in half. Seeds of 14 cross combinations in F_3 generation were planted in 5-m-long rows in spring. From a total of 2533 seeds, 804 g of seeds were

Table 6. AVRDC soybeans released by cooperators as of 1995

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
Wilis[b]	G 2120	1983	Indonesia	EM,HY,(R)[c]
Kerinci[b]	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,CMMV
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
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 & summer planting
Sukothai No. 1	AGS 9	1986	Thailand	NL,HY,NP,(R,DM,PSS)
Dowling	G 58[a]	1978	USA	R,HY
AK-03	G 2261[a]	1988	Vietnam	HY,EM
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
	GC 30229-8 (AGS 19)	1983	Zimbabwe	NL,EM
Nyala[b]	GC 30229-8	1992	Zimbabwe	HY,EM,Det
Seti Bhatta	KS 419 x KS 525		Nepal	HY, adapted to intercropping with corn
Total	23		11	

[a] Selected at AVRDC, but not an AVRDC improved line

[b] Cross between AVRDC line and local cultivar

[c] Parentheses indicate moderate levels of resistance

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

Table 7. Distribution of AVRDC vegetable soybean and other enhanced germplasm to different countries, 1995

Country	No. of cooperators	Type of seed sent				
		AVSET	AGS line	GC pedigree	Acc.	Others
Chile	1		1	4		
Germany	1		1		1	2
India	4	1	16	5		
Kenya	1	1				
Malawi	1		10			
Malaysia	1	1				
Mauritius	2	1	5			
Nepal	1		3	2		
Nigeria	1		6			
Philippines	3	1	36	9		1
Singapore	1		1			
Solomon Is.	1		6			1
Swaziland	1	1				
Tanzania	1	2				
Thailand	1	1				
USA	1		4		2	4
Vietnam	2	2				
Total	24	11	89	20	3	8

Table 8. AVRDC vegetable soybean released by cooperators

Local name	AVRDC ID #	Year	Country	Remarks
MKS 1	AGS 190	1995	Malaysia	HY
Rawal-1	AGS 190	1994	Pakistan	HY
	AGS 190	1993	Sri Lanka	HY, suitable for soy milk and ice cream making and soynuts, less beany flavor
Kaoshiung 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
Total	7		5	

HY: high yielding
MH: suitable for mechanical harvesting
DM: resistant to downy mildew
EM: early maturing

Table 9. Graded pod yield of different entries in Grenada and the Philippines

Country	Entries	Graded pod yield (t/ha)
Philippines	AGS 335	26.0
	AGS 334	24.5
	AGS 292	14.0
Grenada	AGS 328	12.0
	AGS 331	11.5
	AGS 335	10.0

collected. One set of seeds was collected to advance the generation by single-seed-descent at AVRDC. Another set was advanced to F_4 in the summer in the greenhouse. They are currently in F_5 generation.

Sixteen local black soybeans with green cotyledons from Chungnam Provincial Rural Development Administration, 11 breeding lines from the Korean Atomic Energy Research Institute, and Suweon 169, a new selection null for lipoxygenase 1 and 2 (*lx1 lx2*) were planted to multiply the seeds.

One hundred-seed weight of black soybean entries varied from 19.6 g for CN 342 to 45.6 g for CN 9401. A total of 4.1 kg of black seeds were produced from 313 g seed.

Korea wanted to release Suweon 169 early to farmers. Therefore, seeds were multiplied at AVRDC. From 40 kg seed, a total of 600 kg seed was produced and shipped to Korea in time for distribution to farmers.

Evaluation of *lx lx* gene in elite lines

Under this activity elite lines derived from crosses incorporating *lx lx* genes into promising AGS lines are tested for the presence or absence of *lx lx* gene.

Elite lines derived from the *Lx1 Lx2 Lx3* X *lx1 lx2 lx3* crosses made in Japan were planted in replicated plots; seeds harvested from each line were tested. The materials are now in BC_3F_2. They need to be backcrossed two more times to develop isogenic lines.

A grain soybean, AGS 129 (KS No.10), and two vegetable soybeans, KS No.1 and KS No.2, were crossed with a genotype null for three lipoxygenase loci in Japan by Dr. K. Kitamura of the National Agricultural Research Center. Selected F_2s were backcrossed to recurrent parents AGS 129, KS No.1 and KS No.2. BC_1F_2s were screened for lipoxygenase and double and triple nulls were selected (*lx1 lx1 lx2 lx2* and *lx1 lx1lx2 lx2 lx3 lx3*).

A total of 3110 plants from eight crosses in BC_3F_2 were screened for double nulls and triple nulls. For six crosses the observed numbers gave an excellent fit for the expected ratio of 63:1. For two crosses, there was deviation from the ratio. Similarly for *lx2 lx2*, the observed number gave an excellent fit for the expected ratio of 7:1 in five crosses. In three others, there was deviation. However, the test for goodness of fit for the pooled data showed a good fit with the expected ratio (tables 10 and 11).

At present, there are 41 BC_3F_2 plants with triple nulls which are near isogenic. There are also a total of 73 BC_4F_1 seeds which are triple nulls.

Partial shuttle breeding of soybean and vegetable soybean

AVRDC hopes to develop widely adapted soybean and tropically adapted vegetable soybean types with multiple disease resistance through shuttle breeding in various locations in Thailand.

Segregating populations of grain soybean were advanced during the dry season at the Field Crop Research Center in Mae Jo. Selection was made for adaptation, yield, and rust tolerance. Selected materials were screened for downy mildew and bacterial pustule at AVRDC headquarters and adaptation to spring and summer seasons. Resulting advanced generation materials were included in the standard yield trial in Chiang Mai, Thailand and ASET at AVRDC.

Table 10. Frequencies of phenotypic classes for triple-null and others in eight crosses and the chi-square test

Cross	Frequencies in phenotype		Ratio tested	Chi-square	
	others	*lx1 lx1 lx2 lx2 lx3 lx3*		value	*P*
GC 94038	325	1	63:1	2.576	<0.05
GC 94039	518	8	63:1	0.001	<0.05
GC 94040	623	0	63:1	8.899	>0.05
GC 94041	434	6	63:1	0.021	<0.05
GC 94042	149	0	63:1	1.458	<0.05
GC 94043	387	10	63:1	0.008	<0.05
GC 94044	408	13	63:1	5.416	>0.05
GC 94045	225	3	63:1	0.001	<0.05
Total	3069	41	63:1	1.052	<0.05

Table 11. Frequencies of phenotypic classes (*lx2 lx2* and others) in eight crosses and chi-square test

Cross	Frequencies in phenotype		Ratio	Chi-square	
	Others	*lx2 lx2*	tested	value	*P*
GC 94038	303	23	7:1	8.345	>0.05
GC 94039	457	69	7:1	0.131	<0.05
GC 94040	551	72	7:1	0.424	<0.05
GC 94041	349	91	7:1	26.187	>0.05
GC 94042	124	25	7:1	2.118	<0.05
GC 94043	346	51	7:1	0.018	<0.05
GC 94044	406	15	7:1	29.932	>0.05
GC 94045	201	27	7:1	0.040	<0.05
Total	2737	373	7:1	0.684	<0.05

In the rainy season SYT, the improved lines yielded up to 2.7 t/ha compared to 1.8 t/ha for the check. From ASET, 2.1 t/ha was obtained by the new breeding line compared to 1.3 t/ha for the check.

Similarly in the regional yield trial at Chiang Mai, GC 81031-6-3-1 yielded 2.4 t/ha in 87 days (check 2.2 t/ha in 91 days). In the Phrao RYT, GC 81031-6-2-2 yielded 2.3 t/ha compared to 1.9 t/ha for the check.

Among the vegetable soybeans, AGS 190 gave a total pod and graded pod yield of 26 t/ha and 9.7 t/ha, respectively in 70 days. Compared to KPS 292 which yielded 1.4 t/ha in 65 days, AGS 335 produced 5.2 t/ha in 70 days.

Screening of mungbean germplasm for resistance to bean pod borer

During the past 2 years *Maruca* has become a very damaging pest of *Sesbania indica*, a popular green manure crop in summer in Taiwan. In this crop, *Maruca* larvae fold *Sesbania* leaflets and feed concealed inside. At the height of the damage, the entire plant gets defoliated. Taking advantage of the high pest population, about half of AVRDC's mungbean

germplasm was screened for resistance to this pest during summer 1995.

A field of more than 1 ha was plowed and after rototilling the land was worked into 0.75-m-wide beds divided into 2-m-long plots. A distance of 0.75 m was maintained between two adjacent plots. Each of 2500 accessions was planted in one row on the top of an individual bed. Simultaneously after every 20 rows of mungbean, one row was planted to *Sesbania indica*, a *Maruca* source plant. Both crops were raised using traditional cultural practices. When majority of the mungbean pods were mature but not starting to dry, each plant in each accession was observed and the total number of plants and *Maruca*-damaged (mainly in pods) plants recorded. The percent plants damaged was calculated.

The percentage of *Maruca*-damaged plants was analyzed by a statistical procedure based on mean (X) of percentage damaged plants of all entries included in the test and standard deviation (SD) of mean. Entries with percentage damaged plants less than X - 2 SD were considered as highly resistant (HR); those between X - 2 SD and X - 1 SD, moderately resistant (MR); between X - 1 SD and X, with low resistance (LR); between X and X + 2 SD, susceptible (S); and more than X + 2 SD, highly susceptible (HS).

After severe damage to *Sesbania* foliage, *Maruca* adults moved to mungbean plants. *Maruca* larvae attacked both flowers and pods. None of the mungbean accessions escaped depredation. The percent plants damaged varied from the lowest 2% to the highest 84.4%. The mean damage was 24.8 ± 13.9 plants. Based on the statistical criterion for determining resistance levels, 206 accessions could be considered as having a moderate level of resistance, 1152 with low resistance, 867 susceptible, and 131 highly susceptible. Because of the large number of accessions in the moderately resistant category, only the least damaged 10% were selected for further evaluation to confirm resistance and potential use in resistance breeding.

Testing of *Bacillus thuringiensis* strains against bean pod borer

To combat bean podborer, some mungbean farmers have resorted to spraying chemical insecticides. Since the insect feeds concealed inside the pod and pupates in soil, the insecticide toxicant very rarely reaches the larvae to kill them. To kill neonate larvae before they bore into the pod or flower, frequent application of insecticides becomes necessary. This type of pesticide use increases cost of production and environmental contamination, and poses health hazards. Pesticide use also kills natural enemies which once used to keep this and other insects in check. As a result, this insect has become even more serious in recent years.

The use of *Bacillus thuringiensis* (Bt) to combat this pest appears to be an attractive control alternative. Bt is used widely as a microbial insecticide to control Lepidoptera pests effectively. However, it was never used successfully in controlling *Maruca*. Environmentally, Bt is the safest insecticide in the world. There are a large number of Bt strains and serotypes with varying effectiveness on insect pests. In this experiment insect larvae were fed with various strains of Bt sprayed on *Sesbania* leaves on which *Maruca* larvae feed readily to find out whether Bt is effective against *Maruca*.

Several second and third instar *Maruca* larvae were collected from the *Sesbania* field around AVRDC. They were fed on *Sesbania* leaves placed in acrylic jars. Both ends of the acrylic jars were closed by muslin cloth to prevent the larvae from getting out. Only third instar larvae were used for testing.

Several Bt products (i.e., Delfin, Florbac, Dipel, and Biobit) were selected to study their effectiveness against *Maruca*. When preparing Bt concentrations, a locally available spreader (1000 X) was added to enhance Bt spore adhesion to leaves. Fresh *Sesbania* leaves were harvested and bundles of six leaves were dipped in each concentration of Bt or water for 5 sec. The leaves were then air-dried. Three bundles of

treated leaves from each concentration were placed in three filter paper-lined petri dishes, each petri dish being one replicate. Before putting leaves in the petri dish, their petioles were wrapped in moist cotton wool to retain their freshness. At this time 10 third instar *Maruca* larvae were released in each dish. After 48 h, the number of dead larvae was recorded and percent mortality and corrected percent mortality were calculated. All experiments were conducted at room temperature.

LC_{50} of each product was calculated from graphs of corrected percent mortalities against product concentration. Linear regressions were calculated to draw a regression line from which LC_{50} values were calculated.

The results of the mortality of *Maruca* larvae in varying concentrations of Bt products are shown in fig. 1. The higher the concentration, the higher is the insect mortality. Florbac which contains Bt aizawai had the greatest mortality at lowest concentration. All other products had Bt strain kurstaki. The insect mortality increased more steeply with increasing concentration of Bt. *Maruca* larval mortality was much less in Biobit.

Florbac has the lowest LC_{50}, 1116 IU/ml, making it the most effective Bt product for controlling *Maruca*.

Gene transformation in mungbean and vegetable soybean

To improve nutritional quality, a sulfur-rich protein gene from paradise nut is being constructed at the University of Hawaii at Manoa. It is planned to incorporate this gene construct into mungbean and vegetable soybean for protein quality improvement. Before doing that, vegetable soybean Kaohsiung No. 2 and mungbean VC 1973A were used to develop the transformation system.

Current research focused on the improvement of established protocols. Shoot tips or cotyledons with shoot tips were bombarded with a particle gun followed by the *Agrobacterium* infection for the transfer

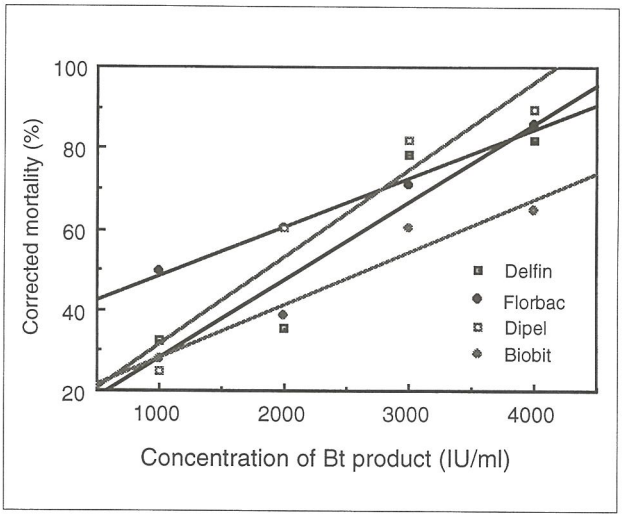


Fig. 1. Dose response curves for various Bt products used against bean podborer

of NPTII and GUS genes. Results indicate the possibility of the gene transfer to a mungbean variety, VC 1973A, with this system. For soybean, Kaohsiung No. 2, results show only kanamycin resistance without GUS staining.

In VC 1973A, most bombarded explants survived in the selection media. Some one-cotyledon-removed explants showed blue spots or sectors on cotyledon, primary leaves, embryonic axes or cotyledonary nodes, indicating the successful transformation of cells in these regions. However, no GUS activity was detected in shoot-tip explants (table 12). Explants showing GUS staining are being confirmed by the Southern blot analysis.

Table 12. Transformation of mungbean, VC 1973A, by particle bombardment in association with the *Agrobacterium* co-cultivation

Explant	No. tested explants	No. kan-res explants	No. GUS^+ explant
Cotyledon + Shoot tip	20	17	7
Shoot tip	30	24	0

SUSTAINABLE USE OF NATURAL RESOURCES AND INPUTS

The objective of this project is to develop practices and technologies that maintain or increase agricultural productivity without ecologically damaging consequences. Quantification of effects is a significant aspect of the research. In 1995, research focused on the management of nutrients from organic and inorganic sources, and on vegetable production from two systems designed for small-scale producers.

Vegetables have nutrient requirements that are large and which often must be met in brief growth phases. To meet these requirements, farmers apply excessive quantities of nutrients from inorganic and organic sources. A major focus of soil fertility research in 1995 was to quantify the availability of nutrients from selected agricultural wastes, to determine the fate of inorganic N applied to sequences of vegetables in which the animal waste was also a source, and to quantify the fixation rates of fertilizer P and K.

Nutrients are recovered by crop root systems and therefore the distribution of root activities have important implications for fertilizer placement and other factors that influence nutrient recovery. Root activities were determined with tracer N in the rows of three solanaceous species. The study was conducted to establish an effective method of quantifying distributions as well as to compare the systems of the three species.

Home gardens have been a focus of research at the center for many years as a source of biodiversity and contributor to a significant proportion of the micronutrient requirements for a family of six in the tropics. Research focus has slightly shifted however, toward the development of new techniques to overcome seasonal deficits in vegetable supply during hot-wet periods and enhance the sustainability of garden production. Over 35 vegetable species were grown on three types of gardens: (1) monoculture, (2) intercropped, and (3) high-raised bed and, wherever possible, the same species were grown or transplanted simultaneously in each garden. No pesticides were used and garden wastes were composted and recycled.

Interest in simple hydroponic systems has grown recently because vegetables produced by this technique are easy to maintain free of pesticides and are protected from many of the vagaries of weather as well. The technology is also suitable for urban production, making the nutritional and economic benefits from small-scale production systems available to city dwellers. In 1995, the effects of alternative nutrient sources on crop productivity and the chemistry of the hydroponics solution were measured.

Contributions of agricultural wastes to N, P, and K uptake

This section contains results from four experiments related by the inclusion in each of organic waste treatments. Yields and nutrient uptakes were determined on treatments in the modified Continuous Cropping Experiment (CCE). Total N and soil organic C as well as soil enzyme activities were measured on selected treatments. In a second experiment, leafy vegetables were grown in a three-crop sequence but with inorganic N and agricultural waste treatments applied only to the first crop. A third experiment, with treatments similar to those of the second, included inorganic P and K treatments to measure responses to these nutrients as well as to inorganic N. In a fourth experiment, common cabbage was used to measure nutrient availabilities from inorganic fertilizers and from agricultural wastes in fresh and composted (with rice straw) forms.

Modifications to the compost treatments of the CCE produced expected changes in total soil N and organic C concentrations: a negligible increase where the "old compost" treatment was continued (OR vs. CR) but a large increase where the "recent compost" treatment was imposed (C+R vs C+C in table 1). Exploratory determinations of selected enzyme activities in soils sampled from the CCE agreed with expectations. These activities are related to the mineralization of wastes and, therefore, to the availabilities of N and P from the wastes.

The effects of compost and P and K treatments on crops in the CCE were shown by cumulative eggplant yields and nutrients in the fruit. Yields and N and P uptake were affected by both the old and recent compost series and by P fertilizer where composts were not applied. The exclusion of old compost had a slight effect on the daily accumulation rate of fruits whereas the exclusion of recent compost had a pronounced effect. Exclusion of P in the absence of all compost had an even larger effect. The analysis

Table 1. Mean concentrations of total N and organic C and available P and K in soils sampled from compost treatments of the Continuous Cropping Experiment, summer 1995

Compost series[a]				Available	
Old	Recent	Total N	Organic C	P	K
		(%)		(mg/kg)	
C	C	0.076	0.48	25	22
O	C	0.168	1.12	102	32
C	R	0.110	0.78	43	26
O	R	0.168	1.18	88	35
	SE mean	0.006	0.05	2.7	1.6

[a] C = control; O = old series continued
R = new series initiated; — compost not applied to the old or recent series

revealed that K did not have an effect similar to that of P on fruit yield even though it had a marked effect on K uptake. Clearly the compost reduced the requirement for N and eliminated the need for P. The need for K was largely met by soil sources.

Nitrogen recovered from inorganic N and waste treatments applied to the second year of a sequence of three leafy vegetables are given in fig. 1. As in the first year, recovery was dominated by the first two crops. The cumulative recoveries by the three crops (61, 38, and 17% for inorganic N, and N in animal wastes and in sugarcane compost, respectively) exceeded the corresponding recoveries of the first year (53, 25, and 9%) probably because N continued to mineralize slowly from the wastes and NH_4^+ fixed by soil minerals was released slowly. In a similar experiment but to which inorganic P and K treatments were incorporated, inorganic N recovery followed a pattern similar to that observed in both years of the previous experiment (fig. 2). P uptake from the inorganic P source was negligible but was significant from the waste sources. Moreover, a yield response

to inorganic P was not detected, indicating that soil P was not deficient whereas a response to inorganic K was significant. Recoveries of K from the inorganic source as well as from the wastes were significant. Among the wastes tested in this experiment and the previous one, poultry manure was most and sugarcane compost was least effective in supplying nutrients.

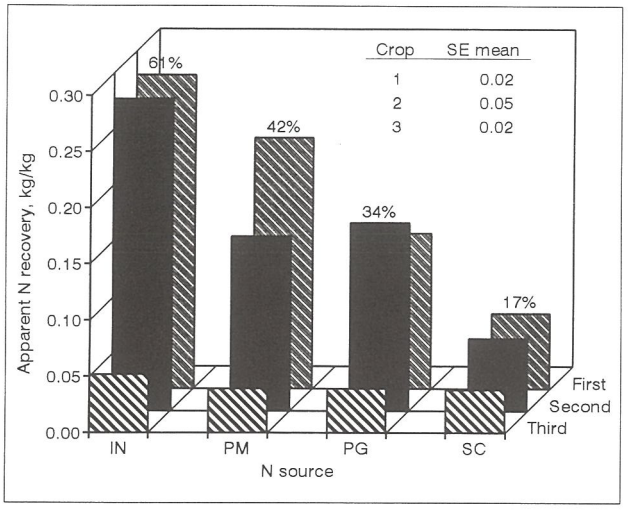


Fig. 1. Apparent N recovery from inorganic N and waste sources by three successive leafy vegetable crops (IN = inorganic N, PM = poultry manure, PG = composted pig manure, SC=sugarcane compost)
Values above bars are total apparent recoveries summed for the three crops

In an experiment in which common cabbage (75 days in the field) was the test crop, apparent N recovery from an inorganic source was 80% whereas apparent N recovered from wastes was only 31%. This smaller N recovery, however, generally agreed with cumulative recoveries by the sequences of three leafy vegetables (sugarcane compost was not a treatment in the experiment on common cabbage). Likewise, yield response to inorganic P was negligible. A small but significant percentage (2.3%) of P from the wastes was recovered, however. The 67% apparent K recovery from the inorganic source was in the expected range. The 101% recovery from the waste

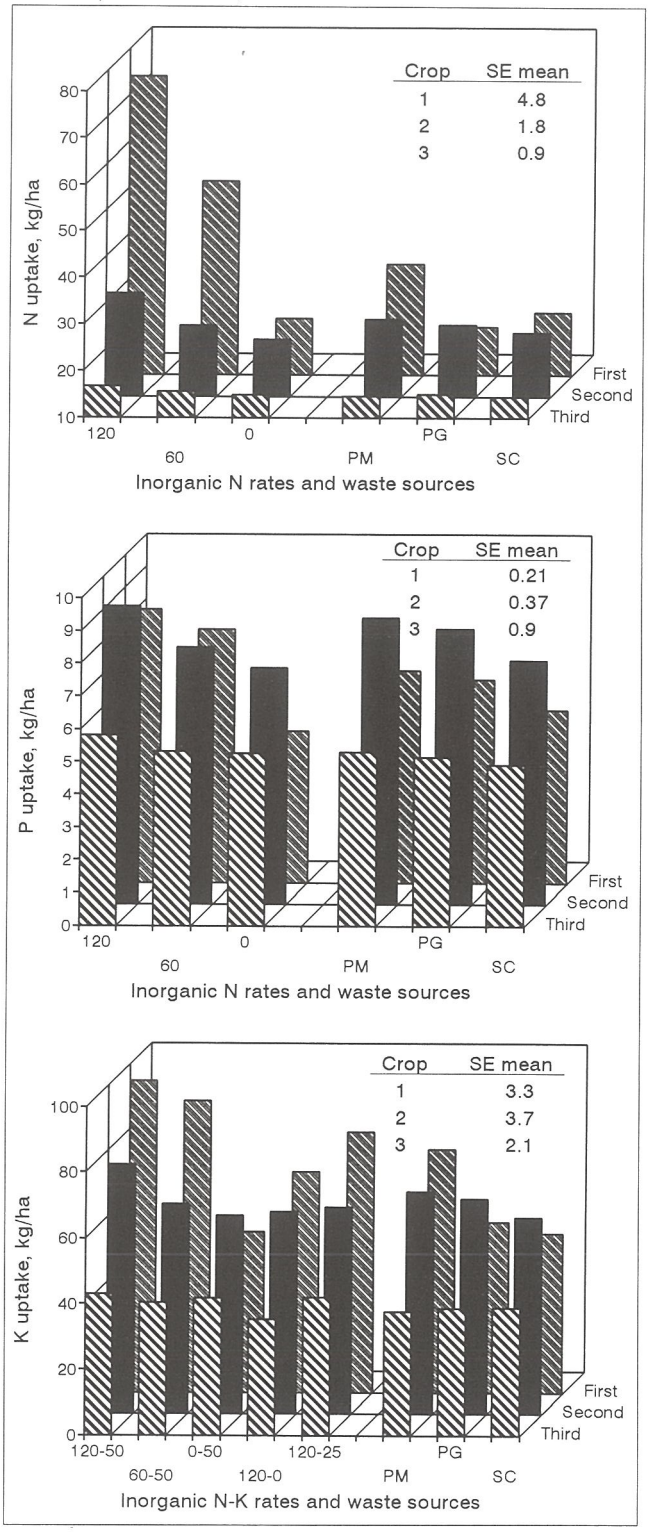


Fig. 2. N, P, and K uptake from inorganic and waste sources by three successive crops of kangkong
Only treatments that contributed significantly to the explanation of the uptake of each nutrient (PM = dried poultry manure, PG = composted pig manure, SC = sugarcane compost) are shown

sources (including crotalaria used as a proxy for a nutrient-rich residue from a well fertilized vegetable crop) exceeded expectations but confirmed observations from the leafy vegetable experiments that apparent recovery of K contained in wastes exceeded recoveries from inorganic K sources.

Recovery of K, depletion of exchangeable K, and K and NH_4-N fixation

Trends of K uptake from CCE control, compost, and K treatments were examined by regression analysis.

Cumulative K uptake clearly diverged with time (fig. 3). Differences in K uptake before and after crop number 12 were evident in the regression coefficients regardless of K or compost treatment.

Analyses of exchangeable K in the surface soil of the "without compost, minus K" treatment for the corresponding interval showed that availability decreased asymptotically from 38 to 20 mg K/kg soil (fig. 4). Even the largest ex (exchangeable) K concentration (38 mg/kg) would be deficient in most soils. Although uptake decreased, the effect of K treatments on relative yields was seldom significant.

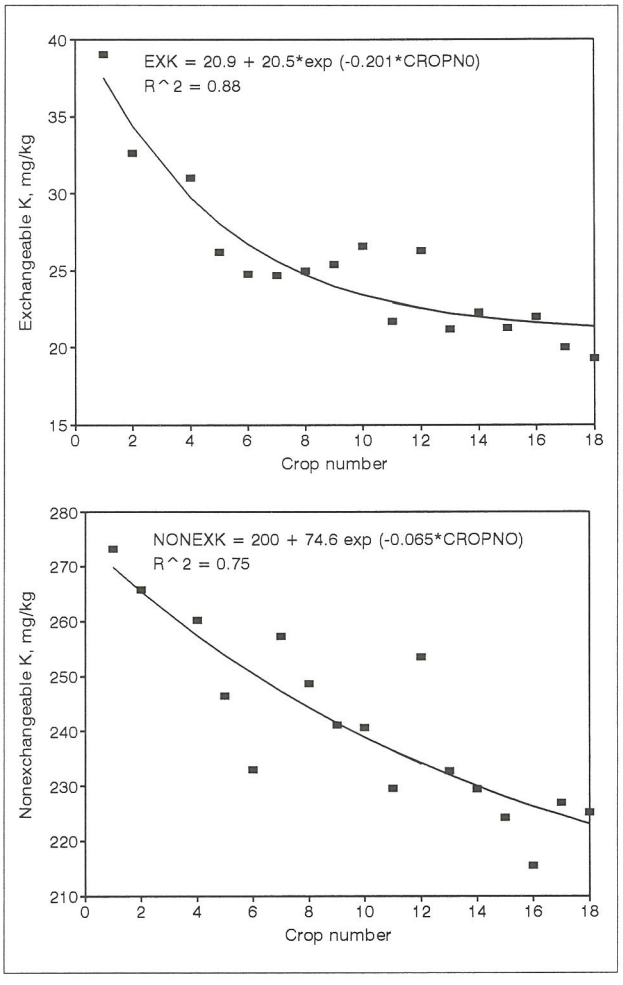


Fig. 4. Exchangeable soil K in the "minus compost, minus K" treatment of the Continuous Cropping Experiment Observations: filled boxes; estimations: line

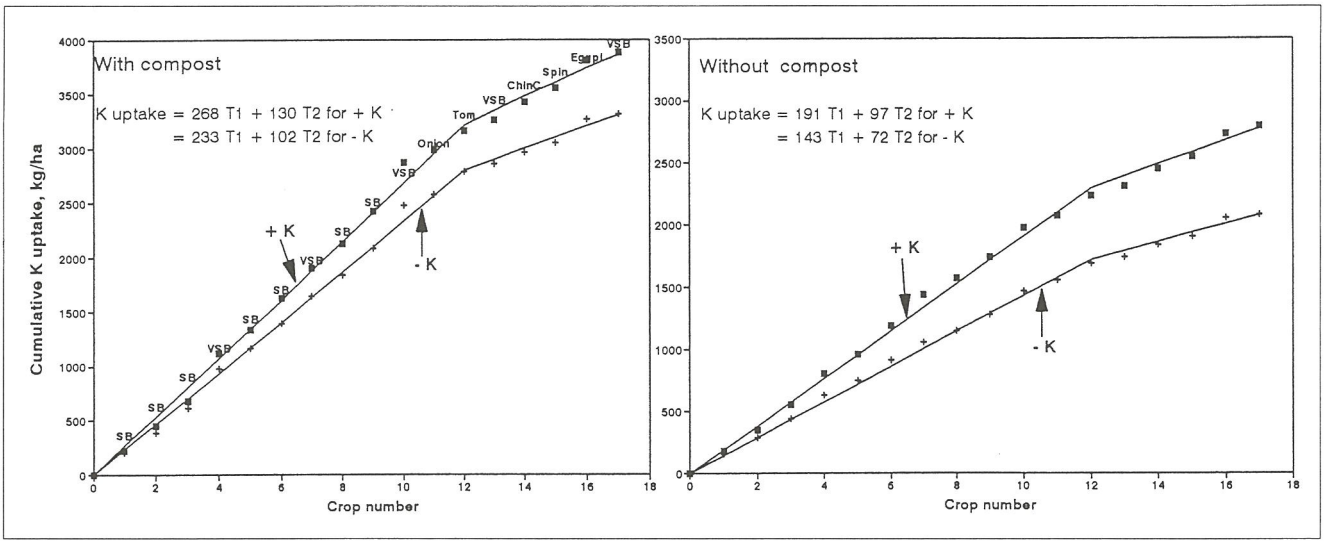


Fig. 3. Cumulative potassium uptake from compost treatments in the Continuous Cultivation Experiment with and without inorganic K

(V) SB = (vegetable) soybean, TOM = tomato,CHINC = Chinese cabbage, SPIN = spinach

R^2 exceeded 0.99 for all regressions. T1 was crop number to 12, T2 was crop number beyond 12

An available but nonex (nonexchangeable) K pool was suspected as a source of the nutrient in the "without compost, minus inorganic K" treatment. Moreover, if abundant K^+ was found in a nonex pool, NH_4^+ should be as well. Table 2 shows concentrations of K^+ and NH^+-N pools in soils sampled at two depths from an experiment on leafy vegetables. In this experiment, a sequence of six crops was harvested without application of K but with application of NH_4^+ to some treatments. Ex K was well below a deficient level but nonex K over the two depths averaged an order of magnitude greater. Slow but steady release from this pool probably explains why K deficiencies did not occur. It is evident from fig. 3 that nonex K decreased with crop number like ex K did.

Table 2. Mean extractable and nonexchangeable K^+ and NH_4^+-N concentrations in surface and subsurface soils

	Depth (cm)		
	0-15	40-55	Difference
Potassium	(mg/kg)		
Labile[a]	12.2	3.4	**
Exchangeable[b]	29.0	21.6	**
Nonexchangeable[c]	234.0	280.9	ns
Nitrogen			
Extractable[d]	4.8	1.8	**
Nonexchangeable[e]	227.3	299.5	*

[a] Extracted with 0.01 M $CaCl_2$ after equilibration for 7 days
[b] Extracted with 1 M NH_4Cl (labile K deducted)
[c] Extracted with boiling 1 M HNO_3 (labile and ex K deducted)
[d] Extracted with 2 M KCl. The nitrate of the extractable N portion averaged 81% in the surface but only 45% in the subsurface soil
[e] Extracted with KOBr + HF + HCl

Evaluation of a quick test to measure P fixation

Fifty soils were incubated with P at four rates. Available P was extracted after progressively longer intervals up to 120 days with either Bray (HCl, NH_4F) or Olsen ($NaHCO_3$) solutions, depending on soil properties. For each soil, the set of available P determinations were fit to the following model: $AVP = AVP0*\{\exp[(\ln(DI+1)]^{V1}\}^{B1}*PRATE^{B1}$ where AVP was available P (mg P/kg soil), DI was days of incubation, and PRATE was mg P applied/kg soil. For all soils, the coefficients of determination exceeded 90% and exhibited relationships with time and P rate that were similar to those for soil No.75. (fig. 5) For each soil, AVP was estimated at 60 mg P/kg after a 5-day incubation. These estimates were correlated with available P (Bray solution) remaining after the 2-h incubation (1 ml solution in 2 g soil) (fig. 6). The overall simple correlation was only 0.74 but the correlation for available P estimated for soils fitted to Bray P data exhibited closer agreement (r = 0.95).

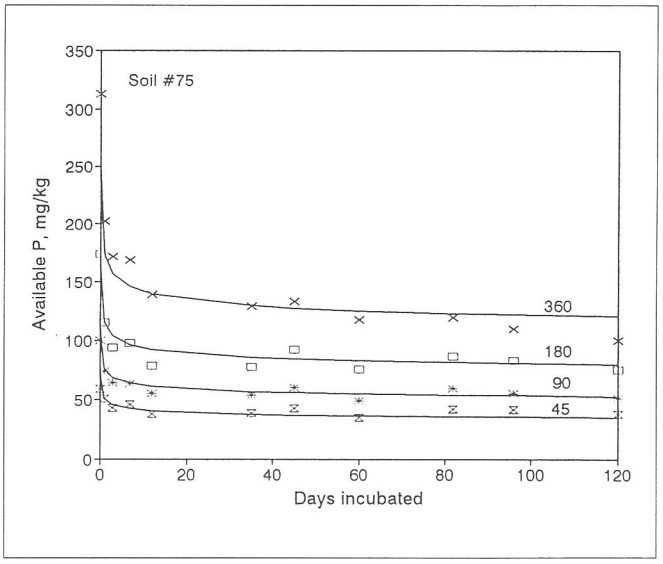


Fig. 5. Estimated P sorption curves for 45 to 360 mg applied P/kg oven-dry soil

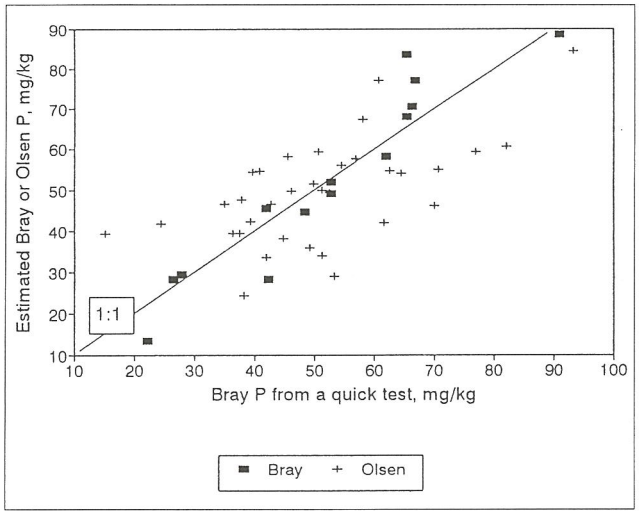


Fig. 6. Correspondence between Bray P from a quick test for fixation vs. Bray or Olsen P estimated from regression models (functions of P rate and time) for each soil
Two soils with available P exceeding 100 mg/kg were excluded from the 50 on which tests were conducted

Impacts of intensive nitrogen nutrition management on vegetable cultivation and the environment

Nitrogen balance for vegetables Efficiency of use of N fertilizers by crops continues to be of major agronomic interest. To reduce the detrimental effects of N fertilizer on the environment, it is important to maximize the efficiency of N uptake by plants. However, to achieve further improvements in using N in vegetable production, more precise data is needed for the N balance accounts. To obtain reliable balance accounts, a calculation has to be done with equal precision between N inputs and outputs. Using ^{15}N as a tracer is a precise way to quantify the balance. The calculation of the amount of N taken up in plants and that added as a fertilizer and pig manure is shown in fig. 7. Inputs and outputs from three different cropping systems (I. onion - soybean - rice, II. processing tomato - Chinese cabbage - rice, III. Chinese cabbage - cherry tomato - rice) varied. Unlike that in paddy rice N recovery by Chinese cabbage, tomato, and onion do not exceed the additions, especially in the plots of pig manure where values are much less than supply. The smaller the balance, the less is the chance of N losses. Poor fertilizer efficiency as a result of losses is assumed to be responsible for this reversal in the N balance.

Estimation of biological N_2 fixation by legume Obviously, methods that will increase N_2 fixation will result in greater net N input for vegetable production. The N balance in soybean clearly showed a negative value. This imbalance is attributed to biological N fixation (fig. 8). Using the ^{15}N isotope dilution principle the amount of N derived from the atmosphere was calculated to be 38% which is equivalent to 52 N kg/ha in chemical fertilizer. These values, however, declined to as low as 18% or 29 kg/ha, when pig manure was applied, probably due to the large amount of N supplied from the manure which was calculated to be 42 N kg/ha. Thus, use of legumes to enhance the levels of biological N_2 fixation not only helps to lessen the need for N fertilizer, but also helps to maintain the sustainability of vegetable production.

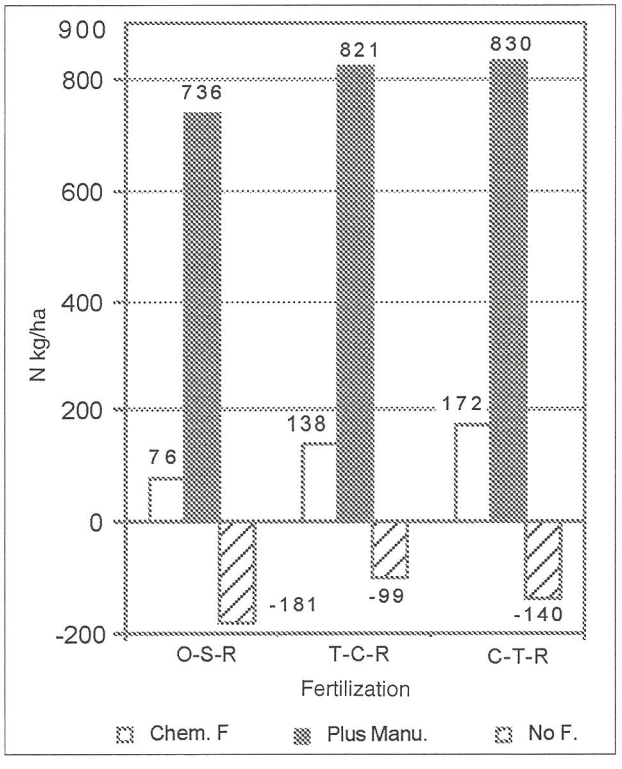


Fig. 7. N balance in different cropping systems

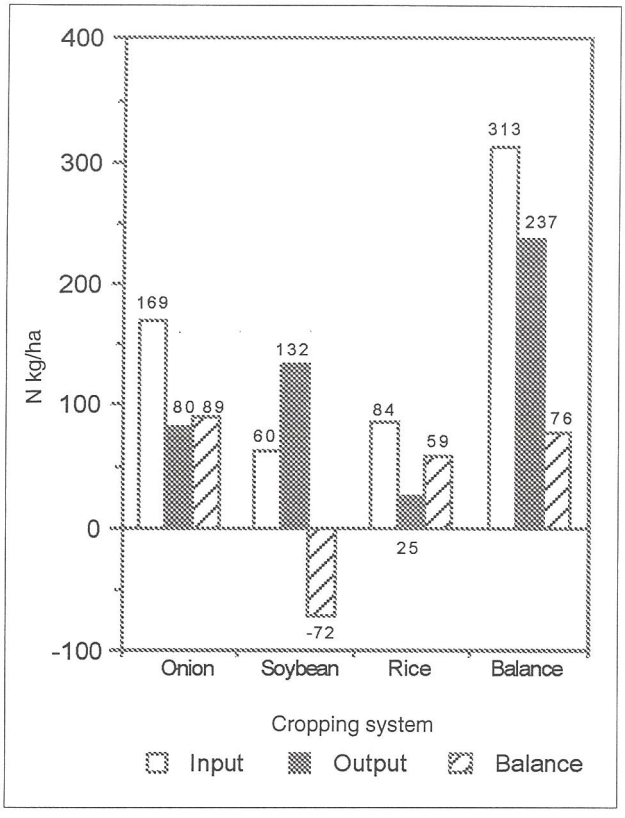


Fig. 8. N balance in onion-soybean-rice (chemical fertilizer plot) cropping system

Uptake efficiency of pig manure-N by vegetables Because organic fertilizer is limited, chemical fertilizer supply has to be increased. In vegetable cultivation organic N sources such as animal manure or organic fertilizers are extensively used combined with inorganic chemical fertilizers. It is, however, difficult to assess the net recoveries of organic N sources and distinguish the N from both chemical fertilizer and soil sources. The ^{15}N isotope dilution principle helped to measure recovery rates of N in pig manure by vegetable crops. These rates were less than those of chemical fertilizer, and also varied remarkably with different vegetable species and seasons. Soybean was found to depend more on inorganic N than organic N, whereas tomato depends on both sources equally. Chinese cabbage and onion depend less on organic N than inorganic N. It is clear that there is a large room for improving N efficiency in the tomato plant.

Residual effect of fertilizer N In vegetable cultivation, vegetable crops utilize only part of the large amounts of fertilizer N applied so that considerable quantities of fertilizer N remain in the soil after harvesting. Therefore, the residual effect of fertilizer N for succeeding crops has become a matter of increasing importance. It is, however, difficult to detect residual effect of fertilizer N. The ^{15}N tracer technique can quantify this effect.

The second crop recovered 2-7% of fertilizer N applied in the first crop, but only 0.1-0.5% in the third crop.

These results indicated that in the second crop it was necessary to take into account the residual effect of fertilizer N in the preceding first crop but the effect is negligible in succeeding third crops.

Effect of Mo spray on reducing nitrate content in vegetable tissues The amount of nitrate in vegetables is an important index of food quality, as an excess is harmful to human health. Vegetables are the main sources of nitrate in human food. However, large differences in nitrate content were observed among vegetable crops (table 3). Since molybdenum (Mo) is a key component of nitrate reductase, a hydroponic experiment with three different N sources was carried out to clarify the effectiveness of Mo spray in reducing nitrate content in Chinese cabbage. The effect of molybdenum spray application on reducing excessive nitrate accumulation in Chinese cabbage was clearly observed except in the ammonium plot as shown in fig. 9.

Studies on effective root zone of vegetables

Root development in vegetable crops has received relatively little attention. This is because roots are hidden from sight and are the most difficult part to study. Usually, excavations are done to collect root samples. This kind of work is difficult and does not give satisfactory results, because small root hairs and

Table 3. Nitrate contents in fresh vegetables

Vegetables	Plant part	NO_3 ppm
Leafy & flower vegetables		
Common cabbage	Whole	618
Chinese cabbage	Inner	1,736
	Outer	1,994
Kangkong	Stem	4,703
	Leaves	1,435
Pai-tsai	Whole	2,596
Spinach	Whole	1,527
Cauliflower	Stem	1,005
	Flower	237
Fruit vegetables		
Bell pepper	Whole	136
Bitter gourd	Whole	661
Cucumber	Whole	274
Tomato	whole	4
Bulb & root vegetables		
Onion	Whole	29
Carrot	Whole	124
Radish	Whole	2,338

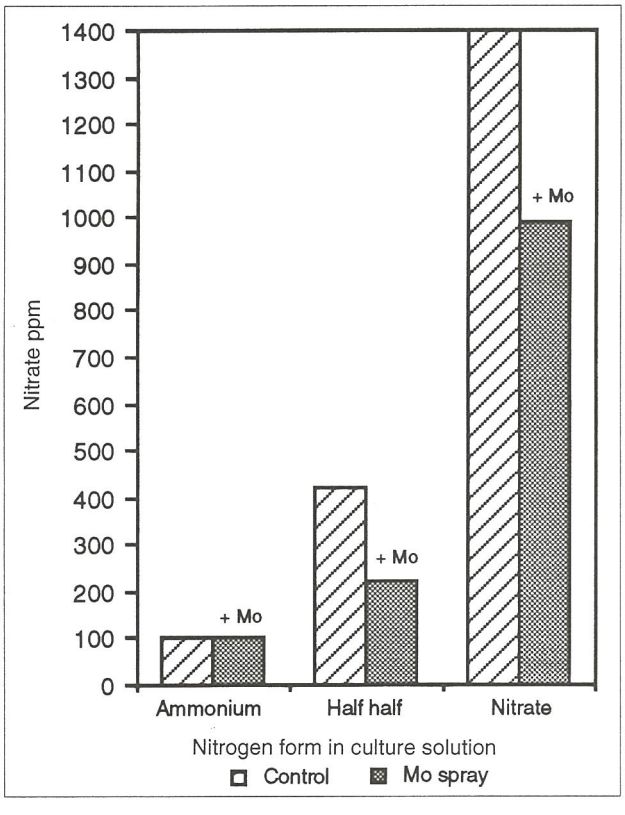


Fig. 9. Effect of Mo spray on the nitrate tissue content of Chinese cabbage

fine roots which absorb the major nutrients are difficult to separate from soil particles. Hence, large sampling losses cannot be avoided.

Development of ^{15}N soil injection method Nowadays, nuclear techniques are being used and improved for agricultural research. Many isotopes have been used for root studies. Based on the concept that the isotope content of the sample leaf reflects the root activity in the area in which the isotope is applied, subsequent isotope assay in the leaf sample will provide the delineated root activity pattern with a given isotope. A ^{15}N soil injection method was developed to study the effective root zone of vegetables. A small amount of liquid agar solution containing a high enriched ^{15}N stable isotope was injected into the soil to measure root activities of pepper, tomato, and eggplant, at six different distances from the plant and four or five depths. After 14 days of injection, leaf samples were collected from the middle part of the plant height and subjected to isotope analysis by using Tracer MAT mass-spectrometer. Data were expressed as relative activity. The basic requirements for successful application of the injection method are that the ^{15}N solution remains at the place of injection. By using the dye technique, dispersion of injected solution was tested. The dye in the soil took the clod shape or dispersed horizontally, but not too far from the injection point. The solution was observed to run down along the crack of the soil. This cannot be avoided in root studies. The advantages of this method are it obviates the difficulty of root sampling and gives a quantitative measure of the actual feeding zone irrespective of the overall morphology.

Root activity in various vegetable systems Root activity defined by this method is evaluated by measuring plant uptake of tracer ^{15}N from the soil at each injection location as a function of tracing time. The root activity to be measured by this method thus expresses the ability to absorb nutrients from a unit volume of soil mass at each injection location.

Root activity distribution in soil differs according to vegetable species. However, the physiological response of the root to the soil environment is also a significant factor.

Thus, positioning the fertilizer in the soil to match the individual root system of the species should be a promising method to supply fertilizer nutrients to the vegetables with minimum losses.

Root activity distribution in tomato expressed as relative activity was determined at flowering stage (30-40 days after transplanting) as shown in fig. 10. The highest root activity distribution occurred 7 cm away from the plant and at depths of 20 cm. The most active root zone was divided into two parts: upper and lower, with the upper part located at a shallow soil layer of 8 cm depth and lateral spread reaching more than 20 cm away from the plant. This can be well explained by the fact that at early growth stage the prominent part of the root system consisted of very abundant laterals. The lower part of the root is located deeply, more than 20 cm (20 cm depth is the deepest testing point) and spreads laterally up to 23 cm away from the plant.

In eggplant at flowering stage (30-40 days after transplanting), active roots spread both outward and downward. Consequently, total area of most active roots was bigger than in tomato. It seems that the total absorbing surface of root for eggplant was larger than that of tomato or pepper. Observation by excavation showed that the underground parts were characterized by a strong taproot which, with its deeper branches, furnished nutrients to the major absorbing area. This agreed with the results of the study using the ^{15}N isotope tracer technique. The highest relative activity (100%) was at a 10-cm distance from the eggplant and at the plowed soil layer of 13-cm depth. The root characteristics of old eggplant (70-80 days after transplanting) differed from those of the younger plants at flowering stage. Highest root activity was observed below the stem. The widest active root was at the 20-cm depth and the highest relative activity shifted downwards with depth. Root activity was less the farther the root from the stem. Forty centimeters away from the plant, the relative activity at 0-8 cm depth was only 1.

In pepper at flowering stage the most active root activity occurred below the stem at the13-cm depth,

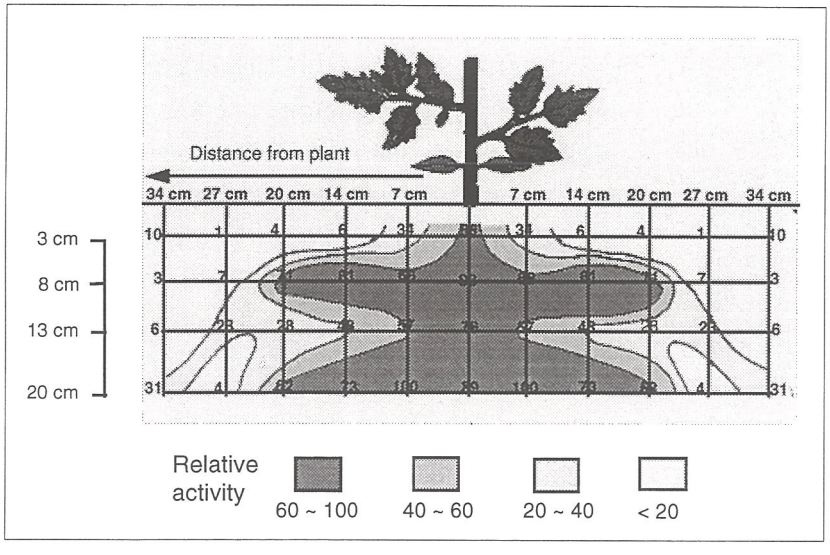


Fig. 10. Determination of root activity distribution of tomato using ^{15}N isotope as tracer at flowering stage

Samples were taken from middle position leaves and data were expressed as relative activity

and the highest root activity was in a triangle shape. However, unlike its relatives, tomato and eggplant, active root distribution in pepper grew less and less the farther away from the plant. This is because most of the pepper roots spread rather vertically. Usually main roots of pepper penetrate downward to a maximum depth of 60 cm. Considering the underground part, its high root activity zone is narrow and located below the plant stem at a rather deeper soil layer.

Management of vegetable soybean

This activity aimed to quantify the long-term benefits of incorporating vegetable soybean (VSB) into a vegetable crop rotation.

The effect of residue return of vegetable soybean on the yield of the following crop was evaluated in rotation with different vegetable species such as Chinese cabbage, kangkong, tomato, buckwheat, lettuce, and spinach. The experiment was started in spring 1991 and terminated in spring 1995. Vegetable soybean was planted twice a year, in spring and autumn. Soil and plant samples were collected after harvest to determine N uptake by each species and soil N status. The vegetable yields were also recorded for data analysis.

Neither the yields of the following crops (Chinese cabbage, kangkong, tomato, buckwheat, lettuce, and spinach) nor the soil N content was increased by the continuous incorporation of vegetable soybean residues (table 6). Rotation with VSB dramatically reduced the yield of kangkong compared to the rotation with corn (fig. 11). Although the amount of total N uptake by VSB reached nearly 200 kg/ha, 75% of that was accumulated in its pod and seed, hence returning the residue to the soil did not effectively increase the soil N. In addition, atmospheric N fixation by VSB is, in most cases, not high enough to support its high yield, and it frequently consumes more soil/or fertilizer N than other crops.

Spring planting associated with a long duration always produced dry matter substantially higher than autumn planting with a short duration due to a sharp decrease in temperature at the later growth stage. There was a linear correlation between N uptake by VSB and VSB's total dry matter production over the four years of cultivation.

Studies on simple hydroponics

AVRDC is developing simple systems that are well-adapted to local conditions and that can provide safe vegetables for consumption.

The AVRDC noncirculating hydroponic system has successfully grown a variety of leafy vegetables without any check of pH, EC, nor any additional supply of nutrient. In 1995, the performance of four chemical mixtures were compared with the AVRDC standard solution for the nutrient solution. Five vegetable species, i.e., pai-tsai, kangkong, lettuce (two varieties), and mustard were cultivated by turns, with the five chemical mixtures all year-round. Kangkong was also grown successively up to four harvests without replacing the media nor emptying surplus solution after each harvest. Two locally available fertilizer mixtures, (1) solid compound fertilizer mixture (Taiwan Fertilizer Co. CF No. 1, 5, and 43), and (2) Yeou Fa straight fertilizer (YHSF) mixture were used for the continuous kangkong cultivation at different application rates. In cooperation with the Far Eastern College (Tainan, Taiwan), the nutrient solution from each hydroponic box was sampled at both transplanting and harvesting times. The major nutrient elements were analyzed on these samples to determine nutrient uptake by each vegetable species.

Both mixtures produced similar yields of kangkong as the standard solution. TFCF linearly decreased kangkong yield by decreasing its application rate, but YHSF did not show such a trend. TFCF sharply decreased the solution pH due to high NH_4-N content, as the frequency of the kangkong cultivation increased.

Table 6. Effect of incorporation of vegetable soybean residues on the succeeding crop yields and soil N content

Cropping system		Vegetable soybean residue[a] incorporated			removed	
1991	VSB	21.4	(9.0)		21.0	(8.9)
	CC	4.6			5.0	
	KK	7.3			7.1	
	VSB	14.8	(5.9)		14.2	(5.8)
	TM	31.0			29.5	
1992	VSB	19.3	(9.8)		18.6	(9.2)
	CC	4.7			4.29	
	KK	15.8			15.70	
	Soil N[b]	1461			1442	
	VSB	15.5	(6.9)		15.2	(6.8)
	Buckwheat	9.5			8.44	
1993	VSB	20.4	(8.4)		20.16	(8.3)
	CC	18.4			18.9	
	KK	13.6			13.7	
	Soil N	1320			1280	
	VSB	17.7	(13.9)		17.6	(13.6)
	Spinach	21.4			21.2	
	Lettuce	43.6			42.9	
	Soil N	1840			1280	
1994	VSB	19.5	(9.0)	**	18.52	(8.3)
	CC	8.8			7.4	
	KK	14.8		**	11.5	
	Soil N	1300		*	1220	
	VSB	16.4	(7.0)		16.0	(6.7)
	Spinach	19.2			18.9	
	Soil N	1400			1340	

[a] Amount of plant residues (t/ha) in fresh weight
[b] Soil N (kg/ha)

* significant at 5% level
** significant at 1% level

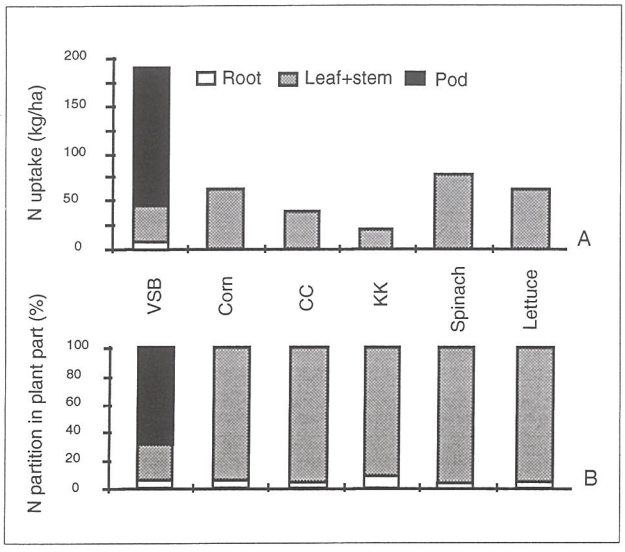


Fig. 11. N uptake by various vegetables (A) and N partition in each plant part (B) in vegetable soybean based-rotation system

The five chemical mixtures including the AVRDC standard solution did not show any significant difference in yields of five different vegetable species. When the same species was grown using hydroponic system in different seasons, the dry matter production per unit water consumption in the autumn and winter planting was nearly six times as much as that in the summer planting without regard to species grown. Both high evapotranspiration rate and high transpiration loss are responsible for this inefficiency in water consumption in the summer planting.

Enhancing biodiversity through home gardens

The center continues to conduct research on home gardens. The role of home gardening as a source of biodiversity and contributor to a significant proportion of the micronutrient requirements for a family of six in the tropics was assessed. Since the middle of 1995, however, research focus has slightly shifted toward development of new techniques to (1) overcome seasonal deficit in vegetable supply during hot-wet periods, and (2) enhance the sustainablility of garden production.

Over 35 vegetable species were grown on three types of gardens, (1) monoculture, (2) intercropped, and (3) high-raised bed and, wherever possible, the same species were grown or transplanted simultaneously in each garden. Each garden type was replicated twice. No pesticides were used. Garden wastes were composted and recycled.

Total edible outputs of the corresponding gardens were 13.8, 12.6, and 7.4 kg/m^2 (table 7). From the high-bed garden, 3.1 mg of vitamin A, 368 mg vitamin C, 23 g protein, 16.6 mg iron, and 756 mg calcium were obtained per square meter on a yearly production basis. The intercrop garden produced almost the same amount of the relevant nutrients except protein (19.5 g) as the high bed, but only 60% of these was recovered in the monocrop.

Seasonal variation of vegetable output from the AVRDC gardens was substantial, and their productivities were greatly reduced due to hot-wet weather in summer to autumn (fig. 12).

The total output gradually decreased with the cultivating years, and in the third year the monocrop garden produced only 75 % of the first year's output. Consequently, both enhancing sustainability and minimizing seasonal variation in vegetable production need to be resolved.

Table 7. Relevant nutritients obtained from the high-raised bed garden on a yearly basis

Species	Edible (g)	Vit. A (mg)	Vit. C (mg)	Protein (g)	Iron (mg)	Calcium (mg)
1. Amaranth	4.8	1.6	121	10.0	10.2	1072
2. Broccoli	15.5	2.7	568	34.4	9.2	401
3. Chinese cabbage	15.2	3.4	467	15.0	22.9	898
4. Carrot	5.9	10.1	64	6.2	13.0	223
5. Celery	20.2	0.2	188	6.0	13.4	851
6. Coriander	4.6	2.5	393	9.9	23.2	370
7. Kangkong	14.0	7.0	393	28.3	24.2	870
8. Leeks	11.8	4.5	173	19.8	21.9	793
9. Lettuce	16.4	2.6	184	10.9	34.4	747
10. Mustard	10.6	2.4	886	18.6	15.5	1,383
11. Pai-tsai	17.6	1.2	521	12.2	12.8	1,674
12. Sweet corn	12.1	6.1	289	90.0	21.2	756
13. Veg. soybean seeds	0.5	0.1	39	34.8	12.2	37
14. Others	98.7	10.7	2,337	117.9	65.4	3,537
Total/18 m^2	248.0	55.0	6,620	413.9	299.4	13,612
Total/m^2	137.8	3.1	368	23.0	16.6	756

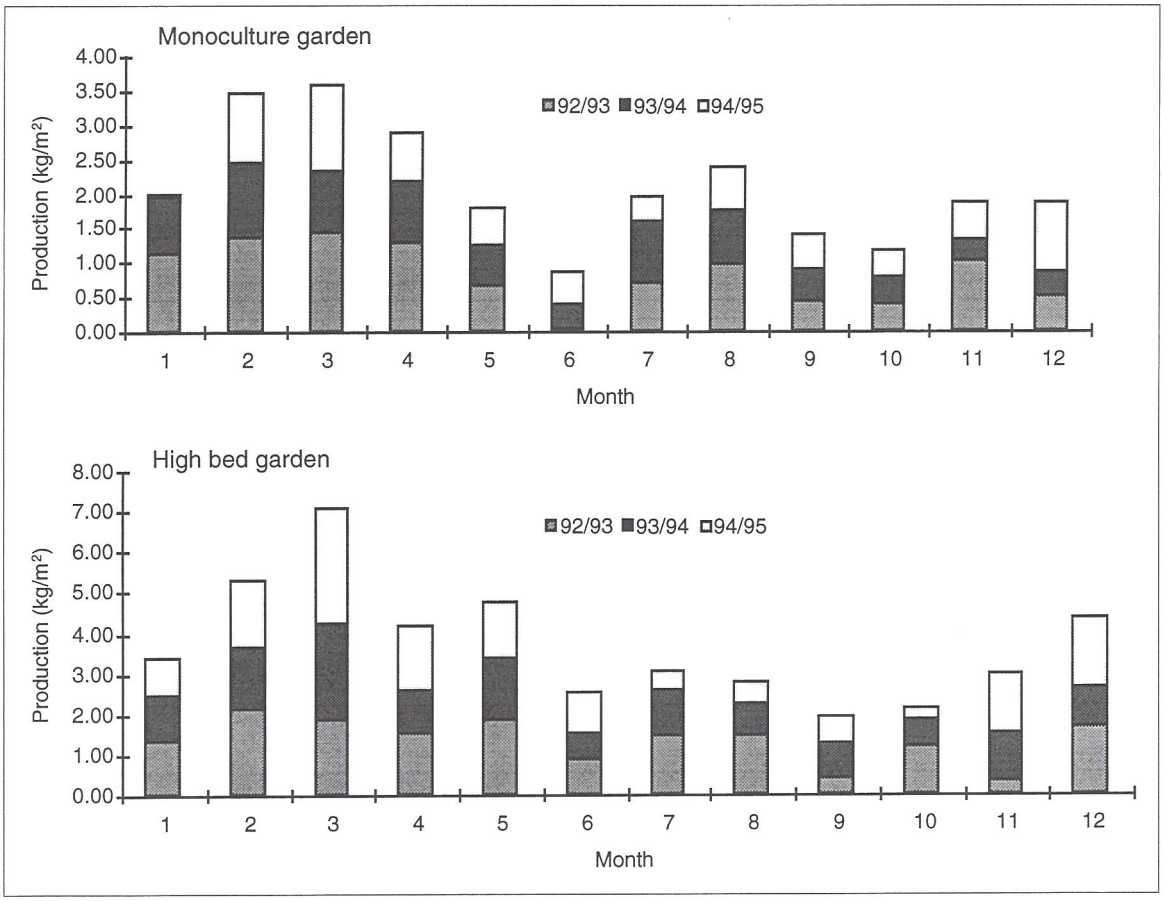


Fig. 12. Seasonal variation in vegetable production in AVRDC gardens, 1992-95

OVERCOMING SEASONAL STRESSES OF PRODUCTION

The yields as well as kinds of vegetables producible in summer decrease sharply in the lowland humid tropics due to both high temperature and flooding. Even AVRDC advanced lines of heading crucifers and fruit vegetables do not possess a satisfactory level of heat and flood tolerance. Heavy pressure of diseases and insects associated with high temperature and humidity further aggravates this situation, resulting in substantial yield loss in summer vegetables.

This project aims to develop integrated technology to overcome seasonal stresses and to enhance vegetable production in an environmentally acceptable manner during hot and wet periods in the lowland tropics. Through appropriate crop, and soil and water management, both the aerial and edaphic environments will be better tuned to vegetable production. New and traditional techniques are assessed independently and/or in combination to see how effective they are in enhancing summer vegetable production. Finally, economically viable and sustainable vegetable-based systems for production in the lowland tropics will be proposed.

Increase in fruit setting of summer tomato by hormone spray

Even AVRDC's advanced lines do not show a satisfactory level of heat tolerance to overcome the tropical summer heat for a high fruit setting rate. Hormones such as tomatotone and gibberellin are well-known to increase the fruit setting rate of fruit vegetables to a great extent and the hormone spray is a common practice among farmers in developed countries.

This activity examines the effect of the hormone spray on the fruit setting rate of cherry tomato in hot-wet summer cultivation.

Two tomato varieties, Known-You Santa and AVRDC CHT 154, were used in this trial. The seedlings were transplanted to the experimental plot on 17 July. Two different concentrations of gibberellin (5 and 10 ppm) were sprayed alone or by mixing with tomatotone (10 ppm) two times a week starting on 4 August when a couple of flowers in the first cluster began to bloom.

Tomatotone application increased all the fruit-related characters significantly. The fruit setting rate increased by 20% using the spray (table 1). Both 5 ppm and 10 ppm of the GA3 spray also increased the fruit setting rate and fruit yield dramatically, but 5 ppm GA3 gave better results than 10 ppm. The 5 ppm GA3 spray at the time of full bloom of the third flower in each cluster gave the best fruit setting in both varieties, but the treatment caused a decrease in the fruit length-width ratio. Seed became smaller due to the hormone spray. A slightly positive interaction was observed in the fruit setting rate between both the hormones at

5 ppm while there was a small negative interaction between them in the fruit yield. It is, therefore, highly recommended that either 5 ppm of GA3 or 10 ppm of tomatotone be sprayed at the time of full bloom of the third flower.

Integrated cropping systems for year-round intensive vegetable production in the lowland tropics

This activity aims to study the reduction of seasonal variation in vegetable production in tropical, rice-based lowlands through permanent high beds and introduce the N_{min}-method to maintain productivity, but minimize N-fertilizer application and reduce nitrate leaching.

From 1993 to 1995, the feasibility of permanent high beds (50 cm high) and N_{min}-method (reduction of the N-fertilizer rate by the amount of soil-NO_3 before application) was compared to standard practices (20-25-cm-high flat beds and the recommended N-fertilizer rate) in intensive, year-round vegetable production of four species (table 2).

Permanent high beds successfully alleviated the negative impacts of overwet soil conditions in the rainy season. Crops developed profound root systems and absorbed available soil nitrate effectively. Consequently, yields were significantly higher compared to traditional flat beds, and less nitrate leached below the root zone. Rainy season conditions induced water stress and shallow root systems on flat beds. Water stress in the rainy season and accumulation of soil nitrate during the dry season with negligible leaching were responsible for the success of the N_{min}-method on flat beds. About 600 kg or 56% N was saved without significantly affecting yields, but reducing nitrate leaching. The greater biomass and yield potential of vegetables could, however, not be sustained with the N_{min}-method on high beds.

Table 1. Effect of application of tomatotone and/or GA3 on fruit setting

Treatment	Fruit yield (kg/plant)	Fruit setting rate (%)	Fruit length-width ratio	No. of seed/ fruit
Variety	**	ns	**	**
CHT 154	23.6	52.6	1.69	67.2
CHT Santa	16.2	51.7	1.78	53.8
Tomatotone	**	**	**	**
1 (-)	14.7	42.0	1.67	54.7
2 (+)	25.1	62.3	1.79	66.4
GA3	*	**	ns (pr. = 0.065)	*
0 ppm	17.4b	32.0b	1.75ab	65.7a
5 ppm	22.5a	64.2a	1.68b	56.8b
10 ppm	19.8ab	60.3a	1.76a	59.7b

* (0.05 > P)
** (0.01 > P)

Table 2. Marketable yield (kg/m^2) of vegetables as influenced by different bed heights (flat bed, high bed) and fertilizer rate (N_{min}, standard)

	1993			1994			1995		
	Chinese cabbage	Chili	Carrot	Veg. soybean	Chinese cabbage	Chili	Carrot	Veg. soybean	Chinese cabbage
Analysis of variance									
Flat bed									
N_{min}	1.49 a	0.20 a	1.40 a	1.19 a	0.19a	0.07a	3.00a	0.88a	1.80b
Standard	1.37a	0.22a	1.29a	1.26a	0.75a	0.17a	3.06a	0.89a	2.43a
High bed									
N_{min}	2.14a	0.53b	1.16a	1.05b	1.32b	0.29b	2.99b	1.28a	1.32b
Standard	2.10a	0.62a	1.10a	1.10a	1.99a	0.36a	3.24a	1.31a	3.07a
Comparison, probability of no difference									
High bed vs. flat bed	< 0.01	< 0.01	0.13	< 0.01	< 0.01	< 0.01	0.43	< 0.01	< 0.01
N_{min} vs. standard	0.31	0.04	0.39	0.06	< 0.01	< 0.001	< 0.001	0.23	< 0.01

MANAGEMENT OF INSECTS AND PLANT DISEASES

Insect pests and plant diseases are major economic constraints in vegetable production in the tropics and subtropics. To combat these biotic constraints, AVRDC is developing technology, in addition to host-plant resistance, which emphasizes a combination of biological control, cultural control, and sex pheromones, with 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, it significantly reduces cost of production and makes available to consumers good quality vegetables. At the same time, it also reduces the risk that chemicals pose to humans and the environment.

AVRDC's past IPM research focused mainly on the control of diamondback moth (DBM), *Plutella xylostella* (L.), a destructive pest of crucifers in the cool-dry season. During the past few years, however, in addition to DBM the control of associated insect pests in the hot-wet season was also studied and technologies to combat the whole crucifer pest complex were investigated. The IPM technologies included use of parasites, predators, sex pheromone, biological insecticides based on *Bacillus thuringiensis*, and minimum use of chemical pesticides.

During these years IPM of soil-borne diseases emphasized the use of soil amendments that have shown promise in reducing population of soil pathogens, antagonistic microorganisms combined with crop rotation practices, and use of moderately resistant cultivars to control economically important plant diseases such as bacterial wilt and Fusarium wilt. These diseases are major problems in solanaceous and other important crops in the tropics.

Integrated management of crucifer pests in the cool-dry season

In the cool-dry season, DBM is far more destructive on crucifers than all other species throughout Asia. AVRDC's past research emphasized control of only DBM in the cool-dry season.

Four 0.05-ha parcels of land were transplanted to common cabbage. At 1 and 5 weeks after transplanting 100 pairs of DBM adults were released in each parcel to augment ambient low pest population. Starting 1 week after first DBM release, 1000 *Cotesia plutellae* adults were introduced in one parcel, 4000 larvae of *Mallada basalis* in the second, and 1000 *C. plutellae* and 4000 *M. basalis* in the third parcel. The fourth parcel was maintained as a check.

Natural enemies were introduced again in identical fashion 4, 6, and 8 weeks after transplanting. Thirty randomly selected plants in each parcel were observed and the number of DBM larvae and pupae on each plant recorded. Monitoring of DBM continued until harvest.

DBM larvae and pupae population at each weekly observation was lowest in the *C. plutellae* plot. Except for the last observation, this was also true for the *M. basalis* and *C. plutellae* plot. However, the differences in DBM populations among all treatments, including the check, were not as striking as they were in autumn 1994. Parasitism averaged around 34% throughout the season. Introduction of *C. plutellae* helped to check DBM population. Towards the end of the first season and into the second season the self-sustaining population of this parasite multiplies rapidly negating any significant benefits of the inundative release of this braconid. Future research during the second cool-dry season will emphasize introduction of other parasites or predators to combat DBM and other pests.

Other insect pests observed during the season included *Pieris rapae*, *Spodoptera exigua*, and *Spodoptera litura*. *Mallada basalis* did not control these pests nor did it have any population-suppressing effect on DBM. This predator, therefore, will not be used in future tests.

Integrated management of crucifer insect pests in the hot-wet season

In the hot-wet season in Taiwan and elsewhere in Asia, DBM is not a serious pest of crucifers unless the dry period extends into the traditional hot-wet season. Rain is an important mortality factor in the biology of DBM. During this time, however, cabbage head caterpillar (*Crocidolomia binotalis*, Zeller) and cabbage webworm [(*Hellula undalis* (F.)] are important pests of crucifers. In localized areas striped flea beetle (*Phyllotreta striolata* F.) and imported cabbage worm (*Pieris rapae* Boisduval) can become a problem. The control strategy devised for DBM in the cool-dry season, therefore, rarely works in the hot-wet season. Two experiments were conducted during summer 1995 to combat *Crocidolomia binotalis*, *Hellula undalis*, and *Pieris rapae*.

Four 0.05-ha parcels of land were plowed and after applying basal fertilizers, worked into 1.5-m-wide, 20-m-long beds. In the first experiment, 5-week-old common cabbage seedlings were transplanted in each parcel in early May. Indian mustard was sown 2 weeks before cabbage transplanting in parcels no. 1, 2, and 3. It was again sown 2 weeks after cabbage transplanting. In the fourth parcel which was maintained as a check, the beds to be planted to Indian mustard were left fallow.

Starting 1 week after transplanting in parcels 1 and 3, 1000 adults of *Cotesia plutellae* were released once every 2 weeks until harvest. In parcels 2 and 3, 500 adults of a polyphagous pentatomid predator, *Eocanthecona furcellata* (Wolff) were released. No parasite or predator was introduced in the check plot.

In the second experiment, planted in mid-August, instead of common cabbage, seedlings of Chinese cabbage were transplanted. Indian mustard was also planted in parcels 1, 2, and 3 and *E. furcellata* was released in parcels 2 and 3. Parcel 4 was maintained as a check.

Thirty randomly selected plants for each experiment were observed and the number of larvae and pupae of DBM, imported cabbage worm, cabbagehead caterpillar, cabbage webworm, and adults of striped flea beetle per plant were recorded.

Results of the first experiment are summarized in fig. 1. When at the beginning of the season, imported cabbage worm population was high, *E. furcellata* effectively reduced the pest population. It also fed upon imported cabbage worm larvae later in the season. This resulted in the absence of any significant differences among the treatments. *E. furcellata* can thus be used successfully to control imported cabbage worm on crucifers.

Though *E. furcellata* fed voraciously on larvae of cabbagehead caterpillar in the laboratory, it failed to control the surging pest population in the field.

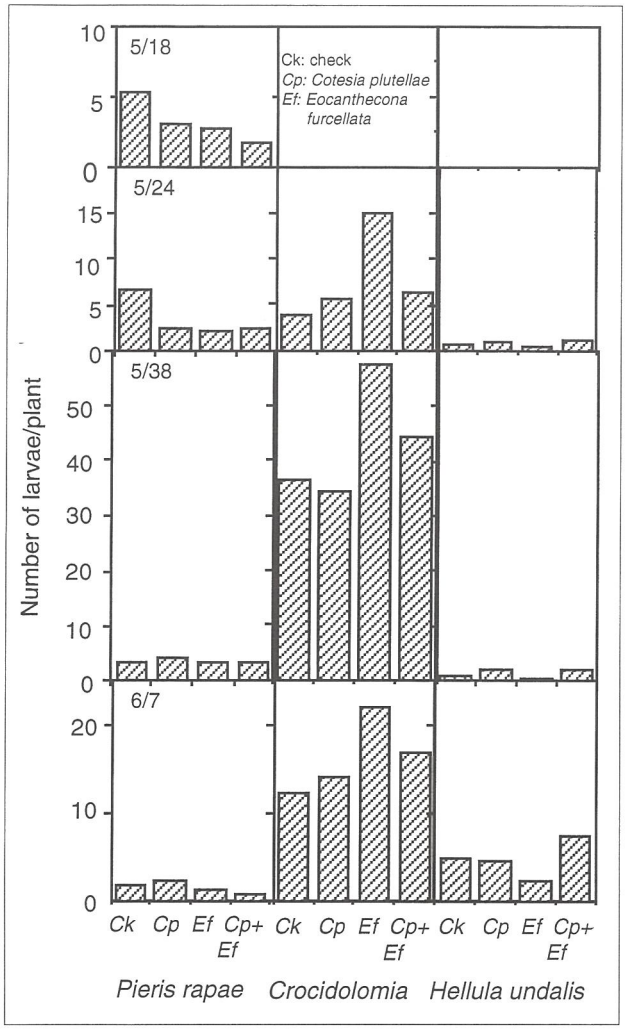


Fig. 1. Effect of various natural enemies on the infestation of cabbage by three insect pests, AVRDC, summer 1995

Indian mustard which was planted specifically to control cabbage head caterpillar did not survive the severe attack of striped flea beetle beyond 2 weeks. As a result cabbagehead caterpillar feeding destroyed the crop in all four parcels of land. In future tests other suitable means will be used to control striped flea beetle on Indian mustard.

DBM population was very low throughout the season and striped flea beetle was common only during the first 2 weeks after transplanting.

Results of the second experiment are presented in fig. 2. As expected cabbagehead caterpillar was the dominant pest during the entire season.

DBM and cabbage webworm were encountered only occasionally. Most Indian mustard crop was destroyed by striped flea beetle within days after germination. Frequent releases of the predator *E. furcellata* reduced cabbage head caterpillar population but no satisfactory control was achieved.

In future tests, Indian mustard crops need to be protected for it to give adequate control of cabbagehead caterpillar. A new strategy needs to be used to increase efficiency of *E. furcellata* in controlling cabbagehead caterpillar.

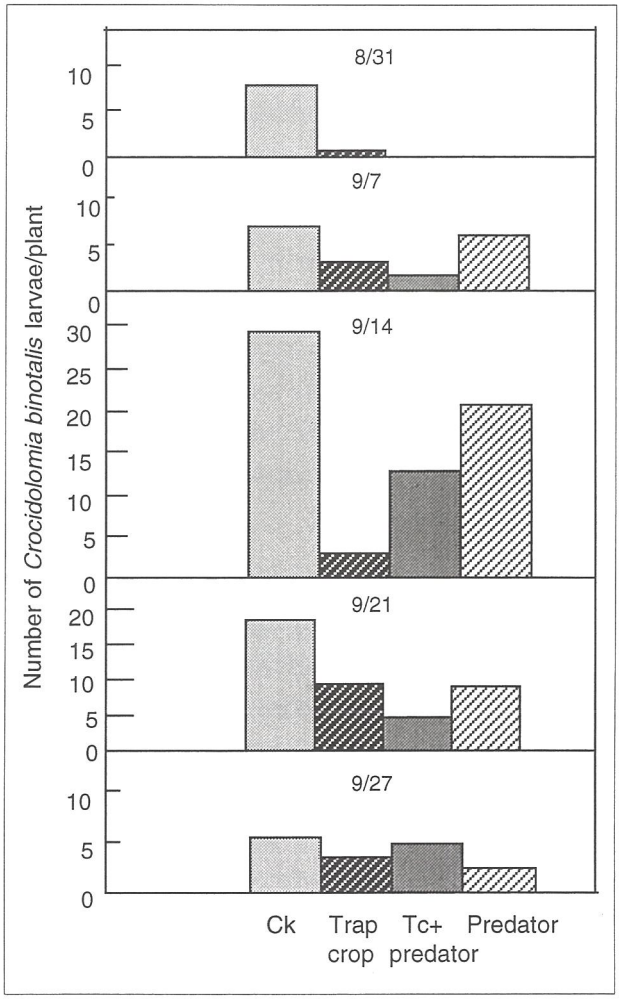


Fig. 2. Effect of trap cropping and various natural enemies on the infestation of Chinese cabbage by cabbagehead caterpillar, AVRDC, summer 1995

Predation of cabbagehead caterpillar by *Eocanthecona furcellata*

Cabbagehead caterpillar, *Crocidolomia binotalis* is one of the destructive pests in hot and wet summer months in Taiwan and throughout the year in Southeast Asia. Adults lay eggs on crucifer foliage and larvae feed voraciously on cabbage leaves. *Eocanthecona furcellata*, a polyphagous pentatomid bug, feeds voraciously on larvae of cabbagehead caterpillar in the laboratory. In this experiment various aspects of this predator's feeding behavior were investigated to assess its usefulness in controlling various pests, especially cabbagehead caterpillar.

Insect source Cabbagehead caterpillar larvae were collected from a Chinese cabbage field. Insects were fed on Chinese cabbage or common cabbage foliage and maintained at 22-28°C in the laboratory.

E. furcellata was reared in the laboratory on cabbagehead caterpillar larvae and on artificial diet. First, second, third, fourth, and fifth nymphal instars and adults from that culture were used in this study. Antennal length, head width, and body length of each instar and adult male and female of *Eocanthecona* were measured separately.

***Eocanthecona* feeding study** Four individuals of first, second, third, fourth, and fifth instar nymphs and four adults (2 males and 2 females) were confined in plastic containers. Insects were fed four times a day. Larvae were weighed before feeding them to the predator. All dead larvae were collected on the next day and the cadavers weighed. The amount of larval mass consumed daily by the predator was calculated. The feeding of each instar stopped as soon as *Eocanthecona* nymphs cast skin and changed into the next instar. At this time, duration of the instar was recorded. Newly emerged adults were fed for only 10 days to study their feeding habit.

***Eocanthecona* feeding habit** *Eocanthecona* was observed to vibrate its antennae in search of pest larvae. When it touches the larva, the predator stretches its mouthparts to suck. Other *Eocanthecona* individuals usually feed on the same larva together. The first instar nymph does not feed on any larva but feeds on dews on leaves for about 4 days. The *Eocanthecona* starts feeding on larvae when it is second instar and consumes very little at this stage. The third instar nymphal period is about 4 days. The fourth instar lasts about 4-7 days and the fifth instar 7 days. Food consumption of adults increases very quickly. About 8 days later, adults start mating and after 1 to 2 days, lay eggs. When a *Eocanthecona* nymph molts into the next instar, it will not eat anything for about a day. Before becoming an adult, it also does not eat for 2 days.

Eocanthecona has a good searching ability in a limited space. In caged cabbage plants it could find over 76% of third instar cabbagehead caterpillar larvae. In the laboratory, *Eocanthecona* could find nearly 100% pest larvae. The searching ability in the field probably decreases. In the field, *Eocanthecona* can suck dew drops and other liquid and many kinds of larvae and even pupae. Besides cabbagehead caterpillar, *Eocanthecona* could feed on *Spodoptera exigua*, *Spodoptera litura*, *Plutella xylostella*, *Pieris rapae*, *Trichoplusia ni*, and *Hellula undalis*. The presence of these alternate food sources decreases the chances of preying on cabbagehead caterpillar larvae.

Larval instar preference For this study third and fourth instar nymphs and adults of *Eocanthecona* were used. The insects were starved for 1 day. One adult of *Eocanthecona* was released inside a petri dish holding two larvae of each cabbagehead caterpillar instar. The larval instar first attacked by the predator was recorded. Then one nymph of the third or fourth instar was released in another petri dish containing a similar number of cabbagehead caterpillar larvae. When the cabbagehead caterpillar larvae were attacked, the attacked larvae were removed and replaced with another one of the same instar. This experiment was repeated 10 times.

Among the five instars, *Eocanthecona* nymphs and adults both preferred to feed on third and fourth instar cabbagehead caterpillar larvae. Very few predators attempted to feed on first and second instars. Fourth instar nymph tended to prefer older larvae than adult or other instar nymphs.

Effect of webbing on *Eocanthecona* predation Thirty third instars of cabbagehead caterpillar were transferred on three Chinese cabbage plants, with 10 larvae on each plant. Three plants represented three replicates. Each plant was confined in a 50 cm^3 nylon net cage. After 12 h two fourth instar *Eocanthecona* nymphs were introduced in each cage for 3 days. After 3 days the number of dead and living pest larvae were recorded.

Three Chinese cabbage plants, each plant with only one leaf, were selected. Ten third instar cabbagehead caterpillar larvae were placed on each plant to feed and form web for 1 day. The excised leaves with webbing material and larvae were placed in three large petri dishes lined with moist filter paper. In another three similar petri dishes cabbagehead caterpillar larvae feeding on Chinese cabbage leaves were kept clean by frequent removal of webbing material. All six petri dishes with pest larvae were confined in a cage. After 1 h, 10 fourth instar *Eocanthecona* nymphs which were starved for 1 day were introduced inside the cage. After 4, 8, 12, and 24 h the number of *Eocanthecona* found in each petri dish was recorded.

The presence of web on feeding areas of the host plant did not prevent *Eocanthecona* from attacking cabbagehead caterpillar larvae. *Eocanthecona* attacks the larvae through gaps in the webs. The fifth instar cabbagehead caterpillar larvae can surround themselves rather successfully by webbing material making it difficult for the predator to attack them. When *Eocanthecona* finds a larva, it hauls the larva out and hides it. The predator can walk on the webbing surface easily, but when it gets surrounded by web, it is unable to feed because it cannot pierce through the web material.

Morphological observations Length of antennae, width of head capsule, and length of entire body of each of the five nymphal instars and adults were recorded to study the insect growth habit. There was a proportional increase in the dimensions of antennae, head capsule, and body as the insect grew from first instar nymph to adult. Highly significant positive correlation was found between growth of these body parts.

Sex pheromone and reproductive behavior of *Crocidolomia binotalis*

Cabbagehead caterpillar, *Crocidolomia binotalis*, is more serious on Chinese cabbage and radish than in other crucifer species. In most Asian countries, its damage is second only to DBM. *C. binotalis* has become resistant to chemicals and farmers are forced to use increasing quantities of insecticides. To control this pest effectively with minimum damage to the environment, AVRDC is exploring various environmentally compatible control practices such as trap cropping, sex pheromones, and biological control agents.

Sex pheromones are volatile chemicals released by insect females that attract male insects for mating. Sex pheromones of a large number of insects, especially Lepidoptera, have been identified and synthesized and some of them are even used commercially. The sex pheromone of cabbagehead caterpillar has been identified but never developed for field use. In this experiment pheromone-related reproductive behavior of cabbagehead caterpillar was studied.

Insect rearing Cabbagehead caterpillar larvae were collected from a Chinese cabbage field. The larvae were reared in the laboratory on common cabbage or Chinese cabbage leaves in a screen cage (45 cm^3) at

26± 2°C. When the larvae were at prepupal stage, they were placed in a plastic cage (23 x 14 x 8 cm) with sandy soil at the bottom layer for pupation. Pupae were collected and placed individually in small plastic cups. Newly emerged adults were divided into males and females and used for sex pheromone and other related studies.

In most cases eggs were laid in masses on the upper surface margin of leaves and stem. Initially, the eggs were green but turned brown towards hatching time. The life cycle took about 26 to 40 days to complete, with larval, pupal, and adult stages lasting 8-10, 9-14, and 9-16 days, respectively, on common cabbage. First and second instars had a habit of aggregating together. After second instars, the larvae dispersed. Cabbagehead caterpillar larvae had five instars. Towards the end of the fifth instar larvae pupate in the soil.

Adult emergence periodicity A large number of cabbagehead caterpillar pupae were collected from laboratory rearing culture and placed individually into plastic cups. Adult emergence was observed hourly during a 24-h period and the number of adults emerging was recorded. Newly emerged adults were separated into males and females.

Most of the adults emerged between 1900 hours to 0200 hours. Very few adults emerged during the daylight hours. The females emerged earlier than males.

Mating periodicity and mating duration Male and female cabbagehead caterpillar pupae were placed individually in small plastic cups and the 2- to 5-day-old adults used for the mating periodicity study. One male and one female of the same age were confined in a plastic container. A cotton plug dipped in sugar solution served as food source. There were 10 groups of each age in this experiment. Insects were observed once every 10 min throughout the period from 1930 hours to 0800 hours of the next day and the duration of mating recorded.

Characteristics of calling behavior of cabbagehead caterpillar female were observed just before the mating.

Adults were motionless during the daylight. At the initiation of darkness, they started moving their antennae backward and forward. Before mating, males and females walked and made short distance flights. The males approached the females from the back and started mating. The mating began at 0230 and ceased at 0445. Female age did not influence mating duration.

Mating age In the laboratory test, virgin females, ranging from 1 to 5 days old were confined individually in plastic containers. One unmated 1- to 2-day-old male was then introduced in each container. A cotton plug dipped in sugar solution served as the food source. One common cabbage leaf was placed inside to facilitate egglaying. After 24 h, the male was taken away. Females were maintained until oviposition. Eggs were observed once a day until larvae appeared to determine mating success.

The 2-day-old females had a higher percentage of successful mating. Female age did not influence mating success.

Synthetic sex pheromone Japanese researchers have identified a three-chemical component sex pheromone of this insect: (Z)-9-tetradecennyl acetate (Z-9-TDA), (Z)-11-hexadecenyl acetate (Z-11-HDA), and (Z)-11-tetradecenyl acetate (Z-11-TDA). Combinations of two or three compounds were tested in the field.

A bioassay with these same chemicals was conducted in the laboratory. For this bioassay, 2- to 5-day-old unmated males were confined in 30-cm-diam, 50-cm-high acrylic cylinders. One open end of the cylinder was wrapped in muslin cloth and the other end was placed on a flat bench top. Each sex pheromone was dispensed on an individual rubber septum which was inserted inside the cylinder through a hole. A gentle

stream of air was blown through the hole so that it will pass directly over the pheromone inside the cylinder. The number of males exhibiting movement of antennae, fluttering of wings, or attempting to mate with the pheromone-baited septum was recorded.

Four-day-old males were more responsive to synthetic sex pheromone. All pheromone blends were as active as the virgin female bait. In repeated tests none of these blends as well as virgin female baits were active when placed in a cabbagehead caterpillar-infested Chinese cabbage field. Observations showed very few, if any, adults of cabbagehead caterpillar in the field or its vicinity although it was full of egg masses and larvae of overlapping generations. It is difficult to explain the absence of adults in the field when they could be maintained in the laboratory for up to 10 days. The brief period between adult emergence from pupae and mating and obvious quick demise soon after mating in the field hamper the development of a sex pheromone for cabbagehead caterpillar control. This phenomenon will be investigated in detail during summer 1996.

Oviposition One newly-emerged female each was placed in 14 acrylic jars lined with tissue paper. A cotton plug dipped in sugar solution served as the food source. The insect containing jars were observed once every day for the presence of eggs. Observations were discontinued as soon as eggs were laid.

In another study one newly-emerged female and one similar aged male each were placed inside eight acrylic cylinders. A cotton plug dipped in sugar solution served as food source. The number of eggs laid was recorded every day until cessation of egg laying.

The mated females laid eggs between 3 to 9 days and after mating. Average duration of oviposition was 5.3 ± 2.0 days. The virgin females started laying eggs between 4 to 16 days and average oviposition period lasted 8.0 ± 3.3 days.

Population dynamics and parasitism of eggplant fruit and shoot borer

Eggplant fruit and shoot borer is the most destructive pest of eggplant in India, Bangladesh, Sri Lanka, Nepal, Thailand, Vietnam, and the Philippines. The insect larva bores into the shoot resulting in wilting of that plant part. When fruits form the larva bores into the fruit resulting in direct yield losses. Present control practices used to combat this pest are characterized by frequent chemical pesticide sprays, which has resulted in the now all-too-familiar side effects. In 1994, research was initiated to develop a package of technology to combat this insect. In 1994-95 a year-long field trial to study population dynamics was conducted to find out periods when this insect causes serious damage and study the occurrence of its natural enemies for use in the sustainable control of eggplant fruit and shoot borer.

One-month-old seedlings of locally popular Pingtung Long were transplanted in a single row on the top of each bed. The crop was grown using standard cultural practices including weeding, fertilizer application, pruning, and irrigation when needed. Starting about 1 month after transplanting and every 2 weeks thereafter, each plant was observed for eggplant fruit and shoot borer damage in shoot and fruit. Number of plants with damage in the shoot were recorded. Each fruit was observed and total number of fruit and insect-damaged fruit were recorded. Insect-damaged fruit were brought to the laboratory, dissected, and the eggplant fruit and shoot borer larvae feeding inside the fruit transferred on an artificial diet until pupation. All pupae were placed in a cage and the number emerging into parasites and adults were recorded. From the number of pupae emerging into parasite adults and into eggplant fruit and shoot borer adults, the percentage parasitized larvae was calculated.

Except for February and March the pest was present throughout the year. However, its infestation was

significant only during September and October. During these months, damage was observed in over 30% fruits. During this same period, parasitism of pest larvae by *Eriborus sinicus* in fruits surpassed 31%. Both fruit damage and parasitism tapered off beginning in the cooler months of November. Pest incidence appeared to be related to temperature. The cooler temperatures of November to March seem to restrict pest activity considerably. A similar phenomenon was observed elsewhere especially in India where eggplant is an important vegetable.

A high level of parasitism in October could be related to the higher density of the pest larvae. High density of the pests makes it easier for the parasite to find the host larvae.

To conduct more effective research on eggplant fruit and shoot borer, eggplant must be transplanted from late April to early July.

Sex pheromone of eggplant fruit and shoot borer

AVRDC is looking for other innovative nonchemical control practices that will reduce the damage to eggplant by eggplant fruit and shoot borer on a sustainable basis. A two-component sex pheromone Z11: 16Ac and Z11:10 OH of eggplant fruit and shoot borer has been identified independently by two research groups: a Chinese team and German-Sri Lankan team. However, no attempt has been made so far to develop the pheromone for field use to combat the pest. AVRDC acquired these chemicals and utilized these in combating the eggplant fruit and shoot borer.

Rubber septa were coated with these chemicals individually or in mixtures in varying proportions and baited inside sticky bottom wing traps in the field just above the eggplant canopy in the late evenings. The number of eggplant fruit and shoot borer moths trapped was recorded next morning. A minimum distance of 10 m was maintained between two adjacent traps. The traps were placed in the field for 3 consecutive days.

Because of the sporadic nature of infestation of eggplant fruit and shoot borer in Taiwan, this experiment was done at four locations in India and one location in Bangladesh. In Bangladesh this experiment was done at the Bangladesh Agricultural Research Institute, Joydebpur, on the outskirts of Dhaka.

Only the results of the test conducted in Bangladesh are available. In this test, when used alone only component A was active; component B was not (table 1) even at a very high concentration of 500 µg. However, component B was active when mixed with A at 100:5, 100:10, and 100:20. Higher concentrations of B seem to inactivate the major sex pheromone

Table 1. Performance of various pheromone blends in attracting male moths of eggplant fruit and shoot borer, BARI, Bangladesh, May 1995

Pheromone component	No. insects[a] trapped	Pheromone component µg A : µg B	No. of insects trapped
500 µg A	6	100 : 5	6
400 µg A	5	100 : 10	10
300 µg A	7	100 : 20	5
200 µg A	8	100 : 30	1
100 µg A	1	100 : 50	0
50 µg A	0	100 : 75	0
10 µg A	0	100 : 100	0
500 µg B	0	75 : 100	0
400 µg B	0	50 : 100	0
300 µg B	0	30 : 100	0
200 µg B	0	20 : 100	0
100 µg B	0	10 : 100	0
50 µg B	0	5 : 100	0
10 µg B	0		
Virgin female	16[b]	Blank trap	0

[a] Data are sum of 3 days' insect catch

[b] All insects were trapped only on the first day of the test

component A; at low concentrations it synergizes A. For example when used alone component A at 100 µg showed barely detectable sex pheromone activity. However, when 5, 10, or 15 µg of component B was added, more insects were trapped.

These tests will be expanded to other countries where eggplant fruit and shoot borer is endemic. The results of the Bangladesh trials are encouraging. These are the first trials on synthetic sex pheromone of this insect anywhere. Additional work is necessary to make practical use of this unique pest control tool.

Using urea and CaO mixture as soil amendment to control bacterial wilt in tomato

The objective of this activity is to study the mechanism of reducing soil population of *Pseudomonas solanacearum* (Ps) by urea and CaO. Amendment of soil with urea (200 kg N/ha) and CaO (5000 kg/ha) can control tomato bacterial wilt in the field but the effect is location-specific.

The effect of various nitrogen forms, i.e., ammonia/ammonium, nitrite, and nitrate, derived from urea through nitrification on the reduction of *P. solanacearum* population in the soil was studied.

Soils collected from different locations in the Philippines were infested with the pathogen and amended with urea/CaO (428 kg/ha of urea and 5,000 kg/ha of CaO). Population of *P. solanacearum* and concentration of ammonia/ammonium, nitrite, and nitrate were determined weekly.

Influences of pH on the bactericidal effect of ammonia/ammonium, nitrite, and nitrate were studied. Various concentrations of ammonium, nitrite, and nitrate were added to nutrient broth with different pH values individually. *P. solanacearum* was transferred into each set of the liquid media and the growth of the pathogen was determined.

Based on the results, the effect of this soil amendment in suppressing the soil population of the pathogen can be classified into three: initial reduction, final reduction, and no reduction based on incubation trials in a 3-week period (fig. 3). The initial reduction effect was related to high pH caused by urea hydrolysis. For example, the pathogen population is significantly lower ($P < 0.01$) 1 week after amendment in the soil collected from Ilocos Norte (MMSU). Results of Ps growth in nutrient broth demonstrated the toxic effect of pH 3, 10, and 11 as well as the strong inhibition that occurred at pH 4 and 9. The final reduction of the pathogen can be observed in the soil collected from Nueva Ecjia (# 19). This effect occurred when nitrite accumulated and 3 weeks after amendment. When formation of nitrite was blocked by adding a nitrification inhibitor, the reduction effect disappeared. The effect of nitrite is pH dependent. At pH 5, nitrite concentrations of 50 ppm were toxic to Ps, and at pH 7, strong inhibition only occurred at 500 ppm. Ammonium can be toxic to Ps but only at high concentrations (500 ppm) at pH 9. However, such a high concentration cannot be measured in any of the amended soils. The soil amendment cannot reduce the Ps population in the soil collected from Bukidnon (BRCI) because of no accumulation of nitrite and the lower pH after amendment.

Using *Allium* crop residues as soil amendment to control tomato bacterial wilt

Dry Welsh onion powder (excluding roots) or crop residues of onion and garlic were used as a soil amendment (SA) to control tomato bacterial wilt caused by *Pseudomonas solanacearum*. The SA showed a significant effect on controlling bacterial wilt in the pot trials. Particularly when Ps population can be completely reduced to an undetectable level, the disease incidence of these treatments was 0 or 5%. The effect of SA is not identical in different soils. In AVRDC soil, concentrations of dry Welsh onion

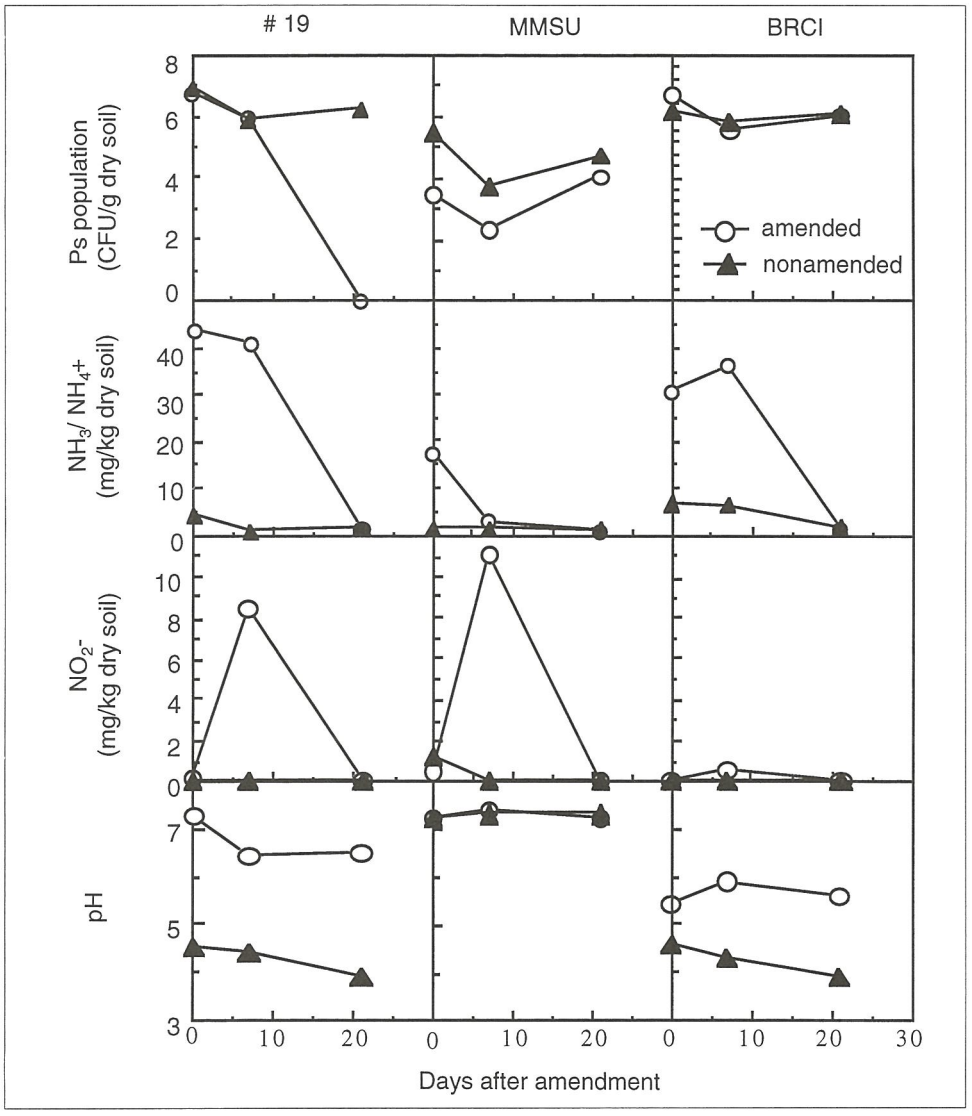


Fig. 3. Population of *Pseudomonas solanacearum*, concentration of ammonium/ammonia and nitrite and pH in three soils collected in the Philippines after amending urea (200 kg N/ha) and CaO (5000 kg/ha)

Soils were collected from Nueva Ecija, MMSU from Ilocos Norte, and BCRI from Bukidnon. During the experiment, soils were incubated at 30°C and soil moisture was kept at -0.3 bar matric potential

powder equal or greater than 0.5% can totally suppress the Ps population as well as the disease incidence. However, similar effects can only be achieved by 1 and 2% in Hsinshe and Puli soils, respectively. The reduction of wilt % is not necessarily related to the lower Ps population. For example, amending 1% dry Welsh onion powder in Puli soil has no effect on the Ps population but the wilt % can be reduced to 60% (fig. 4). The effect of amending crop residues of garlic on the disease incidence and reduction of Ps population was similar as amending dry Welsh onion powder when soils collected at AVRDC were used in the pot trials.

A field trial was conducted to confirm the SA effect. Two factors were used in a factorial design. One was amending 1% dry Welsh onion powder or not and the other was variety including ASVEG #4 (moderately resistant to BW) and Farmers 301 (susceptible to BW). Results showed that the SA effect is highly significant when data of transformed wilt%

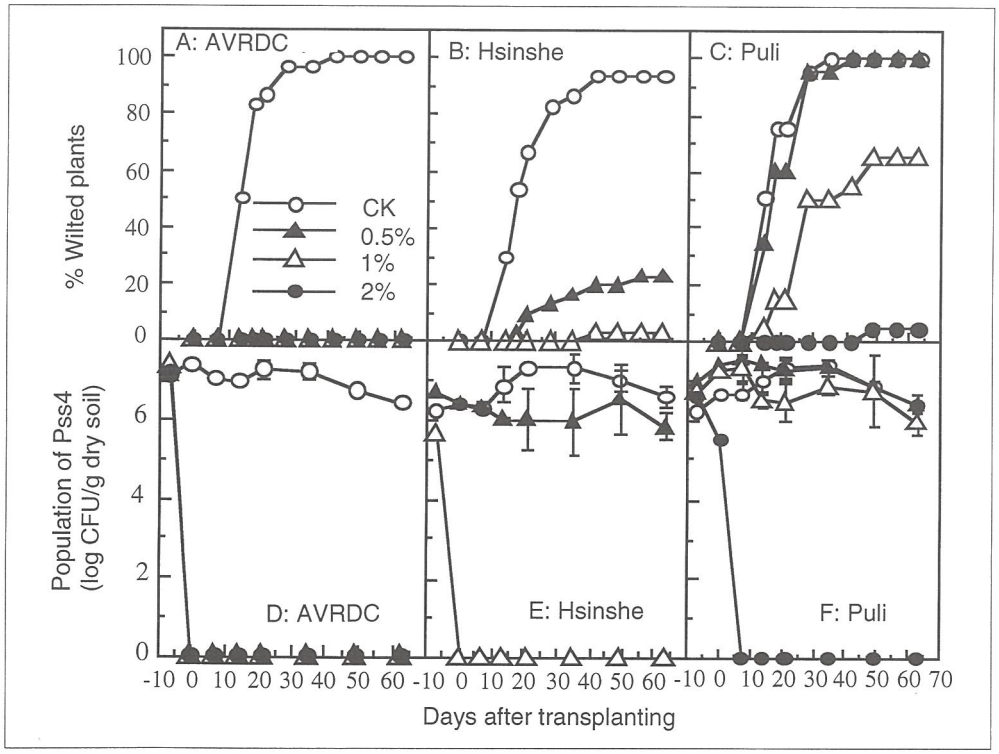


Fig. 4. Effect of amending dry Welsh onion powder on the incidence of tomato bacterial wilt (A, B, C) and the survival of its pathogen, *Pseudomonas solanacearum* (D, E, F) in three infested soils prepared from soils collected from AVRDC, Hsinshe, and Puli (all in Taiwan) in the greenhouse

(by arcSin square root) and area under disease progress curve were analyzed. However, the effect is not as dramatic as in the pot trial (fig. 5). No significant interaction of the two factors was observed which indicated that the SA effect is variety-independent.

Preliminary studies indicated that biotic factors in the soil are essential for the SA to effectively suppress the pathogen population.

Biological control of tomato Fusarium wilt

The objectives of this study are to (1) identify microorganisms that are antagonistic to *Fusarium oxysporum* f.sp. *lycopersici* (Fol) from soils and plant materials, and (2) evaluate microorganisms found antagonistic to Fol for their potential as biological control agents for tomato Fusarium wilt.

Numerous bacteria antagonistic to Fol were isolated from field soils and tomato root rhizospheres during the year. Six isolates that were highly antagonistic to Fol, based on in vitro studies, were placed in long-term storage for future study. This brings the total number of Fol-antagonistic bacterial cultures that are being maintained in storage to 28, among which are 16 *Bacillus* spp., 5 *Pseudomonas* spp., and 7 unidentified species. Nine of the bacteria (3 *Bacillus* spp., 1 *P. aeruginosa*, and 5 unidentified isolates) selected for biological control studies were applied as seed treatments, root dips, and soil drenches to tomato plants transplanted into Fol-infested soil. All nine isolates suppressed Fusarium wilt development at varying degrees when applied as root dip treatments prior to transplanting seedlings into Fol-infested soil (fig. 6). In vitro tests showed that most of these nine bacteria are antagonistic to each other, thus combinations of them probably will not provide an additive benefit for biological control.

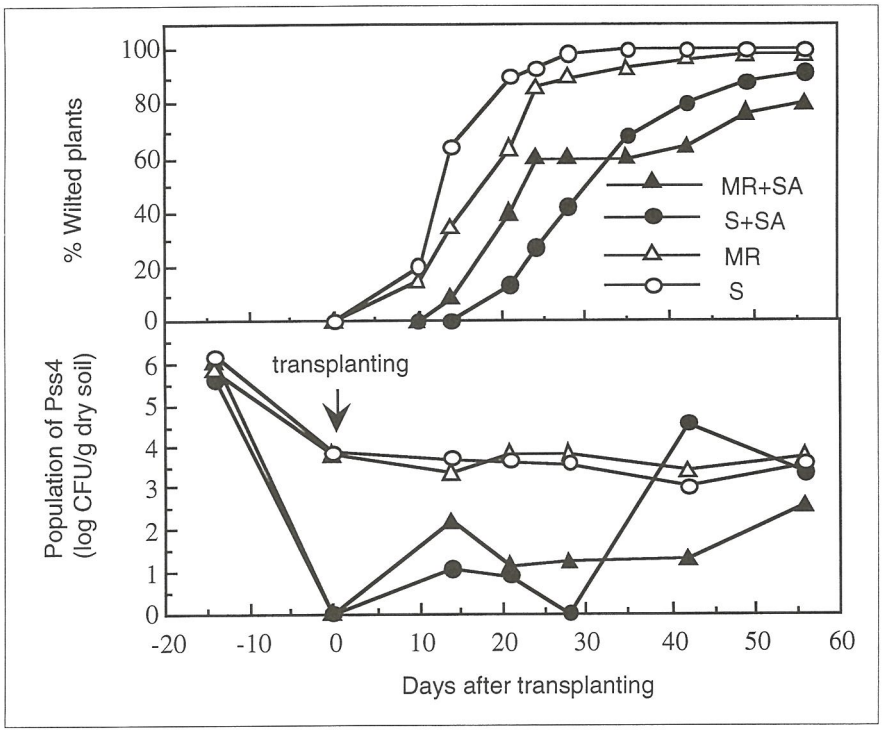


Fig. 5. Effect of amending dry Welsh onion powder on the incidence of bacterial wilt (A) and survival of *P. solanacearum* (B) in artificially infested field at AVRDC
Soil amendment (SA) and tomato variety, Farmers 301 (S) and ASVEG #4 (MR), are the two factors used in the factorial design

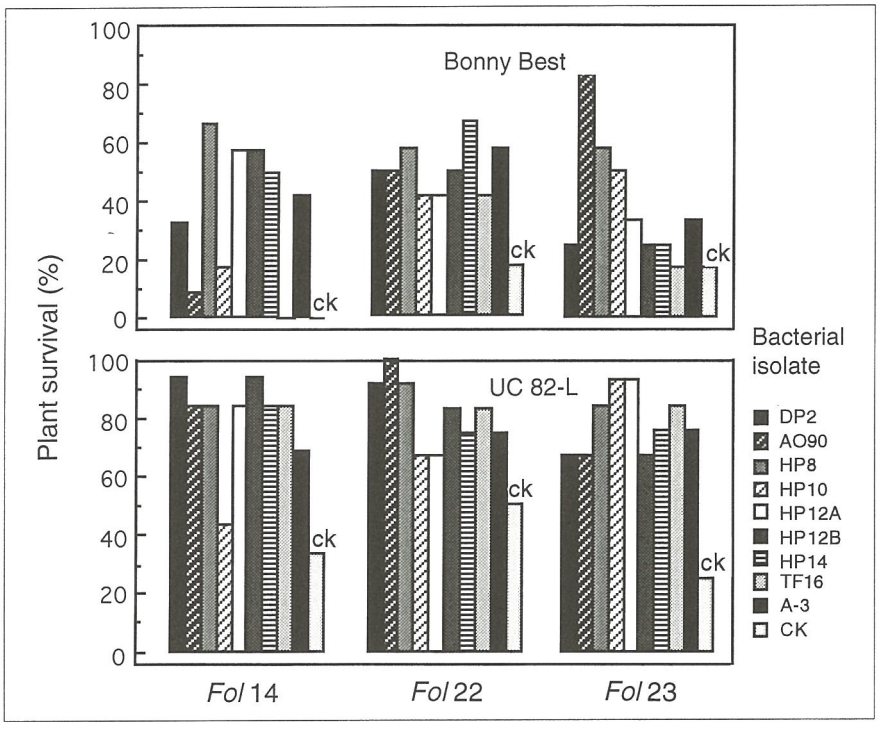


Fig. 6. Survival of tomato seedlings root-dip treated with antagonistic bacteria prior to transplanting into soil infested with *F. oxysporum* f.sp. *lycopersici*
Observations 5 weeks after transplanting

SOCIOECONOMIC STUDIES ON VEGETABLES

The overall objective of the project is to understand the socioeconomic parameters in production and marketing of vegetables to enhance their productivity and profitability, and especially to improve vegetable supply throughout the year. The project activities include characterization of vegetable production systems, understanding the seasonal pattern in vegetable consumption, depicting vegetable market structures and quantification of consumer preferences for horticultural traits, and developing methodologies for the ex-ante and ex-post evaluation of new technologies.

The subproject on characterization of vegetable production systems explores the technical possibilities and constraints to increasing vegetable productivity. It focuses on mungbean cultivation, peri-urban vegetable production systems, and home gardening in different environments.

The causes and consequences of seasonality of vegetable production are studied in the subproject on consumption patterns. Consumer responses, including micronutrient consumption to seasonal availability of vegetables are quantified and analyzed. Results are expected to help explain consumer preferences and highlight more objectively the role of vegetables in human health.

Ex-ante and ex-post evaluation is undertaken to measure the impact of technologies on vegetables developed by AVRDC. A methodology was developed to understand ex-ante onion research prioritization in terms of temperate and tropical onion research and ex-post quantification of tomato research in Taiwan.

The overall targets are to improve interaction between biophysical and socioeconomic research for the purpose of improving resource allocation at AVRDC and at the NARS, and to generate information for policymakers to improve the policy environment in vegetable research and production.

Characterization of vegetable production systems

Mungbean production and supply systems in Pakistan

Baseline data were collected through a survey among 200 farmers in the major mungbean growing districts of the Pakistan Punjab. To explore the possibilities of incorporating mungbean in the intensive cultivation system, an opinion survey of farmers and extension agents was completed. Analysis of the survey data was done at AVRDC jointly by AVRDC economists, a Pakistani economist, and a breeder.

Evaluation of the assets of mungbean growing farmers indicated that these farmers are relatively poor and cultivate light-textured soils. Mungbean is mainly cultivated in a wheat-mungbean rotation, although a potential exists to introduce it in rice-wheat and in a few other field crop rotations.

In collaboration with AVRDC, national researchers developed high yielding, yellow mosaic virus-resistant, uniform maturing, and short-duration mungbean varieties such as NM 19-19, NM51, 54, and NM 92.

The adoption of these mungbean varieties has been rapid (fig. 1). The traditional Desi variety was grown by over three-fourths of the farmers in 1988, but only 10% of them were using this variety in 1994. NM 19-19 was grown by 17% of the sample farmers, NM 51, 54 by 21%, and NM 92 by 51% farmers during 1994.

The introduction of modern mungbean varieties brought about a series of changes in the management practices of mungbean cultivation. For example, most seed of modern varieties were purchased, while home-produced seed of the Desi variety, often contaminated with weed seeds, were used. More farmers used drill, kera, and pore methods to sow the seeds of modern varieties, while almost all fields of Desi were sown using broadcast method. More sample farmers sprayed pesticides on modern varieties.

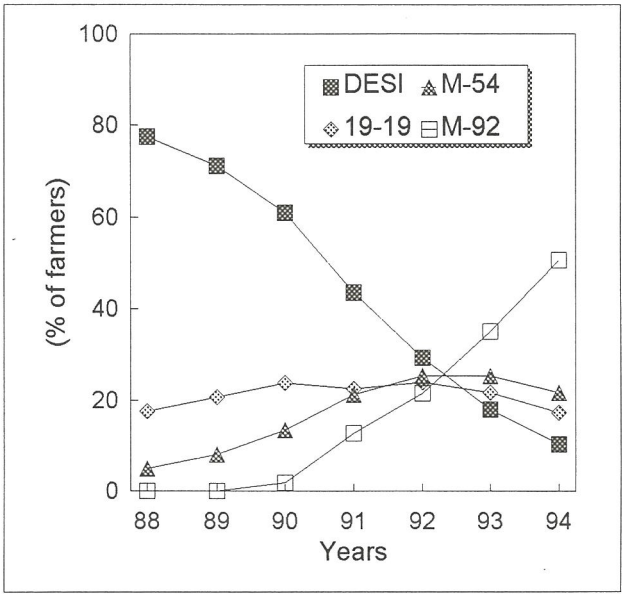


Fig. 1. Mungbean varietal adoption curve in Pakistan

The average yield of Desi in 1994 was 579 kg/ha which was markedly lower than the 801 kg/ha yield of small-seeded NM 19-19, 865 kg/ha of large-seeded NM-51, 54, and 900 kg/ha of NM 92 (fig. 2). Similar relative yields of different varieties were reported during the 1993 production period. The new variety NM 92 had 55% higher yield than Desi, although the difference was only 4% when compared with the yield of the earlier modern varieties.

Mungbean cultivation increased land productivity in the succeeding wheat crop. For example, net return of wheat cultivation in the wheat-fallow and wheat-other crops rotation was US$171.3 (Rs. 5481) and $169.9 (Rs. 5438) per hectare, respectively, which increased to $211.7 (Rs. 6776/ha) in the wheat-mungbean rotation. The regression analysis gave 20% higher wheat production at the controlled level of input use in the wheat-mungbean rotation compared to the wheat-other crops rotation.

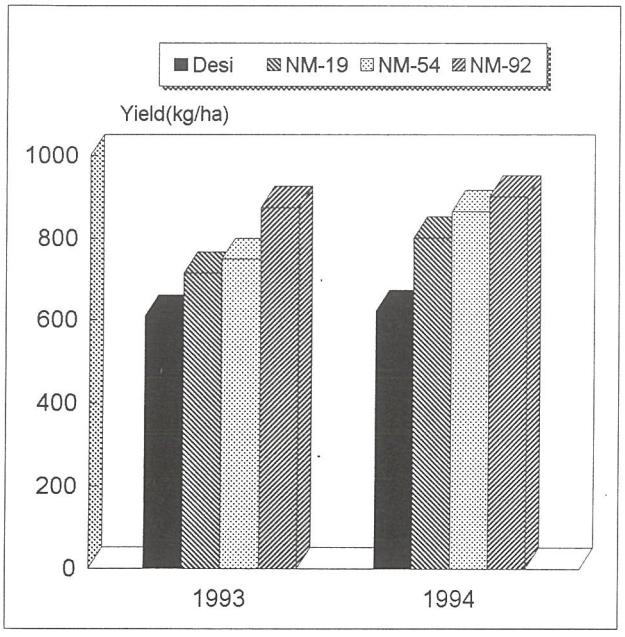


Fig. 2. Mungbean yield by variety in Pakistan, 1994-95

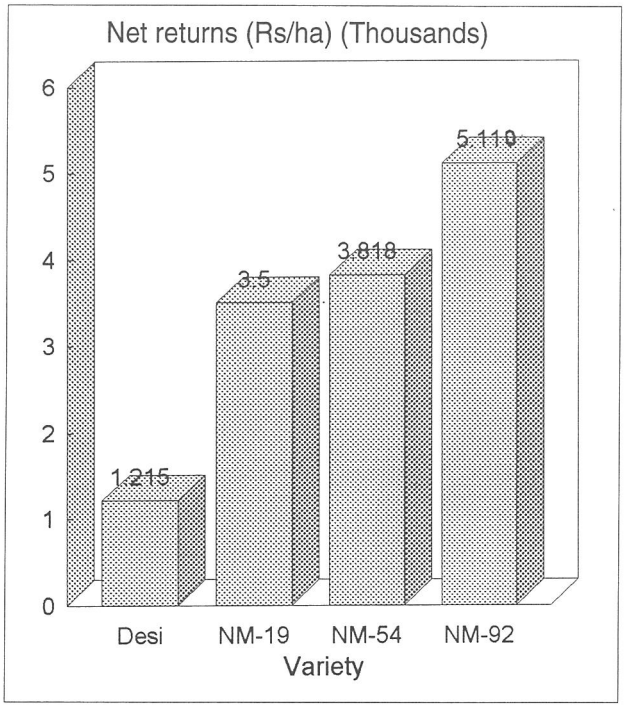


Fig. 3. Net return of mungbean cultivation by variety in Pakistan, 1994-95

The differences in net return across mungbean varieties were more pronounced than the yield difference, mainly because of higher prices paid for seeds of modern varieties. The latest variety, NM 92, fetched $0.32 (Rs 10.4) per kilogram compared to $0.28 (Rs. 8.9/kg) for Desi seed because of its bold seed and shiny coat. The net return of NM 92 was $159.7 (Rs. 5110) per hectare compared to only $38 (Rs. 1215/ha) in Desi. NM 92 has more than 33% higher profit than NM 54 and NM 19 (fig. 3).

The modern mungbean varieties substantially increased the profitability of crop cultivation in the marginal areas of Pakistan. In addition to the higher return from these varieties, the profitability of wheat cultivation also increased (fig. 4). More yield from modern mungbean varieties, higher price of seed, and higher return from wheat cultivation followed by mungbean generated more than $23.8 (Rs. 763) million/annum to poor marginal mungbean growing farmers in Pakistan.

Farmers' perceptions about the mungbean problems indicated that about 12% of yield losses were caused by weeds and insects. There is a need to study the frequency and losses caused by different insects, and develop insect-resistant mungbean varieties. Research to advance management practices for mungbean are needed.

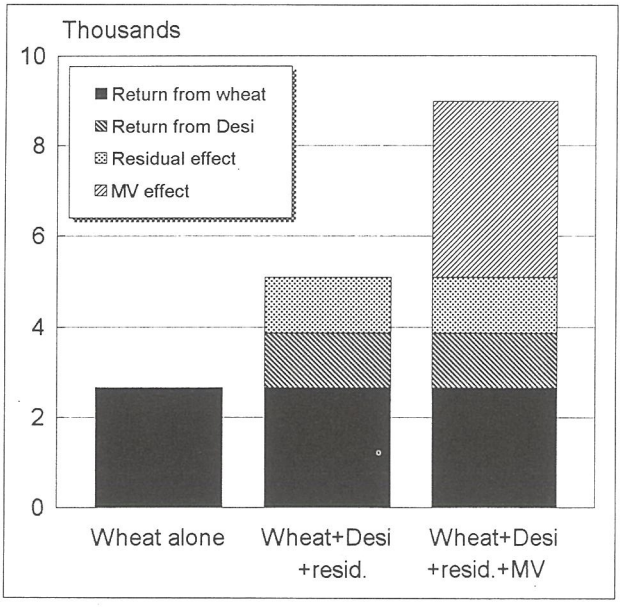


Fig. 4. Enhancement in wheat profitability with the addition of mungbean in the rotation, Pakistan, 1994-95

Consumption patterns

Seasonality and structural changes in the consumption pattern of Taiwan

This activity quantified the seasonality in the prices, consumption of main food items including vegetables, and consumption of major and micronutrients, and estimated the own-price, cross-price, and income elasticities of food items across seasons.

The monthly household expenditure and price data collected by the Taipei Municipal Government for the period 1974-92, substantiated by the price data collected by the Provincial Government of Taiwan, were used in the study. All food commodities were grouped into four major food groups: cereals, livestock products including seafood, vegetables including mushrooms, and fruits. Each group includes respectively 33, 83, 72, and 33 commodities. The group prices were estimated from the individual commodity prices using the expenditure weights of the commodity in its respective group. Household consumption was converted into per capita consumption by dividing it with family size.

Based on the variation in vegetable and fruit prices, which is assumed to drive seasonality in food consumption, each year was divided into three seasons: December-March when vegetable prices are low, but fruit prices are high; April-July when there is a steady increase in vegetable prices, and steady decline in fruit prices; and August-November when vegetable prices reach a high peak, but fruit prices start increasing from the lowest trough.

Implication of seasonality in food availability on nutrient intake The seasonality in vegetable consumption results in seasonality in micronutrient consumption. In spite of the highly developed vegetable and fruit market of Taipei City, high seasonality in their prices and consumption was reported last year. Fig. 5 shows the monthly average micronutrient intake trend from 1974 to 1992. Although seasonal patterns of consumption were observed in almost all the major (energy and protein) and micronutrients (calcium, iron, riboflavin, thiamin, vitamin A, and niacin) they were more pronounced in micronutrient consumption.

Energy, thiamine, and riboflavin intakes have significantly improved over time, and were well above the recommended levels during the early nineties. Protein and iron consumption have also significantly improved, although protein was always above the recommended level. However, despite the high income levels and high per capita consumption of fruits, vegetable, and livestock products in Taipei City, vitamin A, calcium, and niacin are much lower than the recommended levels. Strong seasonality in vitamin A intake makes it far lower than the recommended level during the period when fruits and vegetables are in short supply.

This highlights the need to identify vegetables rich in vitamin A, calcium, and niacin, and change the existing vegetable consumption pattern with one containing vegetables rich in these nutrients.

Consumers' response to seasonality Consumers responded to the seasonal availability of fruits and vegetables by adjusting purchases to the market price in each season. Thus own- and cross-price elasticities varied across seasons. The highest seasonality was observed in vegetable own-price elasticities (table 1). The elasticity changed by about 25% from -0.60 for August-November (when vegetable prices are highest) to -0.75 for December-March (when vegetable prices are lowest). The elasticity was in between during April-July (-0.70) when vegetable prices start drifting toward the peak.

The seasonality in own-price elasticity was lowest in fruits (-0.91 to -0.94), among all the food groups, despite highly volatile fruit prices across the season. Seasonality was observed in cereals and livestock product own-price elasticities (although small),

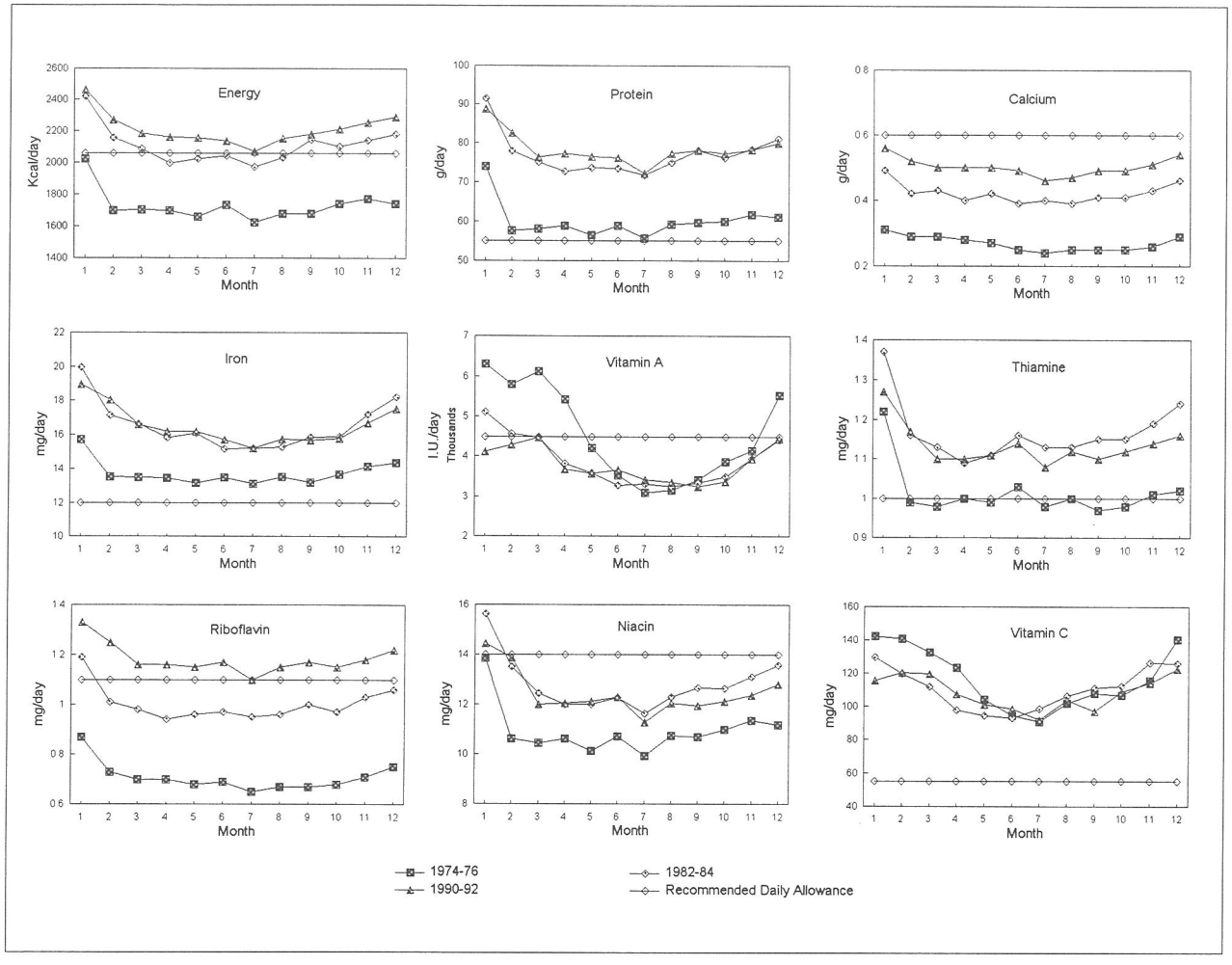


Fig. 5. Seasonality in nutrient intake (unit/capita/day), Taipei City, 1974-92

despite their relatively stable prices. The cereal own-price elasticity increased by 10% from the August-November (-0.54) to December-March (-0.59) seasons, while the livestock own-price elasticity decreased by 7%.

Table 1. Uncompensated own price elasticities in different seasons, Taipei City, 1974-92

	Cereal	Livestock	Vegetables	Fruits
Dec - March	-0.59	-0.74	-0.75	-0.91
April - July	-0.56	-0.79	-0.70	-0.95
Aug - Nov	-0.54	-0.79	-0.61	-0.92

Although seasonality in vegetable prices causes seasonality in the consumers' vegetable and cereal consumption behavior, seasonality in fruit prices does not influence this behavior. This implies that consumers are resilient in changing consumption of cereals and vegetables when vegetable availability is low.

The consumers can afford to change fruit consumption proportionate to the price change since fruit is consumed more like a dessert. However, a small decrease in the own-price elasticities of fruits and livestock products is observed for December to March when fruit availability is lowest (table 1).

Ex-post and ex-ante evaluation of technologies

Onion research prioritization

One of AVRDC's major research thrusts is to reduce seasonality in vegetable supply, which focuses mainly on development of both open-pollinated and short-day varieties that are adaptable and can produce bulbs in the tropical environment. As onion has good shipping and keeping quality, a tropical summer onion must compete with winter-dry season onion from the store. Therefore, an important challenge is to identify how to significantly improve summer season onion production.

AVRDC first looked at how important the meteorological factors are in summer onion production. For this, the summer (kharif) onion production in India which contributes about 15% to the total production of the country, was analyzed. The remaining 85% is grown in late summer (late kharif) or in winter (rabi). Based on the marketing survey in major summer onion growing and marketing regions in India, strong seasonality in market arrivals may be observed which dictates seasonality in onion prices (fig. 6). About 80% of summer onion comes from two districts of Maharashtra (Nasik and Pune) and two districts of Gujrat (Bhavnagar and Amreli). The summer onion is cultivated in May-June and harvested in November-December. The normal seasonal monthly average rainfall in summer onion producing areas is about 100 mm (in Bhavnagar)– 200 mm (in Nasik). The kharif onion yield was 22-37% lower than the rabi and late kharif onion yields (table 2).

The quantitative relationship between the kharif and rabi season district level per hectare yield and each season's monthly average rainfall was then studied. A strong negative relationship between kharif yield at the district level and rainfall during the early

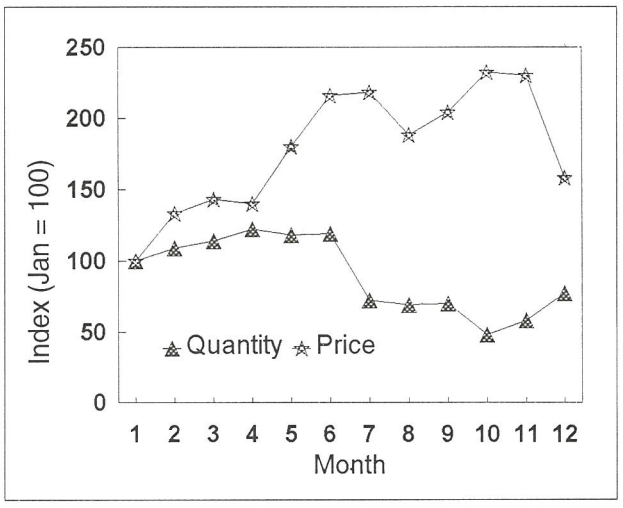


Fig. 6. Seasonality in market arrivals and price of onion (based on market survey, 1995)

Table 2. Onion yield (t/ha) by season in major onion producing districts in Maharashtra

District	Kharif	Late kharif	Rabi	% kharif yield to Late kharif	% kharif yield to Rabi
Nasik	16.5	22.0	21.9	75	76
Pune	16.0	22.2	22.0	72	73
Satana	16.0	22.0	22.0	73	73
Ahmednagar	16.6	21.8	22.0	76	75
Solapur	16.5	21.8	22.3	76	74
Dhule	17.4	22.7	22.3	77	78
Jalgaon	17.00	22.3	21.9	76	78
Aurangabad	13.4	20.5	21.1	65	63
Osmanabad	13.5	20.6	21.1	66	66
Buldhana	13.3	20.5	21.1	65	63

Source: NHRDF 1995

months of onion growth was observed. No such relationship was observed for the rabi season yield.

The data clearly indicate that onion yield is lower in summer than in the cooler dry months and regions. Another factor disadvantageous in summer onion production is that its price is 50-70% of the winter onion price due to its inferior quality.

Winter onion can be sold in summer only after investing substantially in storage. More storage cost means higher price of winter onion in summer and also pushes up summer onion price, as it is valued in comparison to the winter onion price. This phenomenon makes room for summer onion production despite its low yield.

Main storage costs in onion include losses due to different factors and the profit of farmers who store summer onion (table 3). The winter onion price doubles if the onion has to be stored for 5 months. If summer onion fetches 70% of the winter onion price, the summer onion farmer will get a 40% higher price than the winter onion farmer, which more than compensates for the 22-37% lower yield in summer onion. If winter onion is stored for 4 months, the winter onion's cost will be 72% of its price and the summer farmer will get a 20% higher price than his counterpart in winter which may be insufficient to compensate for the lower yield in summer. Thus, if winter onion price is equal to or more than double in summer, it is profitable to produce summer onion.

The analyses show that researchers can help summer onion farmers by increasing summer onion yield so that the winter-summer onion yield ratio is improved from 1:0.75; by improving the summer onion quality so that the winter-summer onion price relationship is improved from 1:0.7; and by developing management practices which can achieve the potential yield as indicated by the difference between experimental and farm-level yields which are currently about 30 and 15 t/ha, respectively.

AVRDC tomato research impact in Taiwan

This research activity aims to quantify the extent of adoption of AVRDC tomato varieties in Taiwan; the difference in yield, overall cost, and net returns between the adopters and nonadopters; the overall impact of AVRDC tomato varieties on the producers in Taiwan, and on the prices and availability of tomato during the summer season; and identify and prioritize the constraints to higher productivity and profitability of AVRDC tomato varieties.

A survey of 200 farmers distributed in five counties of Taiwan where summer tomato is mainly grown was conducted in collaboration with farmers' organizations. Detailed information were obtained on input-output quantities and prices, the year AVRDC varieties were adopted, yields of AVRDC and older varieties over time, farm-management practices, and constraints to improving the productivity of AVRDC variety.

Table 3. Storage cost function (Rs/t) in onion

Cost item	Month 1	Month 2	Month 3	Month 4	Month 5
Loss due to sprouting	0	15	171	397	447
Loss due to rotting	49	169	382	492	844
Loss due to drying	203	382	584	895	1337
Total losses[a]	252	565	1137	1784	2628
Profit and interest (5%/month)	228	479	759	1063	1405
Other storage costs	110	221	331	442	552
Total cost	590	1265	2227	3289	4585
% of the purchase price	13	28	49	72	100

[a] The loss function was estimated from the physical loss percentage reported in Bhonde, Qadri et.al. 1992

Two AVRDC varieties, ASVEG No.4, ASVEG No.5, and two nonAVRDC varieties, Chu huey and Farmer 301 (nonAVRDC varieties henceforth will be called "others"), were observed being cultivated by the farmers. The adoption pattern by the sample farmers of different varieties is shown in fig. 7. Very few sample farmers grew summer tomatoes (or actually any season tomato) in 1989, indicating that tomato cultivation is new for them. The AVRDC varieties were instrumental in starting tomato cultivation among the sample farmers.

ASVEG No.4 was more rapidly adopted than ASVEG No.5, and hardly 10% of the sample farmers grew other tomato varieties during the survey year (the farmers growing other varieties were not randomly selected; they were purposively found and included in the sample for comparison purposes). The sample farmers indicated that tomato was grown at higher altitudes previously but it has been shifted to lower altitudes because of the availability of heat-tolerant varieties. Thus, AVRDC varieties helped to protect highland forestries, which otherwise would have been cut for tomato cultivation, as has occurred in the Cameron Highlands in Malaysia.

Tomato cultivation is a labor-intensive activity. ASVEG No.4 needed about 700 days/ha and ASVEG No.5 about 800 days/ha compared to 600 days/ha for other varieties. Thus, the adoption of AVRDC varieties generated an extra labor demand of 100-200 days/ha. In fact the survey team observed the tendency in young people to come back to their farms from their jobs in industry in Taipei to help their parents in picking, packing, and hauling tomato to market points. Similar additional demand was generated for machines to be used in land preparation for tomato, making ridges, and hauling the output to market points.

The seedling cost was significantly higher in other varieties, indicating that seedling was more difficult to establish in these than in AVRDC varieties. The manure cost was also higher in other varieties, especially when compared to ASVEG No.4; however,

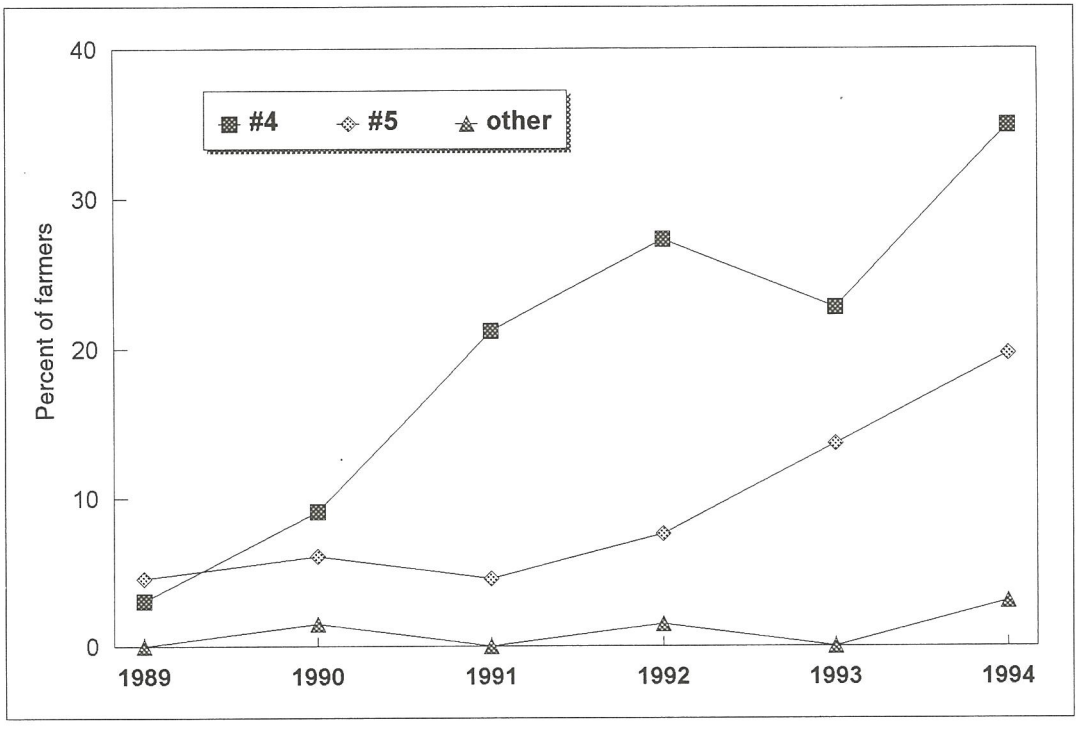


Fig. 7. Adoption curve for AVRDC summer tomato in Taiwan, 1995

fertilizer cost was slightly lower in these varieties. Pesticide cost was significantly higher in ASVEG No.4 compared to ASVEG No.5 and other varieties. The other costs which include staking, packing, etc. were lower in other varieties. Labor cost was highest in ASVEG No.5, followed by other varieties and ASVEG No.4.

The total cost, including material, labor, machine, and all the other costs, was similar in other varieties and ASVEG No.5, but lower in ASVEG No.4. However, gross income from other varieties was significantly lower compared to that from AVRDC varieties (fig. 8). The higher gross income from AVRDC varieties indicates higher yield levels in these varieties, especially ASVEG No.4. The price received by the farmers for ASVEG No.5 output was significantly higher than that for other and ASVEG No.4 outputs.

The net profit after deducting all costs (including family and hired labor) from gross revenue was just at break-even point in other varieties, while AVRDC varieties generated a significant positive profit. An average net profit of about US$12,000/ha (NT$ 300,000) was generated by the cultivation of ASVEG No.4, and a little more than $8,000/ha (NT$ 200,000) in ASVEG No.5 (fig. 8).

Assuming an average net profit of $8,000 for AVRDC varieties over the other varieties, and 700 ha on which AVRDC varieties are grown during summer, Taiwanese farmers earn a total of $5.6 million (NT$140 million) every year from the release of AVRDC varieties. The gain to consumers in terms of reduced seasonal tomato price variation has been discussed in the AVRDC 1994 Progress Report.

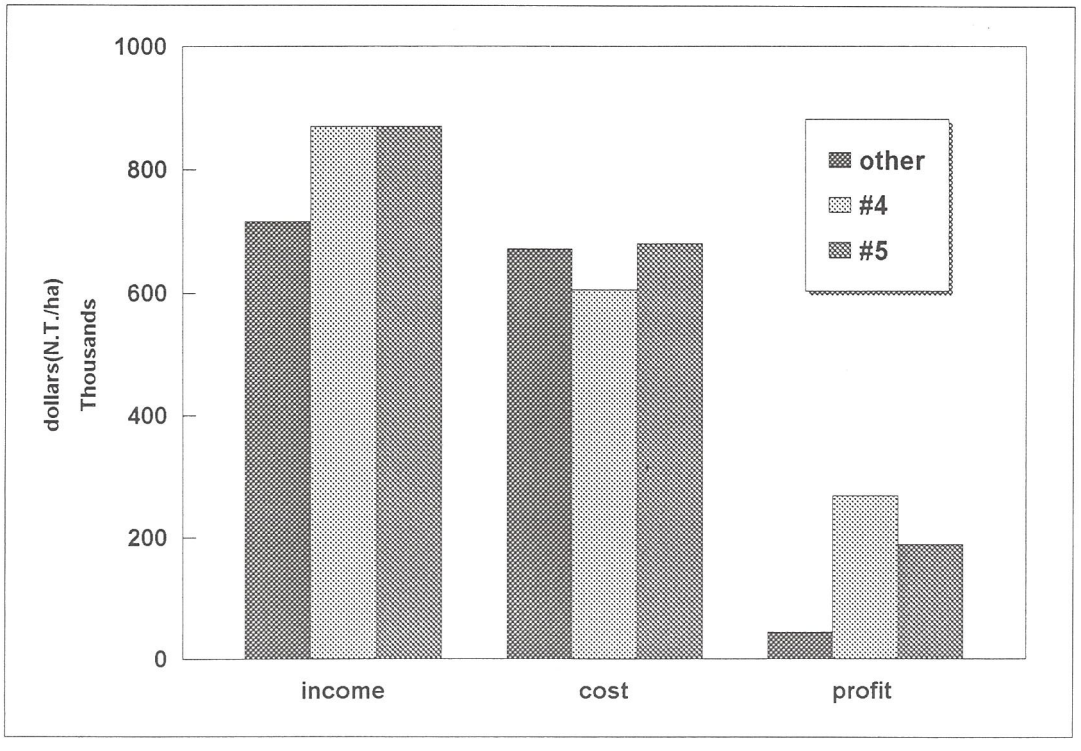


Fig. 8. Comparison of economics of summer tomato cultivation by variety in Taiwan, 1995

RESEARCH SUPPORT

This project aims to develop methodologies for quality assessment of the center's principal crops and improve their nutritional quality. To attain this goal, more than 25,000 chemical composition analyses were conducted in 1995 for such vegetables as grain and vegetable soybean, pepper, alliums, tomato, eggplant, and other crops using mainly near infrared reflectance spectroscopy (NIRS).

Increasing iron bioavailability by cooking

AVRDC recently demonstrated that the bioavailability of iron in some vegetables is enhanced by cooking. The enhancing effect was further studied using cruciferous vegetables and mungbean.

More than 20 kinds of fresh vegetables and eight processed vegetable products were surveyed for in vitro iron bioavailability. A wide variation in iron bioavailability among samples was observed ranging from 0.5 to 16.7% (fig. 1). Not all vegetables tested

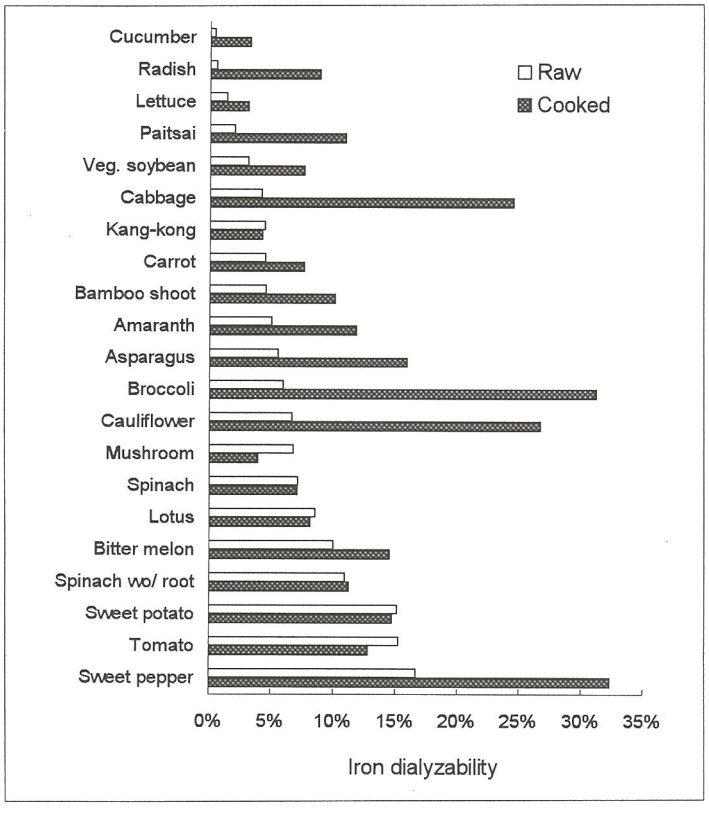


Fig. 1. Effect of cooking on iron dialyzability in selected vegetables
Vegetables from top to bottom are ranked according to iron dialyzability in raw materials

demonstrated higher bioavailability after cooking. The enhancing effect of cooking was diminished by drying and grinding (fig. 2). The enhancing ratio between cooked and fresh samples ranged from 0.8 to 15; this ratio is not related to either iron content or bioavailability of fresh samples.

Boiling and canning had no additive effect on iron availability. The bioavailability of cooked samples can be preserved during cold storage at 4°C (fig. 3). A slow but significant decline on bioavailability was observed after prolonged storage. Recooking cannot recover iron bioavailability in stored samples.

Quality evaluation of dehydrated vegetables

This activity has two purposes: to select suitable crucifer varieties for dehydrated products, and to establish a better dehydration process.

To apply the low temperature/low humidity dehydration system (AVRDC drying system) for commercial uses, a dehydration process currently used by a local company was slightly modified. Raw materials were dehydrated at 80°C, and then completely dried at 45°C, 10% RH.

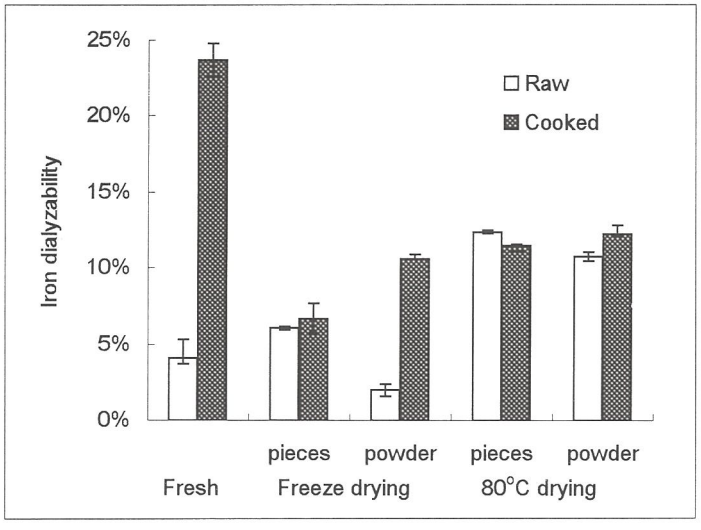


Fig. 2. Effect of drying on iron dialyzability in cabbage

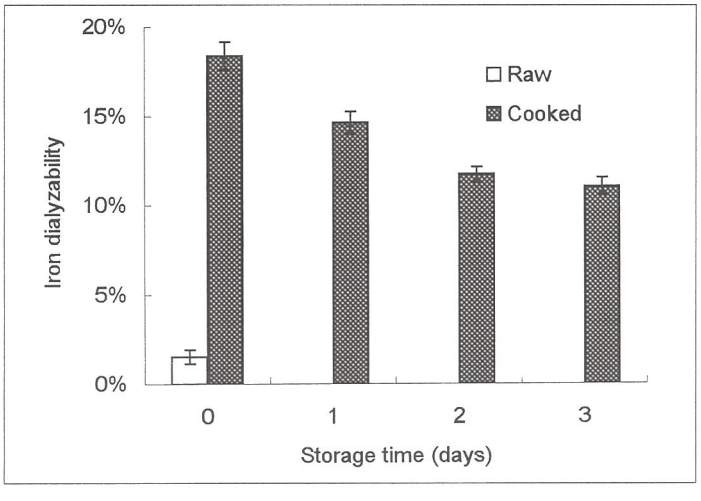


Fig. 3. Effect of cold storage (4°C) on iron dialyzability of cooked cabbage

Treatment of vegetables with sugar solution after blanching increases yield and reduces drying time. The effectiveness of the treatment was reconfirmed using cabbage, nonheading Chinese cabbage, and spinach.

Vegetable samples were processed under the modified dehydration system and their qualities evaluated against commercial products. Results for cabbage are summarized in table 1. Cabbage dehydrated under low temperature and humidity has a higher vitamin C content and dehydration ratio than the commercial product. Sugar solution treatment effectively improved the rehydration ratio.

Table 1. Quality of dehydrated cabbage

Quality	80°C-45°C, 10% RH w/o sugar	80°C-45°C, 10% RH w/ sugar	Commercial product
Browning	0.042	0.047	0.044
Total sugar (%)	32.03	57.41	60.53
Vitamin C (mg/100 g)	189.98	114.50	35.41
Rehydration ratio	6.47	7.01	6.75
Color reading			
L	43.58	43.01	41.50
a	-2.93	-1.82	-2.95
b	16.70	16.63	15.18

The isotherm curves of spinach with and without sugar solution treatment are shown in fig. 4. Moisture content of the dehydrated spinach increased by 2-3% compared with untreated samples at the same water activity. This effect was more pronounced in spinach and nonheading Chinese cabbage than in cabbage.

Dehydration curves of spinach with and without sugar solution treatment are shown in fig. 5. The sugar solution treatment reduced the required dehydration time greatly. This treatment shortened the drying time for spinach and nonheading Chinese cabbage than for cabbage.

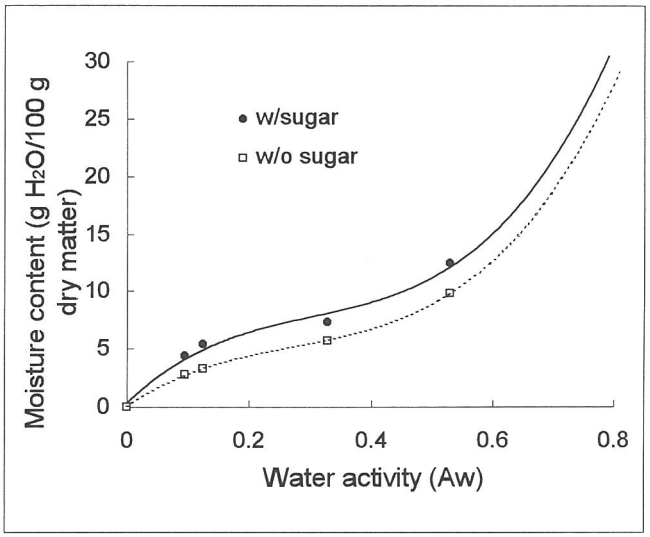


Fig. 4. Isotherm curve of spinach

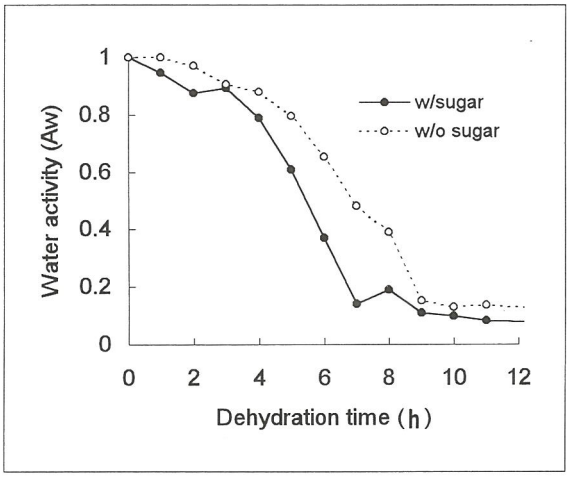


Fig. 5. Dehydration curve of spinach

HUMAN RESOURCES DEVELOPMENT

Training

In 1995, AVRDC trained 65 training scholars from 14 countries (table 1). All except one undertook nondegree training and 52% of the scholars underwent special research skills training. Forty-nine percent of the trainees were women. More than 60% were trained under the Crop Improvement Program. The rest were trained under the Production Systems and the International Cooperation Programs.

In addition to AVRDC 12 other donors supported the center's training program: Australian Centre for International Agricultural Research; Academia Sinica (ROC); Fulan Seeds Co., Ltd.; German Agency for Technical Cooperation; Japanese Special Project; TARI; UNDP/RDA; District Agricultural Improvement Stations (ROC); Hongkong R&D, MOE/Taiwan, ITC/Taiwan, and Agricultural Research Project-II, a World Bank project in Bangladesh.

Table 1. Distribution of training scholars by country and by category

Country	RF	RS	RI	SPT	VS	UST	Total
Bangladesh				1			1
Germany		1					1
Hongkong				2			2
India	1			2	1		4
Korea			1				1
Nepal				1			1
Netherlands	1						1
Nigeria					1		1
Pakistan	1			3			4
Philippines	3		1				4
Sri Lanka				1			1
Taiwan				12		19	31
Thailand	1			4			5
Vietnam				8			8
Total	7	1	2	34	2	19	65

RF= research fellow
RS= research scholar
RI= research intern
SPT= special purpose trainee
VS= visiting scientist
UST= undergraduate student trainee

Research fellowship Research fellows worked on the following research areas: cytological and biochemical studies on Southeast Asian vegetable genetic resources; Thai germplasm collection; development of methodology and principles for mungbean germplasm management; nutrient uptake from organic wastes by common cabbage; conducting and analyzing farm and marketing survey and production data; and communication and training-related materials production.

Research internship Fifteen training scholars, including a research scholar working towards his Ph.D. 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.

Special research skills training Ten training scholars, eight from Vietnam and two from Hongkong, sponsored by the Hongkong Research and Development (R & D), participated in the week-long special purpose training on the AVRDC noncirculating hydroponics system.

Short-term training Nineteen undergraduate students from seven academic institutions in Taiwan enrolled for the summer student training course. Seven scholars from five technical college/institutes in Taiwan participated in a 4-day training course on vegetable breeding, germplasm collection, and conservation. Five technicians from several Taiwan, ROC agricultural technical missions supported by the Committee of International Technical Cooperation came to AVRDC for a short period of study tour and training.

Training materials During the year 154 slide sets with scripts and videos were distributed to 36 training scholars.

Workshops and meetings

CLVNET consultation workshop

Drs. Charles Yang, S. Shanmugasundaram, and S.C.S. Tsou from AVRDC and Dr. Jay Chung from ADB visited the three countries (Cambodia, Laos, and Vietnam) that are part of the network and assisted the country representatives in preparing country profiles on the status of their vegetable production and research activities. The profiles formed the basis for discussion among the participants during the workshop held at AVRDC on 14-18 November 1994.

The country delegations, led by high-level officials included 6 delegates from Cambodia, 5 from Laos, 6 from Vietnam, 2 from ADB, 2 from the Asian Regional Center/AVRDC, 19 from AVRDC, and 1 resource person/observer from CIRAD in France.

The delegates requested institutional strengthening through training, exchange, and evaluation of elite varieties of specific vegetables, methodology for adaptive trials, development of reliable national statistics for vegetables—a database—and improved quality seed production technology.

They jointly prepared a Memorandum of Understanding to establish the Collaborative Vegetable Research Network for Cambodia, Laos, and Vietnam (CLVNET) and asked AVRDC to be their executing agency. All the countries signed the MOU.

The proceedings of the workshop was published in April 1995.

A joint collaborative research proposal for CLVNET was developed and submitted to ADB for funding. Another joint proposal has been prepared and submitted to Switzerland for funding.

COMMUNICATION AND INFORMATION

Information and documentation

Information collection

Some 289 titles of books, 134 photocopies, 325 titles of serial publications, and the Plant Genome Database on CD-ROM were acquired through exchange/gift from 287 institutes/organizations in 58 countries.

Processing information

A total of 2323 titles of books and crop documents, and 31 new serial titles were indexed and added to the Tropical Vegetable Information Service (TVIS) databases which now hold 53,744 bibliographic records and 1594 journal records. The supplementary databases contain 7594 records of control vocabularies, 3563 journal codes, and 3975 records of institution/organization data.

Total library collection is now 13,436 volumes.

Databases from CD-ROM were successfully converted to MINISIS for use in the local library/information network.

Disseminating information

SDI services listed 24 new users for 14 countries, bringing the total users to 253 in 58 countries.

Fifteen issues of Tropical Vegetable Information SDI Bulletin were published. The library recorded 3899 book and crop document loans and a total of 1298 document titles were sent to 51 external users and 77 libraries in 9 countries.

Publications and communications

Communication materials production

Fourteen publications, including the yearly progress report, 3 proceedings, 3 working papers, a technical bulletin, newsletters, a field guide, and special publications were produced. The primer on home gardening was translated to Bangla.

Art, graphic, and audiovisual backstopping was provided to research and documentation activities; 80 groups of local and international visitors (about 3300 individuals) were attended to.

Promotion of public awareness

Some 50 articles about AVRDC and center staff written by journalists who visited the center were published in eight local dailies and five magazines. AVRDC was featured in the special advertising section on ROC, along with more than 30 other government and multinational organizations based in Taiwan, in the October 1995 issue of Scientific American.

Two special television programs on AVRDC's research activities were produced by the Government Information Office and TV Broadcast Development Foundation.

Dissemination of research information

More than 5000 copies of AVRDC publications were sent to 3691 individuals/organizations in 177 countries and territories. CTA supported the distribution of AVRDC information materials to CTA-member countries.

COLLABORATIVE RESEARCH AND NETWORKS

Collaborative Vegetable Research Program for Southeast Asia (AVNET-II)

AVNET-II commenced in March 1993 with financial support from the Asian Development Bank. Its major goals are: (1) field verification and technology packaging for selected vegetables, and (2) disease and pest management. A mid-term review workshop was conducted on 21-25 February 1995 with 64 participants from Indonesia, Malaysia, Philippines, Thailand, AVRDC, and ADB.

Subnetwork I
Field verification and technology packaging of selected vegetables

In Indonesia, Philippines and Thailand, the most promising tomato varieties are FMTT-138F_1, BL 694 MT-1, PT 4225, and Seedathip 3 (table 1).

The yard-long bean CSL 19 has been commercially released to farmers by the National Seed Industry Council in the Philippines. It is also promising in Indonesia, Malaysia, and Thailand. Net income from growing yard-long bean is about US$2,000 to 7,000/ha. In Indonesia, CSL 19, LV 265, and KP 1 were the best yielders. Lower elevation locations are better than medium elevation for growing the crop. In Malaysia, ML 30, KP 5, Rajpuri, and Taiwan White are recommended for cultivation.

In hot pepper, the most promising varieties are given in table 2. Among the hot pepper entries, Jatilaba in Indonesia, Kawit in the Philippines, and Bangchang in Thailand were promising.

In the Philippines, the Indonesian cucumber variety LV 1723 yielded 8.1 t/ha with a net income of US$4,000/ha. A brochure, "Profiles of AVNET varieties" was prepared.

Table 1. Most promising tomato varieties

Country	Variety	Country of origin	Yield (t/ha)	Fruit size	Consumer preference	Net income (US$)	Average yield (t/ha)
Indonesia	FMTT-138F_1	AVRDC	24.3	75 g	yes		
	PT 4225	Thailand	23.5				
	BL 694MT1	Malaysia	20.4				
Philippines	FMTT-138F_1	AVRDC	18.8-39.5		yes	8,000	9
Thailand	PT 4225	Thailand	23			1,910	
	Seedathip 3	Thailand	29.3			1,990	

Table 2. Most promising hot pepper varieties

Country	Variety	Country of origin	Yield (t/ha)	Earliness	Net income (US$)
Indonesia	Jatilaba	Indonesia	17.6	yes	
	Prembun	Indonesia	17.2		
	Tit Super	Indonesia	11.9	yes	
Philippines	Kawit	Philippines	12.6		
	Szechuan 10	Taiwan	12.3		3,000
	Jatilaba (wet)	Indonesia	6.7		4,000 (wet)
Thailand	Bangchang	Thailand	2.04-9.3		200 (for red only)

Meristem culture in shallot is successful. Through tissue culture, 8 shallot and 14 garlic accessions are being maintained. G3 shallot bulbs have been transplanted to the field. The G3 bulbs are also currently being evaluated in the field. Commercial feasibility of micropropagated shallot and garlic as planting material is being explored. An information bulletin on tissue culture of shallot and garlic was prepared.

Subnetwork II

Disease and pest management

Bacterial wilt disease management A preliminary trial of diallel test from AVRDC is being conducted in the Philippines and Indonesia. In Malaysia and Thailand, the following varieties had excellent resistance to bacterial wilt and had good fruit quality: CLN 65-249D5-2-0, CLN 475BC$_1$F$_2$-265-4-19, BL 355, BL 342, BL 312, and CL 1131-0-0-43-4-12 in Malaysia; and BL 342, BL 350, BL 355, CL 143-0-10-3-0-1-10, CL 1131-0-0-43-0-6, CL 5915-93D4-1-0, and CL 5915-223D4-2-1-0 in Thailand.

Although biovar 3 was predominant in all four member countries its virulence differed. The serological method is effective in detecting *P. solanacearum*.

Management of major viruses of peppers Accessions VC 16A and Taiwan 83-168 were immune to CVMV in Indonesia. The resistance of VC 58A and VC 41A was overcome by some new strain of CVMV in Malaysia. Jatilaba is resistant to TMV and ToMV in the Philippines. Accessions VC 160A and VC 16A were resistant to both CVMV and CMV.

IPM of crucifers The parasitoids used in the four countries are given in table 3.

More than 3300 farmers have adopted IPM. In Malaysia, 90% of the farmers trained in IPM either do not use pesticides or used significantly less pesticides. In the Philippines, pilot projects have been initiated in 35 sites in 27 municipalities. About 81% of the farmers use IPM. An IPM primer has also been developed for farmers. Yellow sticky trap and NPV are popular among farmers for beet army worm and flea beetle.

In-country training for AVNET-II

In Indonesia about 400 field staff have been trained on integrated pest management.

A training on IPM of DBM was conducted in Thailand attended by 22 researchers and technicians from the Department of Agriculture and Extension. The staff trained at AVRDC and AVNET-II collaborators in Thailand served as resource persons.

Table 3. Parasitoids and other control measures used in four countries

Parasitoid and other control measures	Countries			
	Indonesia	Malaysia	Philippines	Thailand
Diadegma semiclausum	+[a]	+	+	-[b]
Cotesia plutellae (lowland)	+	+	+	+
Sturnia sp. *Inareolata* sp. (for *Crocidolomia binotalis*)	+	-	-	-
Diadromus collaris	-	+	-	-
Trichogrammatoidea bactrae (lowland)	-	+	+	+
Oomyzus sokolowskii	-	+	-	-
Indian mustard trap crop	+	-	+	-
Neem seed kernel extract	-	+	-	+
Bt	+	+	+	+
NPV	-	-	-	+

[a] Gave good control of one or more pest

[b] No effective control or not tested

South Asian Vegetable Research Network (SAVERNET)

SAVERNET, initiated in 1991, is funded by the Asian Development Bank. Like AVNET, it has two subnetworks. The first subnetwork on exchange and evaluation of elite varieties aims to assemble, multiply, distribute, and evaluate elite local cultivars of priority crops; accelerate the development of improved lines; and facilitate the sharing of information. Subnetwork II on crop and pest management research assembles, disseminates, and assesses technology and information on important pest and diseases; train researchers in these areas to create a mass of trained personnel; and develop new technologies on these components.

Subnetwork I

Exchange and evaluation of elite varieties

Of the 117 varieties of 12 different vegetables, 83 (70%) were exchanged among the six member countries (table 4). The major crops of interest to all countries are onions, tomato, hot pepper, and eggplant.

Subnetwork II

Crop and pest management

Bacterial wilt of tomato and hot pepper Fresh seeds of 21 AVRDC bacterial wilt-resistant lines were sent to five countries (exception Bhutan). In Nepal, Bangladesh, Pakistan, and Sri Lanka, additional surveys for bacterial wilt have been undertaken. Studies in India showed that *P. solanacearum* is transmitted by seed. Three AVRDC lines appear to be highly resistant to BW and promising for other traits (table 5).

Leaf curl virus of tomato and hot pepper Of the 50 tomato samples screened using CDNA probes, some were positive to Indian TLCV while four were positive to the Thailand strain. The whitefly population and TLCV were significantly low in the tomato nursery covered with nylon net + Furadan + corn border crops.

IPM of DBM The use of trap crop plus the release of the parasitoid *Diadegma semiclausum* and a spray of neem seed kernal extract saves the farmer US$130/ha due to withdrawal of insecticides. The farmer's field had 92% harvestable heads in India.

Table 4. Number of elite varieties for exchange from each country

Crops	Bangladesh		Bhutan		India		Nepal		Pakistan		Sri Lanka		Total	
	A	B	A	B	A	B	A	B	A	B	A	B	Agreed	Actual
Onion	2	0	1	1	6	5	1	1	4	2	1	1	15	10
Tomato	5	5	1	1	6	5	2	2	1	1	3	4	18	18
Hot pepper	0	0	3	1	6	1	2	2	5	3	3	2	19	9
Eggplant	4	3	1	1	7	4	2	2	1	1	2	1	17	12
Sweet pepper	0	1	0	0	2	1	0	0	1	0	1	1	4	3
Cauliflower (E)	0	0	0	0	2	2	0	0	1	1	0	0	3	3
Cauliflower (M)	0	0	0	1	2	2	1	1	1	0	0	0	4	4
Cauliflower (L)	0	0	2	1	1	1	2	2	1	1	0	0	6	5
Cabbage	1	2	0	0	2	2	0	0	2	0	0	0	5	4
Muskmelon	0	0	0	0	4	1	0	0	2	2	0	0	6	3
Pumpkin	0	0	0	0	4	2	0	0	0	0	1	0	5	2
Bittergourd	0	0	0	0	2	1	0	0	1	1	2	0	5	2
Cucumber	0	0	1	1	1	1	0	0	1	1	1	1	4	4
Okra	0	0	0	0	4	2	0	0	0	0	2	2	6	4
Total	12	11	9	7	49	30	10	10	21	13	16	12	117	83

A: Agreed, B: Actual, E: Early, M: Medium, L: Late

Table 5. Characteristics of promising AVRDC tomato breeding lines

Lines	Yield/plant (kg)	Avg. fruit no.	Remarks
CL-5915-93D4-10	0.80	73	Sp. oblate to round
CL-5915-206D4-2-2-0	0.94	77	Sp$^+$, round, lg, u & very firm fruits
CLN-675-BC1F2-285-0-21-0	0.87	70	Sp$^+$, u, round & firm fruits

Sp: tolerant to bacterial wilt; Sp$^+$: highly tolerant to bacterial wilt

In-country training for SAVERNET

One entomologist each from Nepal and Sri Lanka and three entomologists from Pakistan attended a 1-month training on IPM of DBM at the Indian Institute of Horticultural Research (IIHR) in Bangalore.

NARS scientists are encouraged to offer in-country training on different speciality areas. AVRDC staff serve as resource persons.

Collaborative Network for Vegetable Research and Development for Central America (REDCAHOR)

The proposal for the Collaborative Network for Vegetable Research and Development for Central America was approved by the Central American Bank for Economic Integration (CABEI) and International Economic Cooperation and Development Fund (IECDF) of Taiwan for three years. CABEI and IECDF signed the agreement on 22 November 1995. The Inter-American Institute of Cooperation in Agriculture (IICA) and AVRDC, the co-executing agencies and AVRDC as technical advisor and partner of REDCAHOR, have signed an MOA to implement the project in Costa Rica, Guatemala, Honduras, El Salvador, and Nicaragua. The Inter-American Development Bank has approved a project to include Panama and the Dominican Republic in REDCAHOR.

Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam (CLVNET)

A joint research proposal on Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam was prepared and submitted to ADB for funding. Another proposal, "Regional Vegetable Research and Development Capacity Building with Emphasis on Cereal-Based Cropping System in Cambodia, Laos, and Vietnam" has been submitted to the Swiss Development Cooperation.

CLVNET will be coordinated by the AVRDC Asian Regional Center in Thailand.

AVRDC-BANGLADESH AGRICULTURAL RESEARCH PROJECT

The AVRDC-USAID-Bangladesh project was extended for another 2 years to further strengthen the introduction and development of adaptive technlogies for sustainable year-round vegetable production and consumption in Bangladesh and transfer these technologies to farmers through demonstrations and training.

One hundred and eighty-eight lines/varieties were introduced from AVRDC and SAVERNET member countries during 1995. These lines were tested at the Bangladesh Agricultural Research Institute (BARI). Promising lines tolerant to any biotic and abiotic factors have been identified in tomato, okra, kangkong, edible podded pea, mungbean, malabar spinach, hot pepper, summer cauliflower, garden pea, vegetable soybean, and Chinese cabbage and are under preliminary yield trial evaluation.

BARI has already applied for the registration of 12 new varieties of 11 vegetable crops this year. Another 19 lines are in the pipeline.

To ensure year-round availability of tomato, cherry type heat-tolerant hybrids from AVRDC have also been introduced along with crop management techniques such as raised bed, grafting, tomatotone spray, and polythene protection. This year, two demonstrations on successful summer tomato crops in a large-scale area under polythene protection were conducted. Lines CL 11d-0-1(TM0111), CL 143-0-10-3 (TM0367), and cherry type hybrid CHT 501, CHT 500, and CHT 499 from AVRDC were found quite promising for summer and summer rainy season.

The project organized an in-country training program on the use of laboratory equipment for vegetable crops improvement. The project also participated in the internal and central research review. Field days on summer rainy season tomato were organized for farmers, extension agents, and NGOs in collaboration with BARI and extension agencies. It also arranged 43 training courses on transfer of technologies and trained 1,275 extension workers and farmers. Farmer's field demonstrations on new vegetable varieties and technologies were arranged throughout the country. A 3-day workshop on vegetable crops agribusiness was also conducted.

Research

Tomato

In an evaluation of 30 tomato germplasm genotypes tested during winter 1994-95, only seven lines were found promising for further evaluation on the basis of their yield and yield contributing characters. The genotypes TM 0774 and TM 0785 yielded more than 60 t/ha while TM 0772, TM 0773, TM 0775, TM 0796, and TM 0792 yielded between 50 and 60 t/ha.

A secondary yield trial with five AVRDC lines was repeated for the second year. FMTT 260, FMTT 304, FMTT 301, and CHT 280 were found very promising and were selected for regional testing.

Two lines (TM 0111 and TM 0367) of summer tomato were transplanted on 22 June and 15 July in an experiment to determine their potentials during rainy season under transparent polythene protection on permanent pipe as well as bamboo structures and using tomatotone for fruit setting. Line TM 0111 gave an average of 865 g and 810 g/plant yield while TM 0367 gave 815 g and 790 g/plant yield in the first and second sowing, respectively.

An observation trial on three selected cherry F_1 hybrids grown under polythene was transplanted on 26 June without hormone application. Hybrid CHT 500 and CHT 501 were quite promising and performed better than CHT 499.

Chinese cabbage

An evaluation trial on seven promising AVRDC lines was conducted during winter 1994-95. Lines CE-77M(3)-35 and CE-77(2/3)-46 were found quite promising for winter with yields of 75 and 71 t/ha, respectively.

Three sowings of Chinese cabbage were done during June to August. From these three trials lines 77 m (2/3)-46, 77M (3)-35, 77M (3)-40, and 77M (3)-27 were selected for summer and year-round production of Chinese cabbage.

The Chinese cabbage line CCE029 was evaluated under regional yield trial in-- different agroecological zones in Bangladesh in winter 1994-95. The highest yield per hectare was obtained at Jamalpur (73.9 t), followed by Ishurdi (59.3 t) and Joydebpur (58.5 t). The seed yield was also highest in Jamalpur (556.6 kg/ha) followed by Joydebpur (365.3 kg/ha) and Ishurdi (298.0 kg/ha). This line is likely to be released for commercial cultivation soon.

The cabbage line CE001 (1-1-52) from AVRDC produces seeds under local conditions. Initially a wide range of genetic variabilities was found in this line. Through mass selection the line has become quite uniform and stable. The line was evaluated in a preliminary yield trial at Joydebpur.

The average total plant weight was 3.1 kg while the marketable head weight was 2.2 kg. The compactness was satisfactory. Percent loose head ranged from 10 to 14. Performance trials will be conducted in the next season at different locations.

Vegetable soybean

A vegetable soybean evaluation trial (AVSET) comprised of nine AVRDC lines was sown on 16 March and completed on the first week of June. Line AGS 190 gave the highest total pod yield. This line has been found quite promising and will be tested in different locations.

Another soybean evaluation trial (ASET) comprised of 12 lines was sown on 4 April and harvested on 22 June. Line AGS 73 gave the highest yield (6.6 t/ha) followed by lines UFV-2 and GC 86017-170-1N.

An experiment was undertaken at BARI, Joydebpur to study the performance of 10 vegetable soybean genotypes from AVRDC during the 1994-95 rabi season. AGS 331 and AGS 190 produced the highest number of pods—62 and 60 per plant as well as yields of 9.3 and 8.1 t/ha, respectively.

An observational trial with nine AVRDC vegetable soybean lines was conducted during the 1994 kharif season at the Magura farm of MCC, a nongovernmental organization; the highest yield of 10.9 t/ha was recorded in line AGS 190.

Pepper

The INTHOPE #4 was evaluated at BARI, Joydebpur during 1994-95. Of the 16 lines evaluated, one line–PBC 074–did not germinate. Lines PBC 600, PBC 830, and PBC 580 were found quite promising.

Mungbean

Out of six mungbean yellow mosaic virus-resistant breeding lines supplied by AVRDC, two lines, namely VC 6144A and VC 6144B, were found quite promising. During kharif II-1995 (August-September sowing), these two lines were included in the advanced yield trial along with the eight other selected lines from the Pulses Research Center at three different locations, i.e., Ishurdi, Jessore, and OFRD Rengpur.

Line NM 92 was found promising; breeder seeds have been multiplied both at RARS Ishurdi and at BARI, Joydebpur. This line will be ready for registration soon.

Onion

An international tropical onion network trial was conducted on 16 lines during the rabi season of 1994-95 at BARI. The line ON 0063 produced the highest (10.6 kg) marketable bulbs. The yields of onion lines under investigation varied from as low as 10.1 to as high as 31.1 t/ha. Nine entries showed higher yield potentials ranging from 20.3 to 31.1 t/ha compared to the BARI line ON 0043 (16.2 t/ha). These nine lines are considered promising for further trials.

Eggplant

An experiment on 10 eggplant varieties under the SAVERNET program was conducted during 1994-95. The line Pusa Purple Long matured in 96 days up to first harvest, followed by Pant Rituraj (98 days); Pant Samrat was the latest maturing variety(127 days). The number of fruits per plant was highest in Pant Samrat (109); variety Pusa Kranti gave the highest yield of 63.6 t/ha followed by Pant Samrat (57.7 t/ha). The highest fruit and shoot borer infestation was observed in Pant Rituraj (83.9%) and the lowest in Pusa Kranti (25.5%). The bacterial wilt infestation was highest (89.3%) in Pant Rituraj and lowest (18.0%) in variety KT 4.

Radish

An evaluation trial on radish lines was sown on 10 November and harvested on 1-7 December 1994. Lines RH 034, RH 021, and Chinese radish were found quite promising. For local seed production line RH 021 showed better potential.

RH 021 was high yielding with good seed production ability under local conditions, but it showed phenotypic variability among the population. Therefore, mass selection technique was adopted to bring uniformity in the line. Seeds of the line RH 021 were sown on 20 October 1994. A population of more than 1000 plants were grown for selection. The line produced roots with an average weight of 457 g. It was observed that within the population there exists variability with respect to root shape, size, pithiness, branching, and bolting time. Considering all the parameters, 150 fifty-day old roots were selected and transplanted in isolation for seed production. The composite seeds were kept for next year's trial.

Malabar spinach

A trial on 11 lines from AVRDC was conducted during 1994-95. Line ID 0001 gave the highest yield (44.3 t/ha), followed by ID 0005 (43.5 t), ID 0009 (43.21 t), ID 0010 (42.7 t), and ID 0006 (40.1 t).

Kangkong

The results of an experiment on kangkong conducted at RARS, Hathazari during 1994-95 showed that the advance line Broad Leaf gave 49.9 t/ha yield compared to the local line Gima Kalmi 41.5 t/ha. The new line will be tested under different agroecological zones before its final registration.

Okra

Promising okra line OK 0285 was evaluated under regional yield trial in different agroecological zones of Bangladesh along with Pusa Sawni as check during 1994-95. OK 0285 gave the highest yield (19.5 t/ha) at Rahmatpur followed by 16.3 t/ha at Jamalpur. Virus infestation was nil in the new line (1-2%) compared to 34-60% in the check. Considering its good performance in different agroecological zones of Bangladesh, OK 0285 is likely to be released by BARI soon.

Garden pea

A trial was conducted on two selected early garden pea lines GP 006 and GP 018 during winter, 1994-95. Both lines were found quite early as well as high yielding. These two lines will be tested under regional yield trial in the next season.

Out of 10 lines tested during 1994-95, line GP 001 gave the highest yield (10.3 t/ha), followed by GP 008 (9.6), and GP 002 (9.4). These three lines have been selected for regional yield trials.

The results of the regional yield trials conducted in different regions during the year 1994-95 on an advance line of edible podded pea showed that in most of the locations the crop was ready for harvesting 71 to 75 days after sowing. Line GP 007 gave the highest yield at Ishurdi (15.6 t/ha), followed by Jessore (12.3 t), Rahmatpur (11.7 t), Joydebpur (10.1 t), and Pahartali (9.8 t/ha).

Homestead vegetable production

BARI has designed and recommended a homestead vegetable production model called Kalikapur with 14 kinds of vegetables for year-round intensive vegetable production. Recently, two new homestead models—I and II—with seven main beds and a corner bed comprised of 24 and 22 different vegetables, spices, and fast growing fruits developed at BARI, were compared with the Kalikapur model (table 1) at Joydebpur. These models were tested for 2 years. Each model was accommodated in a 25-m^2 area consisting of 7 raised beds (3.0 x 0.80 m) and 4 corners (0.75 m^2); the Kalikapur model has 5 raised beds of 5.05 x 0.08 m. Model II gave the highest yield of 306.8 kg/year followed by model I (282.5 kg/year); the Kalikapur model had the lowest yield of 259.8 kg/year.

Other activities

Research areas on vegetables identified for 1996 include germplasm collection and evaluation, varietal improvement and cultural management of solanaceous vegetables, crucifers, vegetable legumes, cucurbits, leafy vegetables, okra, intensive vegetable production, and breeder seed multiplication.

Twenty training programs on vegetable crop technologies were organized for extension workers from BARI, various extension agencies, and NGOs. In all 602 extension workers were trained. Twenty-three farmers' training courses with demonstrations and field visits were organized with 673 progressive farmer-participants.

Table 1. Cropping pattern under different models of homestead gardening

Bed no.	Number of vegetables		
	Model I	Model II	Model III (Kalikapur)
1	Teasle gourd + Gimakalmi (kangkong) /Country bean	Country bean Red amaranth /Yard-long bean	Radish Leaf /Tomato Red amaranth Indian spinach
2	Sweet potato (leaf) + Corn Amaranth Indian spinach	Eggplant + Knolkhol Amaranth Bitter gourd Red amaranth	Eggplant + Red amaranth Red amaranth Okra
3	Batisak Hot pepper + Onion (green) /Yard-long bean	Batisak Carrot /Okra Amaranth	Spinach Garlic Red amaranth Amaranth Red amaranth
4	Cabbage + Spinach Red amaranth Okra Radish (leaf)	Batisak Tomato + Red amaranth Aroids (tuber) Aroids (Stem) Aroids (Leaf)	Batisak Onion Gimakalmi (kangkong) Red amaranth
5	Cauliflower + Knolkhol Red amaranth Aroids (mukhi)	Sweet potato (leaf) Sweet potato (tuber) Indian spinach	Cabbage Red amaranth Bitter gourd
6	Radish (leaf) /Tomato /Indian spinach Red amaranth	Cabbage + Lettuce Gimakalmi (kangkong) Sweet potato (leaf) Sweet potato (tuber)	-
7	Red amaranth Eggplant + Carrot Amaranth Gimakalmi (kangkong)	Red amaranth Radish (root) Radish (leaf) Indian spinach	-
C1	Papaya	Papaya	
C2	Papaya	Papaya	
C3	Hot pepper	Hot pepper	-
C4	Coriander	Coriander	
Total	24	22	14

AVRDC-PHILIPPINES OUTREACH PROGRAM

The AVRDC-Philippines Outreach Program (POP) was established initially with support from the Asian Development Bank to conduct research on several vegetable varieties, evaluate AVRDC varieties and cultural practices, and determine their suitability to local conditions and requirements.

POP now undertakes adaptive trials to select promising varieties for release to farmers. AVRDC has been one of the main sources of vegetable germplasm in the Philippines. From 1990 to 1995, about 2,039 varieties, accessions, and breeding lines of different vegetables were sent through POP to researchers in various universities, colleges, and research stations for testing. These include 277 soybean, 317 mungbean, 548 tomato, 98 Chinese cabbage, 15 sweet potato, 546 pepper, and 238 other vegetables.

These lines are widely used in the national crop improvement projects. Selected promising lines from the preliminary yield trials are evaluated for yield potentials, adaptability to local agroclimatic conditions, and resistance to common pests and diseases. Results from these trials serve as basis for further evaluation of promising entries in the regional yield trials before varietal recommendation or release of new varieties for commercial production. Many recommended varieties released by the National Seed Industry Council (formerly Philippine Seedboard) for commercial production were developed from these AVRDC materials. Since 1974, five mungbean varieties, one each of tomato and soybean, three Chinese cabbages, and two sweet potato varieties from AVRDC materials have been released.

Manpower development is also an important component of the bilateral arrangement with AVRDC. The center has helped strengthen manpower capabilities of the vegetable industry in the Philippines. From 1974 to 1993, a total of 213 national program personnel have been trained at the center in various fields of vegetable R and D.

Pepper

The INTHOPE #4 and INTHOPE #5 cultivars were tested in the 1994-95 dry and 1995 wet seasons, and 1995 wet season, respectively. All trials were laid out in RCBD with three replications, following cultural management procedures provided by AVRDC.

Highly significant differences in yield and other horticultural characters were observed among the INTHOPE #4 entries and local cultivars in the 1994-95 dry season trial. Yields ranged from 4.5 t/ha for Korea-13 to 8.7 t/ha for LC-Serdang. Four entries outyielded the lowest yielding check. The two wet season trials were adversely affected by rains and typhoons.

Tomato

Two sets of single-seed-descent trials in tomato were conducted during the 1994-95 dry season to evaluate the field performance of newly introduced tomato breeding lines under local conditions. Set I evaluated eight cherry tomato lines against local checks, while Set II compared 19 processing tomato varieties to local checks and a processing variety from Taiwan. Screening was based on yield and yield components, resistance to tropical pests, diseases, and physiological disorders.

Each entry in both sets was transplanted in single-row 5-m long plots distributed in RCBD with three replications. Plots were mulched with rice straw and indeterminate growths were provided with trellises. In Set I, CHT 499 gave the highest yield of 35.4 t/ha, comparable to one check (32.5 t/ha), but significantly higher than another (24.6 t/ha). In Set II, PT 4225 had the highest potential yield of 50.4 t/ha, which was comparable to five other PT lines and a check, but significantly different from Pope and Th-103 (checks) and 15 other PT lines.

Two sets of general yield trials for determinate tomatoes were conducted during the dry season with 15 and 10 entries. All test entries except for Alton were from AVRDC. Marketable yields in Set I ranged from 10.1 to 31.4 t/ha. The yields of Alton and CL595-93-D4-1-0-3 were significantly better than the check, Pope, while the rest of the AVRDC test lines had comparable yields as the check. For Set II, four test lines significantly outyielded the check with 39.5 to 48.8 t/ha total yields compared to 32.1 t/ha for the check. CL 595-93-D4-1-0-C-2 and CLN 95-280-D5-1-7-0 produced significantly bigger fruit (85 and 80 g, respectively) than the check (36 g).

In the wet season trial, four lines outyielded the check with highest marketable yields ranging from 5.7 to 8.5 t/ha. CL 5915-93-94-1-0-12, the highest yielder, produced the biggest fruits.

For indeterminate tomatoes, Set I entries yielded 16.5 to 46.6 t/ha. FMTT 22, the highest yielder, outperformed the checks. The FMTT lines had signficantly bigger fruits (63-112 g) than the checks. In Set II, CLN 299BC_1F_2-12-5-3-12-0 significantly outyielded the check.

In the wet season trial, FMTT 105 gave the highest marketable yield of 8.9 t/ha, which was significantly better than the check's 5.9 t/ha.

Three AVRDC lines significantly outyielded the other entries including the check during the 1995 wet season regional yield trial at Los Baños, Laguna. These entries (CL-143-0-10-3-0-1-10, CL-5915-93-1-03, and FMTT 138) yielded 6.3 to 8.8 t/ha, compared to the check's 1.8 t/ha. CL-143-0-10-3-0-1-10 was the highest yielder. FMTT 138 had the biggest fruit (79 g). The RYT was conducted simultaneously in 12 stations strategically located in various parts of the country.

Mungbean

Twenty-six entries were evaluated in two sets of general yield trials following AVRDC's suggested cultural management and data collection procedures. Set I, with 14 entries planted in the dry and wet seasons, produced low bean yields due to adverse weather conditions, but during the wet season eight test entries from AVRDC outyielded the check BPI-Mg 9 with yields ranging from 1.3 to 1.4 t/ha. Differences, however, were not significant. Four entries from AVRDC produced the biggest seeds (6.1–6.2 g/100 seeds), but these were not significantly different from the check's 6.0 g/100 seeds. All entries had moderate to intermediate resistance to cercospora leaf spot and virus. In Set II, seven entries outyielded the two checks with 1.3 to 1.5 t/ha but again, the differences were not significant. All entries had moderate to intermediate resistance to CLS and virus.

In the regional yield trial, eight entries were evaluated during the dry season and 10 during the wet season.

VC 3890 from AVRDC was approved by the NSIC to be released as PSB-MgI for commercial production. Based on the results of 15 wet season and 12 dry season trials, line VC 3890 produced a mean bean yield of 1.5 t/ha during the wet season and 1 t/ha in the dry season (table 1). It is comparable to the checks in terms of resistance to cercospora leaf spot and powdery mildew, and other agronomic characters.

Two other promising AVRDC mungbean lines VC 2764 (Y) and VC 3876 consistently outperformed the check BPI-Mg 9 across locations from the 1993 to 1995 trials. Both VC 2764 (Y) and VC 3876 produced mean yields of ~1.3 t/ha in the wet season. In the dry seaosn, VC 2764 (Y) yielded ~1.0 t/ha and VC 3876 ~1.2 t/ha. These two lines will be submitted for possible NSIC approval in 1996.

Soybean

Of 16 test entries evaluated in the dry season GYT, only GC 82349-6-1 and G 9956 with ~2.0 t/ha and ~1.9 t/ha yields, outyielded the check variety UPL-Sy 4. However, the differences were not significant.

In the regional yield trials, results from 10 wet season trials revealed that the highest yielders were EGSy 93-18-07 (2.7 t/ha), LGSy 12-12 (2.3 t/ha), and IPB Sy 85-03-11 (2.5 t/ha) outyielding the check PSB-Sy 3 by 8-17%. The highest yielders from 11 dry season trials were IPB Sy 85-03-11 (2.2 t/ha), IPB Sy 85-16-08 (2.1 t/ha), and EG Sy 93-62 (2 t/ha), outyielding PSB-Sy 3, the check, by 28 to 41%. EG Sy 93-18-07 and EG Sy 93-63 produced the biggest seed size of 15.9 and 19.5 g/100 seeds. The entries were derived from AVRDC lines GC 50265-2-18-7 and G 0062, respectively. Because of their promising performance from the four-season, across-location trials, seeds of EG Sy 93-18-07, EG Sy 93-62, LG Sy 12-12, and IPB 85-16-08 were multiplied for possible NSIC approval in 1996.

Table 1. Summary of comparative performance of VC 3890 against the check varieties BPI-Mg9 and Pag-asa 7 from 1991 to 1993

Character	Variety		
	VC 3890	BPI-Mg9 (ck)	Pag-asa 7 (ck)
Bean yield (t/ha)			
WS1	1.5	1.5	1.4
DS2	1.0	1.0	1.0
100-seed weight (g)			
WS	6.26	6.10	6.19
DS	6.17	6.10	6.09
Maturity (day)			
WS	61	61	61
DS	61	60	61
CLS rating (1-5)			
WS	2.3	2.3	2.2
DS	2.1	2.2	2.1
PM rating (1-5)			
WS	1.4	1.3	1.4
DS	1.6	1.4	1.5
Rust rating (1-5)			
WS	1.8	1.6	1.4
DS	2.6	1.8	1.8
Virus rating (1-5)			
WS	2.0	1.8	1.6
DS	2.0	1.7	1.8
Chemical analysis (%)			
Protein	24.89	25.25	26.01
Carbohydrate	59.12	59.46	58.13

[a] Mean of 15 trials
[b] Mean of 12 trials

Vegetable soybean

Because of its high nutritional value and ease of production, vegetable soybean was included as a priority crop in the nutrition program of the local government. To support this program, promising lines of vegetable soybean from AVRDC are evaluated for yield potential, eating qualities, and other characters.

AVRDC-ROC COOPERATIVE PROGRAM

Promising AVRDC vegetable varieties/lines are evaluated in the field under different seasons and locations in Taiwan. At AVRDC headquarters, the evaluation trials are organized in cooperation with the national program of ROC. They are supported by the Council of Agriculture, ROC and conducted by AVRDC in cooperation with various District Agricultural Improvement Stations (DAIS) and the Taiwan Agricultural Research Institute. The trials aim to identify promising vegetable varieties for release to Taiwan farmers.

In the past years, 14 AVRDC vegetable varieties have been named and released by the national program in Taiwan. They have significantly contributed to farmers' incomes. In 1994, vegetable soybean Kaohsiung No. 1 comprised 91% of the total vegetable soybean growing areas. Mungbean Tainan No. 5 and two fresh market tomato varieties, Taichung ASVEG No. 4 and Hualien ASVEG No. 5, also occupied 85 and 54%, respectively, of the total growing areas of mungbean and tomato crops.

Regional yield trials

A total of 32 regional yield trials were conducted in cooperation with Tainan and Kaohsiung DAIS in 1994-95. The purpose of the RYTs is to evaluate promising AVRDC lines/varieties of vegetable soybean, mungbean and cherry tomato along with locally developed varieties at different locations in various seasons.

Vegetable soybean

Vegetable soybean is an important export crop in Taiwan. The frozen pods of vegetable soybean are exported to Japan and used by local restaurants. Three vegetable soybean varieties are grown by Taiwan farmers, but a variety with better consumer quality is needed.

In autumn 1994, 14 vegetable soybean entries including 4 AVRDC lines were evaluated at three locations (table 1). Seven entries, GC 87010-34-3-1, KVS 565, KVS 490, KVS 568, KVS 508, GC 87012-20-B-2, and GC 87012-20-B-8-2, outyielded the check varieties in terms of average marketable pod yields across the three locations. The highest mean yield of 7.1 t/ha was obtained from an AVRDC line, GC 87010-34-3-1; however, its yield was only found to be significantly different from the check varieties in Wantan. The same entries were tested at seven locations in spring 1995. The best yielder was KVS 568 with an average of 8.4 t/ha irrespective of locations. Moreover, KVS 568 produced extremely high yields of 14.1 and 14.0 t/ha in Potzu and Yenshui, respectively. In addition, the other four lines, TS 81-105 (8.2 t/ha), TS 81-115 (7.4 t/ha), KVS 490 (6.9 t/ha), and GC 87012-20-B-2 (6.9 t/ha), outyielded the check varieties, KS 2 (6.4 t/ha) and KS 3 (6.3 t/ha), irrespective of locations. Variations in yield were found between locations and seasons in each entry.

Table 1. Yields (t/ha) of vegetable soybean RYTs in Taiwan, 1994-95

	Autumn 1994				Spring 1995							
Entry	Meinong	Wantan	Shanhua	Mean	Likang	Wantan	Shanhua	Potzu	Yenshui	Houli	Taitung	Mean
TS 81-105	3.9	5.4	3.9	4.4	7.7	6.1	5.2	10.1	9.6	3.4	7.8	8.2
TS 81-115	6.2	4.0	3.0	4.4	7.5	7.1	6.3	9.0	10.5	3.7	8.0	7.4
TS 81-135	–	5.0	2.9	4.0	5.3	4.3	6.7	3.4	1.9	3.8	6.0	4.5
KVS 490	8.3	6.4	6.0	6.9	7.5	5.1	4.2	9.3	10.3	3.8	7.9	6.9
KVS 508	7.4	6.9	5.6	6.6	3.2	5.4	4.0	9.1	8.4	2.3	7.9	5.8
KVS 565	7.1	7.6	6.2	7.0	7.8	4.5	3.9	7.3	4.2	2.6	8.4	5.5
KVS 568	9.2	6.5	4.7	6.8	8.7	5.8	5.7	14.1	14.0	2.2	8.5	8.4
GC 87010-34-3-1	5.3	9.8	6.3	7.1	4.5	8.7	6.4	4.7	4.9	4.4	5.7	5.6
GC 87010-66-1-19	2.9	7.4	3.8	4.7	5.0	9.8	6.5	2.3	1.9	3.6	5.5	4.9
GC 87012-20B-2	7.5	6.2	5.1	6.3	6.8	6.3	6.1	8.7	9.6	3.3	7.4	6.9
GC 87012-20-B-8-2	6.9	5.6	6.1	6.2	8.9	7.1	6.0	3.7	2.0	3.0	7.0	5.4
KS 2 (ck)	7.0	6.6	4.0	5.8	6.4	5.3	6.5	7.9	8.1	3.3	7.0	6.4
KS 3 (ck)	7.9	5.4	5.1	6.1	6.8	5.6	3.8	8.3	9.2	2.7	7.6	6.3
Ryokkoh	3.6	6.3	3.8	4.5	3.2	6.1	4.8	3.2	3.1	3.1	4.4	4.0
Mean	6.4	6.3	4.8	5.8	6.4	6.2	5.4	7.2	7.0	3.2	7.1	6.2
LSD (5%)	1.4	1.5	1.3		1.9	1.6	0.9	1.4	2.0	1.4	0.7	–

Mungbean

In mungbean RYTs, nine AVRDC advanced lines were evaluated at two locations in summer 1994 and at three locations in spring 1995. No significant difference in yields was found between the advanced lines and the check variety Tainan No. 5. In the spring 1995 trial, VC 4152B produced the highest yield of 2.0 t/ha in Potzu. However, none of the entries were superior to the check Tainan No. 5. VC 4442 and VC 4152 were promising and produced stable yields comparable to Tainan No. 5 in all locations and seasons.

Cherry tomato

Cherry tomato has become popular in Taiwan. Santa variety developed by the Known-You Seed Company is widely grown by farmers. However, the variety has strong indeterminate growth, is susceptible to virus diseases, heat sensitive, and prone to fruit cracking.

Five AVRDC lines were tested at three locations in summer 1994 and four locations each in autumn 1994 and spring 1995 (table 2). The plants of these lines are semideterminate and have a similar fruit shape as the popular Santa. The results of RYTs indicate that all five lines outyielded the check variety Santa in terms of average yields across locations in both seasons in 1994. CHT 154 had the highest yields of 36.8 t/ha and 40.2 t/ha compared to 22.2 t/ha and 31.3 t/ha for Santa in summer and autumn trials, respectively. In spring 1995, yields of all entries were superior to those of Santa. However, the best yield of 46.9 t/ha was obtained from CHT 151 and CHT 157 which had small fruit.

Based on overall performance, CHT 154 was selected as the best from five entries of cherry tomato. It has yields of 12-66% over Santa depending on planting seasons. CHT 154 exhibited many advantages over Santa such as high yield, more tolerance to heat and leaf curl virus, concentrated fruiting, less cracking, and easy picking. Tainan DAIS is undertaking the process of naming and registration of CHT 154 in 1996.

Table 2. Average yields and fruit weight of cherry tomato RYTs in 1994-95

Entry	Yield (t/ha)			Fruit weight (g)		
	Summer 94[a]	Autumn 94[b]	Spring 95[b]	Summer 94[a]	Autumn 94[b]	Spring 95[b]
CHT 151	29.0	36.2	46.9	8.2	7.7	7.3
CHT 152	31.0	34.6	43.7	7.7	7.5	7.6
CHT 154	36.8	40.2	44.5	8.8	10.0	9.6
CHT 155	26.0	35.6	45.2	8.8	9.5	9.0
CHT 157	27.8	33.0	46.9	7.1	7.4	7.5
Santa (ck)	22.2	31.3	39.8	9.4	9.9	9.6

[a] Data represent the mean of 3 locations
[b] Data represent the mean of 4 locations

Collection and evaluation of nonprincipal vegetables

AVRDC has over the years successfully grown and identified promising varieties of several nonprincipal and potential principal vegetable crops. The purpose of varietal evaluation of nonprincipal vegetables is to search for improved varieties with potential as future principal crops at AVRDC or for recommendation to national programs through collection, evaluation, and selection. Currently, lettuce, snap bean, yard-long bean, broccoli, and cauliflower are included in the evaluation of nonprincipal vegetables in the country program.

Lettuce

Two trials were conducted to evaluate selected varieties of leaf, crispyhead, butterhead, and romaine lettuce in 1994-95. In the autumn 1994 trial, 39 entries including 13 leaf lettuce, 11 crispyhead, 12 butterhead, and 3 romaine were used, while 33 entries including 11 leaf lettuce, 7 crispyhead, 9 butterhead, and 6 romaine were employed in the spring 1995 trial. Lettuce trials were planted on 1-m beds with two-row plots, 50-cm spacing between rows, and 20 cm between plants. The experimental design was RCBD with three replications.

For leaf lettuce, significant differences in yields were observed among entries in both trials. The best yielders were obtained from Marsala (35.6 t/ha) and Sierra (34.6 t/ha) in autumn and spring trials, respectively. The promising varieties were Sierra, Marsala, and Rapidmor Oscura VML with mean yields of 33.7 t/ha, 31.0 t/ha, and 29.3 t/ha, respectively, in two seasons.

Among 11 entries of crispyhead, Georgia and Summergold gave high yields of 37.9 t/ha and 33.6 t/ha, respectively, in the autumn trial. In the spring trial, Sun (43.8 t/ha) and Glacier (42.6 t/ha) were the top yielders. Based on the results of two trials, Georgia, Calmar, Summergold, Sun, and Glacier were considered promising with yields higher than 30 t/ha.

Yields of butterhead lettuce were also significantly different among the entries. Nevada was the best and stable yielder with yields of 40.3 t/ha and 39.2 t/ha in autumn and spring trial, respectively. The other two varieties, Regina 71 and Felicia, also had stable high yields.

Romaine is a new type of lettuce in Taiwan. It is similar to leaf lettuce but is more crispy, which makes it easily acceptable to local consumers. Among six romaine lettuce entries tested, Augustus and

Maravimor Clara VML were the high yielding varieties. In general, yields of lettuce were better in autumn than spring except for crispyhead lettuce which had higher yields in spring. The number of days to harvest were generally shorter in spring than in autumn in all types of lettuce.

Snap bean and yard-long bean

In 1994-95, two trials were conducted to evaluate the general performance of collected bush and pole snap bean varieties. Fifty-three and 39 entries of bush snap beans were planted in autumn 1994 and spring 1995, respectively, on single-row plots 6 m long. Fourteen entries of pole snap beans were planted on two-row plots 4.8 m long in the same seasons. The experimental design was RCBD with three replications. Two observational trials were conducted to evaluate 19 varieties of yard-long bean in 1994-95. The trials were planted on two-row 4.8-m-long plots with two replications.

The results of bush snap bean trials indicate that significant differences in yields were found among the entries in both seasons. However, the yields were relatively low due to insect and disease problems. Among 53 varieties of bush snap beans, Paradise, NY 91-2504, and Pulobaeda performed well in both seasons. For pole snap beans, Witsa and Jemmy had promising yields of 24.8 t/ha and 18.6 t/ha, respectively, in spring, but their yields in autumn were very low. In the 1994 autumn trial, yard-long bean plants were attacked by bean mosaic virus, and no yield data were obtained. White Pod was the best yielder with 15.2 t/ha among the 19 yard-long bean varieties in the spring 1995 trial.

The yields of snap bean trials this year were relatively low compared to yields of last year. However, promising genotypes of bush snap beans have been identified. The adaptation of selected genotypes to mechanical harvesting will be tested in 1996-97.

Germplasm collection and evaluation of tropical leafy vegetables

Leafy vegetables are very popular and important in Taiwan. Almost 37,000 ha of leafy vegetables were planted in 1994, occupying about 22% of total vegetable planting areas. This project aims to introduce diverse leafy vegetables with heat tolerance and disease resistance to overcome the difficulty and shortage of summer leafy vegetable production in Taiwan.

Leafy vegetable germplasm were collected from the field by GRSU, and through germplasm exchanges, regional centers, and Chinese overseas missions. The germplasm collections focused on Southeast Asia, South Asia, China, and Africa. Evaluation and seed multiplication of the assembled leafy vegetables were carried out at the center. The evaluation trials were planted in the screen nethouse during summer, and the evaluation criteria used were adaptation, heat and stress tolerance, disease resistance, yield, and quality.

A total of 725 accessions including 32 kinds of tropical leafy vegetables were collected from the Philippines, Thailand, and Malaysia through GRSU. Multiplication and characterization of acquired germplasm were done by collaborating researchers in the Philippines and Thailand. A total of 418 g of seeds of 47 accessions of *Brassica* and 3600 g of seeds of 25 accessions of amaranth were obtained in 1994. Among the 135 accessions of vegetables collected from mainland China, 79 accessions are leafy vegetables which include nonheading Chinese cabbage, mustard, kale, spinach, lettuce, amaranth, celery, mallow, malabar spinach, and water convolvulus. Other collections in 1994-95 included 121 accessions from Southeast Asia, 43 from South Asia, 23 from Africa, and 39 from America and Europe.

In summer 1994 and 1995, 90 and 87 accessions, respectively, of leafy vegetables were evaluated in the nethouse. These leafy vegetables included amaranth, spinach, garland chrysanthemum, Chinese cabbage, mustard, malabar spinach, kale, mallow, basella, celery, water convolvulus, anise, cleome, coriandrum, and swiss chard. Promising accessions with heat tolerance and high yielding potential were identified—amaranth: TOT 1383, TOT 1602, TOT 1083 and CN 115; nonheading Chinese cabbage: TB 509, TB 510, CN 087, CN 098, CN 099 and CN 100; malabar spinach: TOT 1285 and TOT 1543; and mustard: TB 545, TB 546, and LV 008. Seeds of promising accessions will be multiplied and distributed to national programs for further evaluation.

AVRDC-ASIAN REGIONAL CENTER

The year 1995 marks some structural, research, and personnel changes at AVRDC-ARC brought about by the completion of technical assistance support from the Asian Development Bank on its Regional Training Program.

The mungbean breeding group carried out regular breeding activities as well as the International Mungbean Nursery and the shuttle breeding work with the Nuclear Institute for Agriculture and Biology (NIAB), Pakistan. Progress was made on the development of bruchid-resistant materials. Over 100 short-term research projects were undertaken including those conducted by the training scholars.

Twenty agricultural officials from 8 countries in Asia graduated from the 13th Regional Training Program conducted from October 1994 to 15 March 1995. A special trainee from Korea completed his program last April. The 14th Regional Training Program which started last 15 October has 30 training scholars from 10 countries in Asia, Africa, and the Pacific. The Korean Government sent two special training scholars for the 1995-1996 training period. As part of its intensive manpower development program, AVRDC-ARC through GTZ support has two research interns from China, one working on mungbean and the other on garlic.

The informal networking among Cambodia, Laos, Vietnam, and Myanmar is ongoing with support from the Swiss Development Cooperation. For the last two years, ARC arranged special trainings for researchers from the Rural Development Administration of Korea.

Research

Soybean

Four thousand soybean lines were multiplied as part of the soybean germplasm, characterization, and multiplication project with GRSU. The second set of this characterization and multiplication project will be carried out in early 1996. Germplasm of several vegetable crops like basil, okra, pepper were also multiplied and characterized.

Mungbean

Because mungbean is a regionally important crop, research on varietal development and testing have been devolved to the Asian Regional Center since 1992. Research at ARC is conducted in collaboration with scientists from ARC's host, Kasetsart University, and the NIAB in Pakistan.

Yield trial The advanced yield trial was composed of 10 advanced lines and 2 local checks, KPS1 and KPS 2. In early 1995, VC 5908-B-2-2B-3 had the highest yield of 2.1 t/ha. Its seed size was smaller than KPS 1 but relatively bigger than KPS 2. Yield and other agronomic characters are presented in table 1.

Table 1. Yield components of 12 mungbean entries in the advance yield trial (AYT 1-95), AVRDC-ARC, 1995

Yield ranking	# AVRDC designation	Yield (t/ha)	1000-seed weight (g)	Plant ht. (cm)	Seeds/ pod	Pods/ plant
1	VC 5908-B-2-2B-3	2.1	59.1	82.4	11.2	14.3
2	VC 5960-2B-2-B-2	2.0	64.4	74.2	10.8	13.9
3	VC 5960-2B-2-B-3	2.0	63.5	80.9	11.3	14.0
4	VC 5916-2B-3-B-3	1.9	60.7	89.9	11.6	14.7
5	VC 5926-2B-1-B-1	1.9	61.5	90.9	11.8	14.9
6	VC 5910-2B-3-B-1	1.9	63.5	81.1	10.7	16.2
7	VC 5911-2B-1-B-1	1.9	55.8	85.1	11.0	15.0
8	VC 5895-2B-1-B-1	1.9	58.7	83.4	11.9	13.1
9	KPS 2	1.8	54.8	85.1	12.3	15.3
10	KPS 1	1,.8	61.2	85.1	10.7	14.8
11	VC 5933-2B-1-B-1	1.8	58.7	98.4	12.0	15.5
12	VC 5925-2B-1-B-1	1.7	60.9	93.1	11.2	13.4
Mean		1.9	60.2	85.8	11.4	14.6
CV (%)		8.99	2.08	5.29	4.72	9.53
LSD (0.05)		172.60	1.26	4.54	0.54	1.39

The evaluation of 30 large-seeded lines showed that VC 6216-1-2-1-3 had the highest yield of 1.9 t/ha, significantly higher than KPS 1 (1.3 t/ha). Its plant height was 58 cm and number of pods/plant 21.

The yield of lines from different cycles ranged from 0.5 to 1.6 t/ha. Twenty-five percent of these lines outyielded KPS 2 and KPS 1 which both gave yields lower than 1 t/ha.

Bruchid resistance Evaluation of bruchid-resistant lines developed through backcrossing show that VC 6091-28-26-2-B, a cross between VC 1973A and TC 1966, has the highest yield of 1.9 t/ha. It significantly outyielded the checks KPS 1 and VC 3890A. TC 1966 carries the gene that confers resistance to both *Callosobruchus chinensis* and *C. maculatus*.

RFLP-assisted breeding Selections were made using RFLP markers linked to bruchid resistance. Entry 20 or 28-28-1-B gave the highest yield of 1.0 t/ha. This is significantly higher than the yield of KPS 1 (0.7 t/ha).

Shuttle breeding for mungbean yellow mosaic virus resistance and other important traits The collaborative program between the Asian Regional Center and the Nuclear Institute for Agriculture and Biology in Pakistan started in March 1992. During the duration of the project the hybridization of mungbean varieties developed at NIAB and at AVRDC, the screening of the segregating populations against MYMV at NIAB under strong biotic stress, and the evaluation of new recombinants both at NIAB and at AVRDC under diverse ecological and agroclimatic conditions have led to the development of a number of improved mungbean lines with high levels of resistance to MYMV, uniform maturity, nonshattering pod, and larger seed size. The elite lines are now being evaluated in the macroplot yield trials at both sites. VC 6153-B-31-2B-1-B, a derivative of a cross between NIAB Mung 92 and VC 3902, performed well at both NIAB and AVRDC with a high yield potential (2 t/ha), large seed size (67 g/1,000

seeds), improved plant type, and is resistant to MYMV. The seeds of this line will be multiplied for testing at the national and international level.

Table 2 shows the materials exchanged between AVRDC-ARC and NIAB.

From the 1994 summer crop raised at NIAB 228 lines and 73 single plant selections with desired plant attributes were isolated from different populations.

Table 2. Materials shuttled between AVRDC-ARC and NIAB

Population designation	No. entries received from AVRDC	Further selections made at NIAB: Generation	Further selections made at NIAB: No. of selections
F_7 bulk populations (NM 92 x AVRDC lines) derivatives	59 17	F_8	29
F_5 bulk populations set 2 (NM 92 x AVRDC lines) derivatives	A13 B19 C15	F_6	13
F_4 bulk populations set 3 (NIAB lines x AVRDC lines) derivation	A 7 B24 C29	F_5	21
F_3 bulk populations (NM 92, NM 51 x AVRDC lines) derivatives	33	-	-
Backcrossed populations	6 crosses	B_4/F_2	33
F_1 populations			
NM 92 x 15 AVRDC lines	15 crosses	F_2	687
NM 89 x 15 AVRDC lines	15 crosses	F_2	548
M3 populations			
NM 92	9	M4	7
NM 94	21	M4	3

Performance of advanced lines in yield trials at AVRDC-ARC, Thailand and at NIAB, Pakistan

NIAB Mung 92 was crossed reciprocally with five promising AVRDC accessions, namely VC 2768A, VC 3902a, VC 1973A, VC 1628A, and VC 1560A. The F_1 and F_2 generations were raised at AVRDC and F_3 generation at NIAB to select for resistance to MYMV, yield, and other important traits. The F_4 and F_5 generations were raised at AVRDC and F_6 at NIAB. In the F_7 generation, 17 promising lines were evaluated at AVRDC along with NM 92 and KPS 1 (1973A) for yield, seed size and other important traits. The same lines in F_8 generation were evaluated at NIAB (table 3).

All the entries exhibited a high level of resistance/tolerance to MYMV, cercospora leaf spot, and powdery mildew diseases.

Training

The 13th Regional Training Program in Vegetable Production and Research was attended by 20 training scholars from eight countries in Asia. In addition to classroom and library work these scholars conducted full-term field research. Sponsorships for these scholars came from the Swiss Development Cooperation, International Development Research Centre of Canada, and the Asian Development Bank.

A special training scholar was sent to AVRDC-ARC by the Central Experiment Station of the Rural Development Administration of Korea to conduct research in corn.

Thirty-one agricultural officials from 10 countries in Asia, the Pacific and Africa are attending the 14th Regional Training Course in Vegetable Production and Research which started 15 October. The participant from Zambia is sponsored by FAO while the one from Papua New Guinea is being sponsored by his own government.

Under the special training program for Korean researchers, two agricultural officials from the Rural

Table 3. Performance of advanced mungbean lines for yield and other important traits at AVRDC-ARC, Thailand and NIAB, Pakistan, during 1994

Entry	AVRDC (Spring crop)			NIAB (Summer crop)		
	Days to maturity	1,000-seed wt. (g)	Yield (t/ha)	Days to maturity	1,000-seed wt. (g)	Yield (t/ha)
1 VC 6158-B-5-B-3-1-B	52	74.3	1.8	66	67.3	1.3
4 VC 6158-B-31-B-3-2-B	52	59.8	1.6	67	56.0	1.5
5 VC 6158-B-15-B-2-1-B	59	59.4	1.3	72	54.6	1.2
7 VC 6158-B-22-B-2-1-B	53	75.5	1.8	69	73.3	1.4
9 VC 6153-B-31-2B-1-B	54	70.1	1.9	68	67.0	1.9
10 VC 6153-B-32-2B-3-B	55	64.7	1.5	65	63.0	1.3
14 VC 6168-B-19-2B-1-B	50	71.8	2.1	72	66.8	1.2
16 VC 6173-B-22-2B-3-B	54	78.2	1.8	70	73.4	1.4
18 NM 92	54	50.2	1.4	67	53.0	1.6
19 KPS 1 (VC 1973A)	58	70.6	1.3	Failed to thrive due to MYMV attack		
20 NM 51 (ck)		Not studied		74	43.0	1.5
21 NM 54 (ck)		Not studied		67	57.0	1.4

[a] Entries no. 1, 4, 5, 7 are derivatives of crosses between NM 92 and VC 2768A
Entries no. 9 and 10 are derivatives of crosses between NM 92 and VC 3902A
Entry no. 14 is a derivative of crosses between NM 92 and VC 1628A
Entry no. 16 is a derivative of crosses between NM 92 and VC 1560A
NM 51 and NM 54 are approved varieties of mungbean evolved by NIAB

Development Administration are at ARC for the 1995-1996 training program. Both are conducting advanced yield trials on corn.

GTZ is sponsoring two research fellows from the Crop Germplasm Research Institute of CAAS, Beijing and the Shandong Academy of Agricultural Sciences, China. They are working on the screening of bruchid resistance materials and meristem culture and virus elimination in garlic.

On-farm trials

In cooperation with the Tropical Vegetable Research Center and Department of Agricultural Extension, AVRDC-ARC is continuously conducting on-farm trials of AVRDC materials, especially those that have been released for farmers in Thailand. The Thai Government will soon release a new mungbean variety known as KPS 3 from one of the AVRDC lines. AVRDC tomato PT 4225 is now widely adapted by Thai farmers. AGS 292 is one of the most popular vegetable soybean varieties used by Thai farmers. The AVNET Phase II activities are being carried out in farmers' fields.

As in 1994, the farmers' field trials for various ARC crops were conducted in nearby districts around Nakhon Pathom area. Adaptability trials for vegetable soybeans and tomatoes were carried out as far as the northeastern provinces of Thailand. Results of these on-farm trials and farmers' adaptability tests were used as bases for the promotion and consequent release of varieties for farmers' use all over the country. The nationwide utilization of vegetable soybean variety AGS 292 was the outcome of a joint promotion by ARC and DOAE through farmers' demonstrations.

Germplasm collection, multiplication, and exchange

Multiplication and characterization of eggplant and bittergourd collected from all over Thailand were completed in early 1995. Half of the soybean germplasm from headquarters was multiplied in early 1995; the other half will be multiplied in early 1996.

Germplasm exchange between China and AVRDC-ARC continues.

A total of almost 800 packets of vegetables, including vegetable soybean seeds were distributed to more than 50 institutions with cooperative linkages with ARC (table 4). These agencies or institutions are mostly located in China and Indo-China countries. For 1995 trials, 14 sets of the 20th International Mungbean Nursery were sent out to various cooperators. More than 20 kg of other mungbean lines not included in the 20th IMN were distributed to Myanmar, Vietnam, Cambodia, Laos, China, Thailand, Pakistan, and India.

AVRDC-ARC has also distributed almost 700 packets of vegetable soybean seeds to home garden producers in Thailand and other countries.

Table 4. Seed distribution to various cooperating agencies

Crop	No. of packets distributed	Recipient
Tomato	272	Cambodia, China, India, Myanmar, Sri Lanka, Thailand, Vietnam
Chinese cabbage	198	Bangladesh, Cambodia,China, Myanmar, Papua New Guinea, Thailand, Vietnam
Pepper	209	China, Cambodia, India, Myanmar, Thailand, Vietnam
Eggplant	16	China, Thailand
Yard-long bean	5	Thailand
Cucumber	6	Thailand
Vegetable soybean	19	Cambodia, China, Laos, Myanmar, Philippines,
Okra	11	China, Myanmar
Soybean	32	Laos, Cambodia, Thailand
Lettuce	11	China
Pumpkins	4	China
Sweet potato	6	China
Alliums	5	China
Mungbean	366	Australia, Cambodia, China, India, Laos, Myanmar, Pakistan, Philippines, Thailand, US

Workshops/seminars

AVRDC-ARC co-sponsored two international workshops and one in-country workshop in Beijing, China: International Workshop on Collection and Utilization Studies on Crop Germplasm Resources, the International Symposium on Postharvest Science and Technology of Horticultural Crops, and the Workshop on Tomato Pests and Diseases Control. TVRC and AVRDC-ARC scientists and staff also participated in national workshops and symposium such as the 6th Thai National Mungbean Symposium and the Workshop on Mungbean Germplasm, Collection, Evaluation and Utilization for Breeding Program, among others.

Networking

ARC continues its cooperative projects with Cambodia, Laos, Vietnam, and Myanmar through training. Testing of AVRDC materials is ongoing in these NARS. AVRDC mungbean VC 1973 has been released to farmers in Myanmar. Two sets of IMN were recently sent to Myanmar Agricultural Service.

The cooperative program with China has been expanded.

Phase III of the tomato virus survey and soybean rust survey in China has been completed. Results of the tomato virus survey project were presented in a workshop in Beijing. Continuing activities are being planned by both AVRDC-ARC and the Ministry of Agriculture of China.

AVRDC-AFRICA REGIONAL PROGRAM

The AVRDC Africa Regional Program was established in 1992 with grants from the German Ministry for Economic Cooperation (BMZ), German Agency for Technical Cooperation (GTZ), and the French Government. The program is mandated to conduct vegetable research, training, and information services for the African national programs. ARP implements two projects: the tomato improvement program for the African highlands, and the Collaborative Network for Vegetable Research and Development in Southern Africa (CONVERDS) for the Southern African Development Council.

The goal of the highland tomato project is to develop cultivars with resistance particularly to tomato leaf curl virus and late blight. The project also aims to introduce, evaluate, and promote the adoption of tropical tomatoes for production in hot and humid conditions in the African continent.

CONVERDS is charged with research on strategic vegetables, training, and information services. To date, ARP has trained a total of 60 specialists and NARS personnel in its five-month vegetable production training course started in 1994, and short-term and special courses.

Adaptation studies of tomato germplasm to the African highlands

Two groups of materials were tested during the 1994–95 growing seasons to test the adaptability of introduced tomato germplasm to the African highlands. The first consisted of promising indeterminate fresh market lines derived through further selection under Arusha conditions (Madiira Research and Training Station) among and within advanced lines derived from crosses between AVRDC's tropical lines and Rodade, a South African variety that is grown in several SADC countries. The second group consisted of introduced processing tomato lines from headquarters.

Three preliminary trials of the indeterminate lines were conducted. The first PYT (Batch I) was sown on 26 October 1994 and transplanted on 20 November 1994. Nine lines were evaluated against two commonly grown cultivars, MoneyMaker and Marglobe. The second (Batch II) consisted of the same entries sown on 28 February 1995 and transplanted to the field on 28 March 1995. A third trial (Batch III) was conducted to confirm results from the first two trials. This experiment was sown on July and transplanted on 17 August 1995. The experimental design was RCB for all three trials. Batch I had two replications, while Batches II and III had three replications.

Spacings in the two PYTs were the same: 50 cm between plants within the row in a double-row bed; 1.2 m between furrows or from center of one bed to the center of another. Each plot consisted of two rows, each 6 m long. Effective plant population (excluding border plants) was 10 plants per row x 2 rows or 20 plants per plot.

Triple superphosphate was applied in both trials at planting time at the rate of 45 kg P_2O_5/ha. Two weeks after transplanting, nitrogen in the form of urea was sidedressed at the rate of 45 kg N/ha. This was repeated a week later for a total N application of 90 kg N/ha. Plants were staked and desuckered at appropriate times during the growth period.

Evaluation of determinate processing lines consisted of two PYTs. The first trial was sown on 28 February 1995 and transplanted on 28 March 1995. Eight lines were tested against the local check, Roma VF. Experimental design in both PYTs was RCBD with three replications.

The same spacings and effective plant populations were used as with the indeterminate lines. Rates and forms of fertilizers were the same as with the indeterminate fresh market lines.

Data on yield and other horticultural characters were gathered in all trials and statistically analyzed.

A number of fresh market lines performed better than the checks in the Batch I trial (table 1). The best entry, ARP 366-3, significantly outyielded MoneyMaker but not Marglobe. Other clearcut advantages of the ARP lines were cracking resistance, reduced catfacing and fruit firmness. With the exception of a few ARP lines, Marglobe generally produced larger fruits. However, the ARP lines had generally bigger fruits than MoneyMaker.

In the Batch II PYT, differences in yield between ARP lines and the checks were more pronounced (table 2). Some of the best yielding lines in Batch I PYT were also good yielders in the Batch II PYT. Again, the ARP lines showed better fruit firmness than the check varieties.

In the third trial, only ARP 366-2 outperformed the check, MoneyMaker, in yield and mean fruit weight. The superiority of other ARP lines over MoneyMaker may not be very pronounced statistically but it is apparent in the data (table 2).

The ARP lines also possess resistance to nematode (natural field infestation rating) and tomato mosaic virus. In separate studies in Arusha and Dodoma, ARP pathologists observed that some of these ARP lines are tolerant to tomato yellow leaf curl. These lines are being tested for Fusarium wilt resistance since one of the parents of ARP lines, Rodade, carries resistance to Race 1 and 2 of the pathogen. It is possible to select lines that already carry resistance to four major tomato diseases in the highlands namely, tomato mosaic virus, tomato yellow leafcurl, root-knot nematode, and Fusarium wilt among these materials.

Table 1. Performance of the best fresh market indeterminate lines (ex. Rodade crosses) compared to the checks in the PYT (Batch I), ARP, 1994-95

Entry	Mkt. yield (t/ha)	Fruit wt. (g/fruit)	Crack (%)	Catface (%)	Fruit firmness[a]
ARP 366-3	28.1b	90bc	0a	1.4ab	F
ARP 367-2	24.9ab	104c-e	0a	2.8b	VF
ARP 366-1	24.1ab	94b-d	0a	0a	F
ARP 366-2	23.0ab	94b-d	0.5a	0a	F
ARP 365-2	21.6ab	107de	0a	2.5b	F
MoneyMaker (ck 1)	18.4a	64.5a	26c	.7a	S
Marglobe (ck 2)	21.1ab	116e	25c	2.7b	S

[a] F = firm; VF = very firm; S = soft

Mean separation within columns by DMRT at $P = 5\%$

Table 2. Performance of promising fresh market indeterminate lines (ex. Rodade crosses) in the PYT (Batches II and III), ARP, 1995

Batch II Entry	Total yield (t/ha)	Mkt. yield (t/ha)	Fruit wt. (g/fruit)	Fruit firmness[a]	ToMV[b]	NR[b]
ARP 365-2	73.4c	70.0d	90b	F	R	R
ARP 366-2	66.0bc	64.4cd	80ab	F	R	segs
ARP 366-1	62.8bc	61.1bcd	84b	F	R	segs
ARP 365-1	62.1bc	58.6bcd	86b	VF	R	R
Marglobe (ck 2)	45.9a	43.3a	114c	S	S	S
MoneyMaker (ck 1)	45.0a	42.5a	61a	S	S	S

Batch III Entry	Total yield (t/ha)	Mkt. yield (t/ha)	Fruit wt. (g/fruit)	Fruit firmness[a]	Fruit/ plant[a]
ARP 366-2	97.6a	93.1a	94.8a-c	F	31ab
ARP 367-2	94.5a	92.0ab	104.6bc	F	27bc
ARP 365-2	84.4ab	77.4a-c	103.2a-c	F	23cd
ARP 365-1	78.7ab	74.7a-c	106.0a	VF	23cd
MoneyMaker (ck)	70.7ab	66.2bc	57.9d	S	35a

[a] F = firm; VF = very firm; S = soft

[b] R = resistant; segs = segregating; S = susceptible

Mean separation within columns by DMRT at $P = 5\%$

Overall, the lowest yielding experiment was the dry season trial (Batch I) which suffered from drought stress. The consistently good performers in all trials were ARP 365-2, ARP 366-2 and possibly, ARP 367-2 and ARP 366-1.

Among the new determinate processing lines from headquarters, none significantly outyielded Roma VF, the most commonly grown determinate cultivar in Tanzania and other parts of Africa. The best new line is PT 4674-10-0-1, yielding 51 t/ha compared to 47 t/ha for Roma VF. However, the AVRDC lines showed superiority in firmness and fruit fill. Fruits of Roma VF tend to be puffy and small.

Tomato hybridization program for the African highlands

The backcross program which began in 1993 to improve the the performance of popular local African highland local varieties MoneyMaker and Marglobe continued.

In 1994–95, two backcross generations to the recurrent parents, Marglobe and MoneyMaker, were successfully completed. In each BC generation, selection for resistance to ToMV and root-knot nematode were carried out by ARP pathologists to isolate the double resistant progenies for further crosses. Initially, selection was made for ToMV resistance, discarding all ToMV-susceptible progenies. Only ToMV-resistant plants were then

inoculated with ARP's pure isolate of *Meloidogyne hapla* (The same *Mi* gene controls resistance to *M. incognita* and *M. hapla*). The susceptible BC progenies were eliminated before transplanting them to the screenhouse for crosses. The BC plants were double-checked later for nematode infection and further selections carried out. Only the BC families that closely approximate the expected 1:1 ratio of susceptible:resistant plants for ToMV and nematode were further propagated in each BC generation.

Selfed progenies of the BC_3F_1 were generated for further selection. Better genetic materials (ARP 365, ARP 366, and ARP 367 series) than MoneyMaker and Marglobe are now available for further breeding work. These new lines carry resistance to tomato mosaic virus, root-knot nematode, Fusarium wilt, and tolerance to TYLCV.

Survey of major vegetable diseases occuring in three SADC countries

During June and July 1995, field surveys were conducted in Malawi, Zambia, and Zimbabwe to identify major vegetable (tomato, pepper, cabbage, and squash) diseases affecting vegetable production. The identification of fungal and bacterial diseases was based on symptomatology. Viral diseases were identified by symptomatology followed by immunodiffusion test whenever antibodies were available.

Preliminary results of this survey are given in table 3.

The most damaging tomato diseases identified in these countries were early and late blight, tomato mosaic virus, and root-knot nematodes. Potato virus Y was widespread in pepper crops. Black rot and turnip mosaic virus were the most important cabbage diseases. Watermelon mosaic virus-2 was found in squash crops.

Table 3. Distribution of major tomato diseases in three SADC countries (Malawi, Zambia, and Zimbabwe)

Disease	Distribution
Tomato	
Early blight, *Alternaria solani*	Malawi, Zambia, Zimbabwe
Late blight, *Phytophthora infestans*	Malawi, Zambia, Zimbabwe
Powdery mildew, *Oidium lycopersicum*	Malawi
Fusarium wilt, *Fusarium oxysporum* f.sp. *lycopersici*	Malawi, Zambia,
Tomato mosaic virus	Malawi, Zambia, Zimbabwe
Tomato yellow leaf curl	Malawi, Zambia
Potato virus Y	Zambia
Cucumber mosaic virus	Zambia
Bacterial wilt	Malawi
Bacterial spot	Malawi, Zambia
Bacterial canker	Zimbabwe
Root-knot nematode	Malawi, Zambia, Zimbabwe
Pepper	
Cercospora leaf spot	Malawi
Powdery mildew	Zambia
Potato virus Y	Malawi, Zambia, Zimbabwe
Cucumber mosaic virus	Malawi, Zambia
Cabbage	
Soft rot	Malawi, Zambia
Black rot	Malawi, Zambia, Zimbabwe
White rust	Malawi
Turnip mosaic virus	Malawi, Zambia, Zimbabwe
Squash	
Downy mildew	Zimbabwe
Powdery mildew	Zambia, Zimbabwe
Watermelon mosaic virus - 2	Malawi, Zambia, Zimbabwe
Zucchini yellow mosaic virus[a]	Zambia, Zimbabwe

[a] Identification to be confirmed

Evaluation of tomato germplasm for late blight resistance

Experiments to test late blight resistance sources for their potential use as commercial varieties or as genetic stocks in breeding were conducted at two locations, namely Seatondale Research Station (Iringa) and Madiira Research Farm (Arusha). In these two regions, 100% late blight infection is routinely observed on tomato crops.

Seventy-six accessions were evaluated. Seeds were germinated in seedling trays, and 1-month-old seedlings were transplanted to the field. Plants were scored independently by two people for symptom development at 10, 17, 24, 31, and 38, days after transplanting.

Considerable variation in resistance was found among species. *L. peruvianum* (L 3707), *L. pimpinellifolium* (L 3708), and *L. hirsutum* (L 3683 and L 3684) were the most resistant germplasm (table 4).

High levels of resistance were also noted in backcross breeding families CLN 1775BC_1F_1 (Roma VF x L 3708), CLN 1776 BC_1F_1 (MoneyMaker X L 3708), CLN 1779BC_1F_1 (MoneyMaker x L 3684) and CLN 1782 BC_1F_1 (Marglobe x L 3683).

Table 4. Disease severity ratings of *Lycopersicon* accessions evaluated in two locations in Tanzania

Acc. no.	Arusha	Iringa
LA 1458	1.2	3.4
LA 1482	1.1	NT
LA 2213	1.0	NT
LO 1497	1.4	NT
LO 1959	1.7	NT
LO 3683	1.5	1.2
LO 3684	1.3	1.0
LO 3707	0	1.7
LO 3708	1.4	NT
LO 4155	0.7	NT
LO 4885	0.8	NT
LO 5392	1.1	NT
BC_1F_1 1775	NT	1.8
BC_1F_1 1776	NT	1.3
BC_1F_1 1777	NT	2.4
BC_1F_1 1779	NT	0.5
BC_1F_1 1782	NT	1.9

Disease severity rating made on a scale of 0 to 6; 0 = no symptoms, 6 = 91 to 100% leaf area affected and/or dead plant, NT = not tested

Effect of cultural practices and fungicide sprays to control late blight in tomatoes

An experiment was conducted at Oleigenuro Village (5 km north of Arusha town). Tomato seeds (var. MoneyMaker) were germinated in seedling trays and 1-month-old seedlings were transplanted to the field.

Cultural practices (pruning, no pruning, staking, no staking) and six fungicide treatments (all diluted at the rate of 1.2 g/liter of water) were combined into a factorial set of treatments and laid out in RCBD with three replications. These were evaluated to determine if a combination of fungicide spray with cultural practices could effectively reduce late blight incidence in the African highlands.

Disease incidence (scored as % infected plants) was assessed weekly, up to 60 days after transplanting. A double arcsin transformation of percent data was carried out to normalize the values prior to analysis.

Fungicide sprays significantly reduced the percent diseased plants. The best spray combination was Ridomil-Mancozeb, sprayed alternately at 7-day intervals with a final disease incidence of 13.4%.

Cultural practices also reduced the disease incidence level particularly compared with the control, not pruning/no staking.

When cultural practices and fungicide sprays were combined, the combination of Ridomil - Mancozeb alternately at weekly intervals with staking and pruning of the lateral shoots provided the best integrated control.

Screening ARP tomato lines for resistance to tomato mosaic virus, fusarium wilt, and root-knot nematodes

Nine AVRDC tomato lines were screened for resistance to tomato mosaic virus, fusarium wilt, and root-knot nematodes.

These lines, derived from crosses of tropical lines with Rodade, a South African highland cultivar, were selected for excellent performance under Arusha conditions but were noted to be impure for resistance to ToMV. Seeds of these lines were therefore germinated in plastic pots for screening against ToMV, root-knot nematode, and fusarium wilt. The latter two diseases were added to the test because the Rodade parent of the lines carry resistance to them but against which they have not been screened.

For tomato mosaic virus screening, 2-week-old seedlings were mechanically inoculated with the virus. Inoculum was prepared by grinding infected tomato leaves in phosphate buffer (0.03 M phosphate buffer plus 1% sodium sulfite). Prior to inoculation, carborundum was added to the inoculum.

For fusarium wilt screening, one isolate from Mbeya (Tanzania) was cultured on potato dextrose agar (PDA) for 7 days. Three-week-old seedlings were inoculated.

Eggs of one pure isolate of *Meloidogyne javanica* maintained on susceptible tomato plants were used to infest test plants at the rate of 1000 eggs per pot.

Several ARP lines appear to be still segregating for ToMV resistance although the number of susceptible plants on some lines were either too few or too many and may have originated from inadvertent mixtures.

Screening tomato varieties for resistance to tomato yellow leaf curl virus

Twenty three tomato accessions were screened for resistance to TYLCV.

Seeds were germinated in seedling trays and 3-week-old seedlings were exposed to viruliferous whiteflies in a tomato field showing 100% infection of TYLCV. Ten days later, seedlings were transplanted to the field at Maweni Village. In this area, 100% TYLCV infection of susceptible tomato varieties is often observed.

Plants were visually scored at 1-week intervals for symptom development. At the end of the trial, a few samples were collected from symptomless plants, as well as from the susceptible tomato variety MoneyMaker, and squashed onto nylon membrane (Hybond-N) and sent to headquarters for DNA hybridization tests.

Varieties Fiona and Tyking had the highest level of resistance with symptomless plants (table 5). The results of squash blot hybridization assays on a few samples indicated that Fiona and Tyking plants did not contain TYLCV DNA (table 6).

Only two and three plants of varieties PSR-403511 and PSR-407111, respectively, developed symptoms. Hybridization tests showed that a few symptomless plants of PSR-403511 and PSR-407111 contained viral DNA.

The varieties Jackal and TY-20 showed a lower level of resistance. The other varieties such as MoneyMaker, Roma, Roza, etc., were susceptible.

Adaptation trials of onion cultivars under the African highland conditions

Three cultivar evaluation trials were carried out in 1994–95. The first consisted of two-cultivar paired comparison between Bombay Red, a highly popular variety in Tanzania, and Red Creole, a red-skinned cultivar grown in neighboring Kenya. This experiment aimed to determine if Red Creole could be used to replace Bombay Red in Tanzania, a variety that is prone to bulb doubling and bolting. The first trial was sown on 20 December 1994 and transplanted to the field on 1 February 1995. The design was RCB with six replications. Each raised bed was spaced 90

Table 5. Percentage of plants showing yellow leaf curl symptoms at different days after transplanting in Maweni experimental field

	% of plants showing symptoms days after transplanting				
Entries	15	23	30	37	44
Chepertylc C-1	30	67	96	96	96
E-2	41	72	87	95	95
FI-3	46	70	80	100	100
J-7	62	93	100	100	100
L-7	62	94	100	100	100
Sin-3	51	85	100	100	100
Siv-5	33	60	74	100	100
Siv-6	44	83	94	100	100
Columbian	44	91	94	100	100
EC-104395	46	76	100	100	100
Jackal	41	52	55	55	55
LA 3214	26	40	73	94	100
LA 3216	54	70	91	95	95
Lignon C8-6	40	70	100	100	100
PSR-403511	0	5	5	5	5
PSR-407111	0	9	9	9	9
Roza	37	72	87	100	100
Ty-20	3	23	33	54	54
8476	32	41	55	64	75
Fiona	0	0	0	0	0
Tyking	0	0	0	0	0
MoneyMaker (S)	56	84	100	100	100
Roma (S ck)	60	90	100	100	100

Table 6. Results of squash blot hybridization assays of a few samples (from different tomato genotypes) collected from symptomless plants at 50 days after planting

Tomato genotype	Hybridization assay[a]
Fiona	0/4
Jackal	2/4
PSR-403511	3/4
PSR-407111	3/4
Tyking	0/4

[a] Number of positive samples/number of samples tested

cm from furrow to furrow, with 3 rows to a bed, with rows spaced 10 cm apart. Plants were spaced 10 cm apart in the row. Only nitrogen fertilizer was supplied to the plants in urea form, topdressed between the rows thrice, once at transplanting, the second at 2 weeks after transplanting and the last, a week later. Total N applied was 80 kg/ha.

The second trial consisted of 15 entries from headquarters. These entries were compared with the popular local cultivar, Bombay Red. The trial was also sown on 20 December 1994 and transplanted to the field on 1 February 1995. The experimental design was RCB with two replications. Plot dimensions and fertilization rate were as in the first trial.

The third trial consisted of six red-skinned varieties obtained from Dr. Lesley Currah of Plant Breeding International, UK. These entries were also compared with the local variety, Bombay Red. The trial was sown on July and transplanted on 17 August 1995. The design was RCB with three replications. Plot dimensions and fertilization rate were as in the first two trials.

Red Creole showed clearcut advantages over Bombay Red because of its lower bulb doubling and bolting rates (table 7). However, their yields did not significantly differ although Bombay Red produced bigger bulbs.

Table 7. Paired comparisons of onion cv. Bombay Red and Red Creole for yield and other horticultural characters, ARP, 1995

Variety	Mkt. yield (t/ha)	Bolting rate (%)	Bulb doubling (%)	Mean bulb wt. (g)
Bombay Red	25.2	3.4	21.2	81
Red Creole	22.7	0.0	14.2	68
Significance ($P = 0.05$)[a]	ns	[b]	[b]	[b]

[a] ns = not significant; [b] = significant at 5% P level

If bulb size is not a crucial factor in production, it appears from this initial study that Red Creole may be able to replace Bombay Red as the cultivar of choice in Tanzania and other African countries where the latter is currently grown.

In the adaptation trial of introduced AVRDC onion germplasm, three entries (TA-192, TA-236, and TA-257) with 37.8 to 41.4 t/ha outperformed Bombay Red (20.6 t/ha). These entries also had generally larger mean bulb weights ranging from 115 to 140 g. However, none of the superior entries are red-skinned which is preferred locally.

In the third trial consisting strictly of red-skinned cultivars, two entries (Rio Raji Red and Red Bandana) were clearly superior to Bombay Red in yield, bulb weight, and percent splitting. Rio Raji Red is an open-pollinated variety which could be very useful for African countries that prefer red onions. It yielded 39.3 t/ha compared to Bombay Red's 19.3 t/ha with a bulb weight of 207.3 g. Red Bandana yielded 28.7 t/ha with a mean bulb weight of 141.1 g. Both had 0% bulb splitting.

Evaluation of Michihili-type AVRDC Chinese cabbage germplasm under African highland conditions

Thirteen Michihili-type germplasm were introduced from headquarters and evaluated against Michihili, the most commonly grown variety in Tanzania. The trial was sown on 6 October 1994 and transplanted to the field on 5 November 1994. Spacing between hills in a double-row bed was 40 cm. Rows were 6 m long. Distance from the center of one bed to another was 1.2 m. The experimental design was randomized complete block with two replications. The equivalent of 45 kg P_2O_5/ha in the form of triple superphosphate was applied at planting. At 2 weeks after transplanting, 45 kg N/ha in the form of urea was topdressed. The same amount of N was topdressed a week later for a total N of 90 kg N/ha.

Two new introductions (B 24 and B 34) performed as well as the check cultivar Michihili (table 8). B 24 had significantly higher yield than Michihili. However, the high yields of these new introductions appear to have been attained by producing more leaves per unit area as their mean leaf weight tended to be lighter than that of Michihili although the differences were not significant.

Table 8. Performance under Arusha conditions of introduced Michihili type Chinese cabbage germplasm as compared against Michihili, ARP, 1995

Entry	Mkt. yield (t/ha)	Mean leaf wt. (g/leaf)	Total leaf yield/ha (no. x 000)
B 24	70.6c	160b-d	228.1b
B 34	66.1bc	164b-d	204.2ab
Michihili (ck)	49.5ab	208d	120.8a

Genetic improvement of Ethiopian mustard (*Brassica carinata*)

Five new populations were developed at ARP by intercrossing the S1 families of selections for stem color and apparent TuMV tolerance from two local populations (Local and Mbeya).

These populations were evaluated against a local population that is being distributed for production by HORTI-Tengeru. Seeds were sown on plastic pots on 10 July 1995 and transplanted to the field on 18 August 1995. Individual plot size consisted of two double-row beds, each 6 m long, with plants spaced 50 cm apart in the row. The experimental design was RCB with three replications.

Harvesting started on 8 September and was completed by 27 October 1995.

The two new populations derived out of the Mbeya population significantly outyielded all other materials. Against the local check, Mbeya Green yielded nearly twice as much (fig. 1).

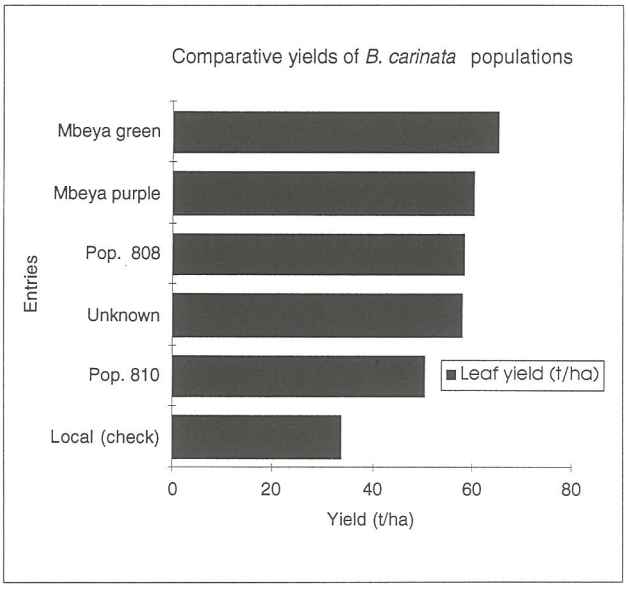


Fig. 1. Comparative leaf yields (t/ha) of different populations of Ethiopian mustard vs. local check, ARP, 1995

Mbeya Green and Mbeya Purple also had longer harvest period than the other entries, indicating that they remained productive longer than the other entries. Mbeya Green also tended to have fewer but larger and heavier leaves than the other entries, and the latest flowering date, a desirable trait for leafy vegetables that are harvested mainly by priming.

It appears from this trial that the two new base populations from the Mbeya population, particularly Mbeya Green, could be excellent replacements for the local population.

Management studies on traditional vegetables

A number of management experiments were conducted by ARP staff and SADC training scholars participating in the ongoing Second Regional Vegetable Production Training Course. Two completed studies are reported here.

One experiment on black nightshade (*Solanum pseudonigrum*) looked at the effect of spacing and nitrogen on yield and other horticultural traits. This study was sown on 6 July and transplanted on 19 August 1995. Two spacing treatments were 30 x 30 cm and 50 x 50 cm (between and within rows). Nitrogen levels were 0, 100, 150 and 200 kg/ha with ammonium sulfate as the N source. Each plot was 6.0 m^2. This study was a factorial experiment laid out in RCBD with three replications.

Another study investigated the effects of manuring and spacing on the yield and other traits of two species of amaranth, namely *Amaranthus cruenthus* and *A. hypochondriacus*. This experiment was planted twice (Planting A and B). The first was seeded on 22 August 1995 and harvested on 21 September 1995. The second was seeded on 23 October 1995 and harvested on 20 November 1995. The following factors were used: farmyard manure (0; 10; 20 t/ha); between-row spacing (20 cm vs. 30 cm); variety (*A. cruenthus* vs. *A. hypochondriacus*). This factorial experiment was laid out on RCBD with three replications. Each plot was 1.2 m x 3 m.

All nitrogen treatments for black nightshade significantly outyielded the unfertilized plot with leaf yields ranging from 19.4 to 21.4 t/ha, giving about twice as much leaf yield. Differences among the N treatments were insignificant. Similar trends were noted for other traits such as stem thickness and days to flowering.

Interaction between nitrogen level and spacing was significant only for yield. The highest yielding nitrogen-spacing combination was between 200 kg N/ha and 30 x 30 cm spacing, with a leaf yield of about 28 t/ha. However, this yield did not appreciably differ from the combination of 100 and 150 kg N/ha with 30 x 30 cm spacing. As expected, the lowest yield of 8 t/ha was recorded in the unfertilized plot combined with wider spacing.

In the amaranth experiment, yield differed significantly among the different levels of manure, spacing and variety, but not for time of planting. For other traits, differences were detected only for two factors—time of planting and variety.

Closer between-row spacing of 20 cm yielded significantly higher than the 30 cm spacing. *A. cruenthus* generally performed better than *A. hypochondriacus* as indicated by its significantly higher yield, longer stem and leaf length, and wider leaves than the latter.

Although yield did not significantly differ between the two plantings, all other traits did, generally showing higher values for the second planting. As amaranth is a fast growing crop (harvestable within a month), it is possible that the effect of manure could be reflected only in the follow-up planting.

The only notable interactions among factors that were detected in the experiment were on yield for spacing x variety and time of planting x variety combinations indicating that the two species responded differently to time of planting and spacing. Other interactions were not appreciable. *A. cruenthus* yielded lower in the first planting but lower in the second, whereas the reverse is true for *A. hypochondriacus* . At closer spacing, *A. cruenthus* yielded higher than at wider spacing. On the other hand, there was almost negligible change in yield of *A. hypochondriacus* when spacing changed.

CONVERDS Training Program for African Researchers and Extension Specialists

Target groups for training are diploma degree holders and African researchers and extensionists.

Courses range in duration from as brief as 3 to 4 weeks for the short-term, highly focused training, to 5 months for the regular vegetable production course.

Training involves a careful blend of practical field activities and theoretical classroom lectures. Ratio between the two is usually 3:1 in favor of the practical work. Classroom lectures are delivered by invited lecturers from universities, NGOs, and other international organizations in Tanzania, Kenya, other SADC countries, and by technical staff of AVRDC-ARP. Backstop support from headquarters is also provided.

In 1995, the Second SADC Regional Vegetable Production Training Course was conducted from 7 August to 15 December.

Twenty-two participants completed the course: Angola (2), Botswana (2), Kenya (2), Malawi (1), Mozambique (1), Namibia (2), Swaziland (2), Tanzania (6), Zambia (2), and Zimbabwe (2).

In addition, one research fellow and two special students from Sokoine University of Agriculture also trained under the guidance of ARP staff.

Adding the 1995 training total to that of 1994, ARP has now trained a total of 60 NARS personnel.

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Shih-chen Chang, M.S., Principal Research Assistant[c]
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Yuh-ling Chen, B.S., Computer Assistant

Farm Operations

Teng-sheng Tu, B.S., Farm Superintendent

---

[a] Left during 1995
[b] Reinstated in 1995
[c] Arrived during 1995
[d] Promoted in 1995
[e] On study leave
[f] Crucifer breeder until July 1995

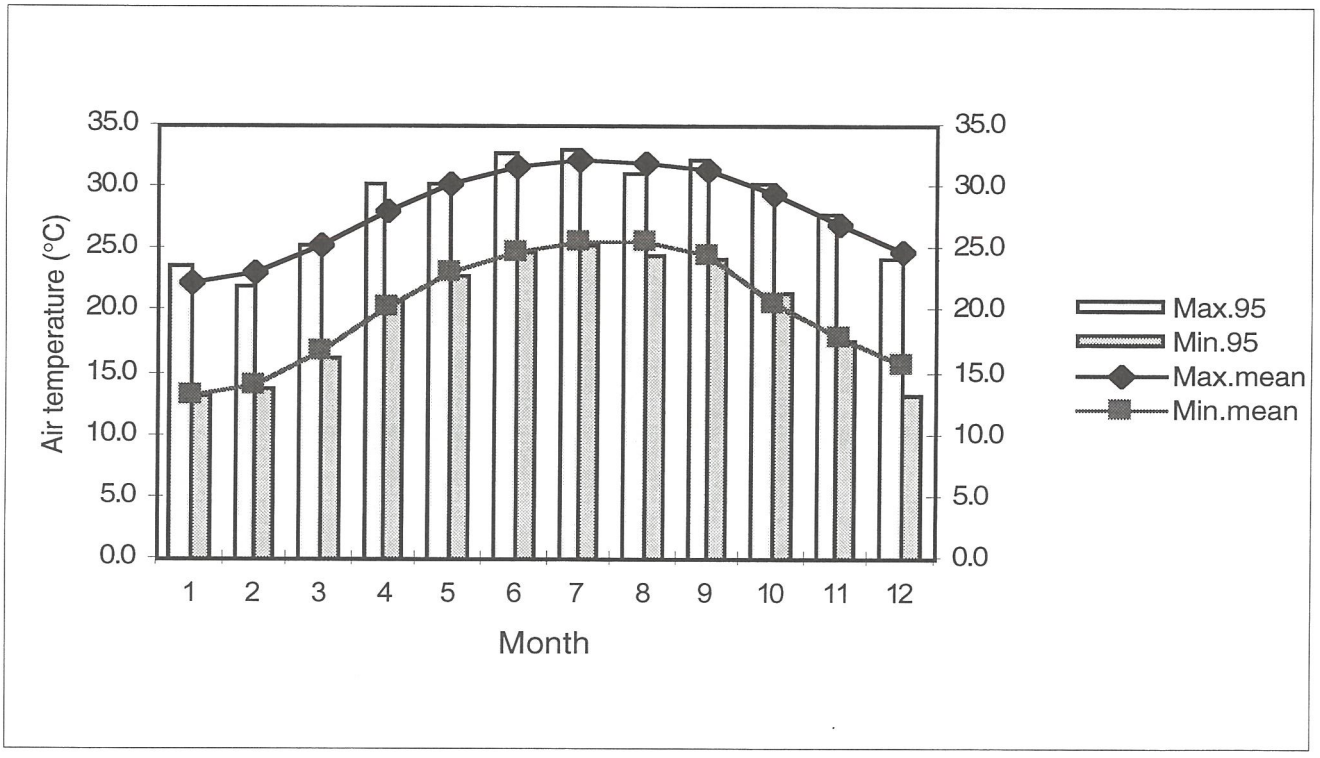
Meteorological information for 1995

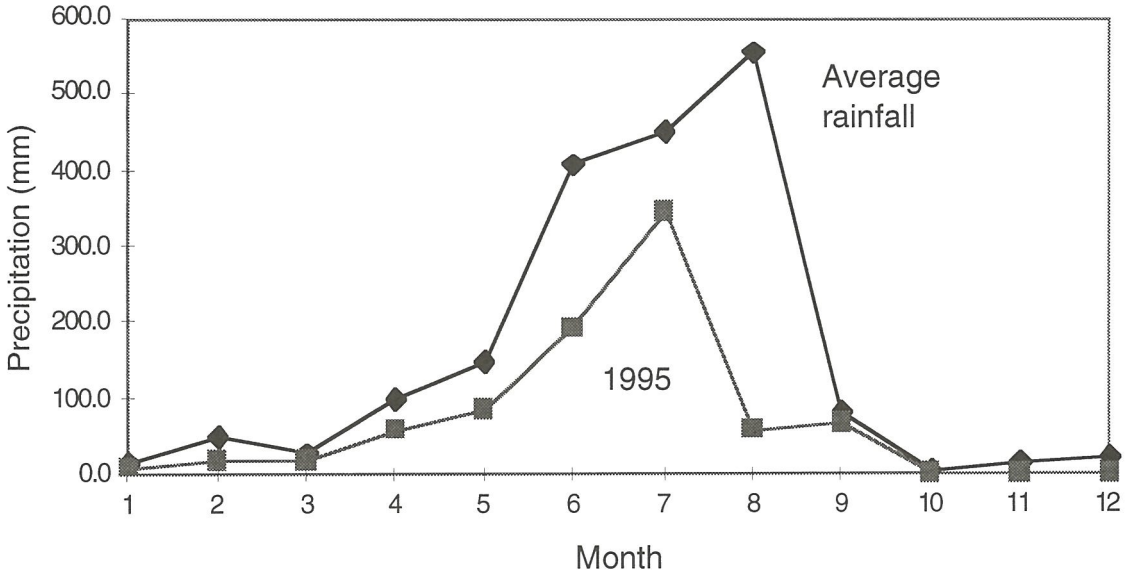
Monthly mean meteorological data collected at AVRDC weather station, 1995

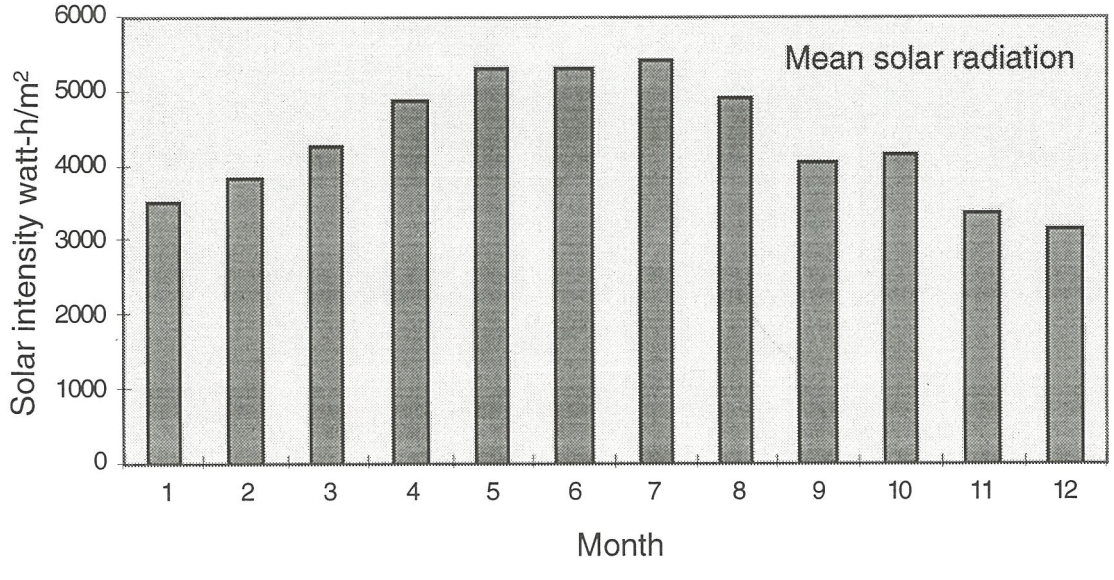
		January	February	March	April	May	June	July	August	September	October	November	December
Humidity (%)	Max.	95.2	94.1	94.8	96.7	96.5	96.1	98.0	97.7	97.4	91.3	91.1	95.9
	Min.	45.5	54.1	54.2	52.2	56.7	53.8	59.3	60.0	56.0	56.7	53.7	55.9
Air temperature (°C)	Max.	23.8	22.1	25.2	30.2	30.4	32.7	32.9	32.5	32.2	31.2	27.8	24.1
	Min.	13.3	13.8	16.2	20.9	22.7	24.7	25.2	25.4	24.1	22.1	17.6	13.2
Soil temperature 10 cm (°C)	Daily	22.4	20.8	22.6	27.6	28.9	30.6	30.8	29.5	29.2	27.8	24.6	21.6
Soil temperature 30 cm (°C)	Daily	23.3	21.5	22.8	27.3	29.5	31.3	31.4	29.1	29.1	27.9	25.3	22.5
Wind (km)	Daily	108	104	85	72	60	-	-	171	186	188	183	173
Solar radiation (Watt-h/m^2)	Daily	3679	3476	3765	5296	5058	-	-	4247	4231	3660	3257	2934
Precipitation (mm)	Total	8.0	17.5	17.5	59.0	85.0	193.0	342.5	56.0	57.5	0.0	0.0	0.0
Evaporation (mm)	Daily	3.8	3.3	3.4	5.4	4.9	5.8	5.2	5.4	5.3	4.2	4.3	4.0

Crop environment

The 1995 crop environment was rather dry compared with an ordinary year. The precipitation total of 846 mm was less than half of the average rainfall of 1870 mm for the last 5 years. This was mainly due to extremely low rainfall in August which is only one-tenth of the average. Temperature was very similar to that of the last 4 years' average. Solar radiation was higher than the 1991-1994 average. Data for 2 months during the wet season were not collected because the solar meter was updated. Thus, data presented for solar radiation are the average for 1991-1995.




600.0
500.0
400.0
300.0
200.0
100.0
0.0
Precipitation (mm)
Average rainfall
1995
1 2 3 4 5 6 7 8 9 10 11 12
Month


6000
5000
4000
3000
2000
1000
0
Solar intensity watt-h/m2
Mean solar radiation
1 2 3 4 5 6 7 8 9 10 11 12
Month

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The Board of Directors
The Asian Vegetable Research and
Development Center

We have examined the statements of assets, liabilities and fund balances of The Asian Vegetable Research and Development Center as of December 31, 1995 and 1994, and the related statements of changes in core fund, working capital fund, restricted core fund, special projects fund, and self-sustaining operation fund for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

As mentioned in Note 2 to the financial statements, the Center:

1. maintains its accounts on a cash basis, except for the inclusion of provisions and reserves for certain employee benefits.

2. accounts for capital expenditures as deductions from funds and, accordingly, does not include them in assets.

3. records its transactions in the currencies in which these are denominated. The accompanying statements reflect the actual U.S. dollar amounts of transactions in U.S. dollars, and the U.S. dollar equivalents of transactions in other currencies based on year-end bank buying exchange rates, except contributions and grants which are translated at the exchange rates in effect when these were received.

In our opinion, the financial statements referred to in the first paragraph present fairly the assets, liabilities and fund balances of The Asian Vegetable Research and Development Center as of December 31, 1995 and 1994, and the changes in its funds for the years then ended, on the basis of accounting described in the second paragraph, which basis has been applied on a consistent manner.

In connection with our examinations, we noted no indication that the Center was not in compliance with any of the terms, conditions, or provisions of its grant agreements. It should be noted, however, that our examinations were not directed primarily toward obtaining knowledge of such non-compliance.

March 18, 1996

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	
A S S E T S	1995	1994
CASH	$3,788,575	$3,405,112
ADVANCES AND REFUNDABLE DEPOSITS (Note 3)	385,057	363,011
PREPAYMENTS	39,117	27,887
TOTAL ASSETS	$4,212,749	$3,796,010
LIABILITIES AND FUND BALANCES		
RECEIPTS FOR CUSTODY (Note 4)	$ 303,895	$ 271,025
RESERVES FOR EMPLOYEE BENEFITS (Note 5)	1,194,741	1,218,654
FUNDS		
Core fund	1,169,584	934,898
Working capital fund	900,000	900,000
Restricted core fund	(193,592)	142,328
Special projects fund	687,948	220,576
Self-sustaining operation fund	150,173	108,529
Total Funds	2,714,113	2,306,331
TOTAL LIABILITIES AND FUNDS	$4,212,749	$3,796,010

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

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	
	1995	1994
ADDITIONS		
Contributions		
Republic of China	$5,544,741	$5,337,614
Japan	1,033,000	733,000
Federal Republic of Germany (from restricted core fund)	956,104	712,461
United States of America	300,000	675,000
France	270,692	296,049
Republic of Korea	-	150,000
Australia	148,478	144,390
Philippines	50,000	100,000
Thailand	424,312	-
Total contributions	8,727,327	8,148,514
Grants from Japan International Cooperation Agency	90,603	85,839
Taiwan Kagome Co., Ltd.	1,835	-
Translation adjustment (Note 2)	(185,756)	19,971
Other (Note 6)	706,414	710,711
Total Additions	9,340,423	8,965,035
DEDUCTIONS		
Capital expenditures (Notes 2 and 6)	599,475	291,699
Operating expenditures (Note 6)	8,531,228	8,671,306
Transfer to working capital fund	-	100,000
Total Deductions	9,130,703	9,063,005
NET INCREASE (DECREASE) IN FUND	209,720	(97,970)
BALANCE, BEGINNING OF YEAR		
As previously reported	934,898	1,000,110
Translation adjustment (Note 2)	24,966	32,758
As restated	959,864	1,032,868
BALANCE, END OF YEAR	$1,169,584	$ 934,898

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN WORKING CAPITAL FUND (Note 7)
(Prepared on a Modified Cash Basis and
Expressed in U.S. Dollars - Note 2)

	Years Ended December 31	
	1995	1994
ADDITIONS		
Transfer from Core Fund	$ -	$100,000
DEDUCTIONS	-	-
NET INCREASE IN FUND	-	100,000
BALANCE, BEGINNING OF YEAR	900,000	800,000
BALANCE, END OF YEAR	$900,000	$900,000

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

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	
	1995	1994
ADDITIONS		
From German Agency for Technical Cooperation	$608,621	$320,554
DEDUCTIONS		
Transfer to Core Fund	(956,104)	(712,461)
NET DECREASE IN FUND	(347,483)	(391,907)
BALANCE, BEGINNING OF YEAR		
As previously reported	142,328	478,935
Translation adjustment (Note 2)	11,563	55,300
As restated	153,891	534,235
BALANCE, END OF YEAR	($193,592)	$142,328

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

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)

	Year Ended December 31, 1994					Year Ended December 31, 1995			
Sponsors	Balance, Beginning of Year	Translation Adjustment	Additions	Deductions	Balance, End of Year	Translation Adjustment	Additions	Deductions	Balance, End of Year
Council of Agriculture/ROC	$ 792,027	$ 8,723	$ 799,973	$1,492,408	$ 108,315	($ 3,657)	$1,035,450	$ 926,216	$ 213,892
Asian Development Bank	63,852	-	40,000	317,624	(213,772)	-	370,968	198,391	(41,195)
Japan	172,632	-	310,000	311,434	171,198	-	310,000	232,890	248,308
U.S. AID	(105,817)	-	306,349	195,190	5,342	-	433,407	302,393	136,356
International Development Research Center	5,462	-	103,276	105,462	3,276	-	-	-	3,276
National Science Council/ROC	-	-	20,737	-	20,737	(700)	46,059	43,059	23,037
Potash and Phasthate Institute of Canada	3,219	-	11,995	9,744	5,470	-	-	5,470	-
Rural Development Administration/Korea	23,122	-	19,985	19,003	24,104	-	-	17,349	6,755
Federal Republic of Germany	-	-	387,338	336,579	50,759	-	321,296	343,875	28,180
Swiss Development Cooperation	29,820	-	95,649	100,975	24,494	-	-	24,494	-
Others	149,085	(372)	85,670	213,730	20,653	(439)	181,757	132,632	69,339
	$1,133,402	$ 8,351	$2,180,972	$3,102,149	$ 220,576	($ 4,796)	$2,698,937	$2,226,769	$ 687,948

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN SELF-SUSTAINING OPERATION FUND (Note 10)
(Prepared on a Modified Cash Basis and
Expressed in U.S. Dollars - Note 2)

	Years Ended December 31	
	1995	1994
ADDITIONS (Note 10)		
Dormitory rentals	$ 57,937	$ 56,572
DEDUCTIONS (Note 10)		
Dormitory expenses	(16,293)	(60,085)
NET INCREASE (DECREASE) IN FUND	41,644	(3,513)
BALANCE, BEGINNING OF YEAR	108,529	112,042
BALANCE, END OF YEAR	$150,173	$108,529

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 18, 1996)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS
(Amounts Expressed in U.S. Dollars Unless Otherwise Stated)

1. ORGANIZATION AND OPERATIONS

The Center was established in the Republic of China as an autonomous, philanthropic, and non-profit research and development organization for promoting production, marketing and utilization of vegetables in Asia. Its members consist of the original signatories to the Center's Charter and other countries or organizations approved for membership by the Center's Board of Directors.

The financial requirements of the Center are funded mainly by contributions and grants or donations from member and non-member countries or organizations.

The Center may terminate its operations by a resolution adopted unanimously by all members of the Board of Directors. In case the Center terminates its operations, all buildings, equipment and other assets belonging to the Center (and/or affiliated sub-centers) will be transferred, upon the concurrence and approval of the Board of Directors and host country, to organizations in the host country which were formed and are operated exclusively for scientific or educational purposes and which meet certain conditions prescribed in the Center's Charter.

2. BASIS OF ACCOUNTING

The Center maintains its accounts on a cash basis, except for the inclusion of provisions and reserves for employee benefits, namely, unused compensated annual leave and repatriation expenses.

The Center records its transactions in the currencies in which these are denominated. The accompanying statements reflect the actual U.S. dollar amounts of transactions in U.S. dollars, and the U.S. dollar equivalents of transactions in other currencies based on year-end bank buying exchange rates, except contributions and grants which are translated at the exchange rates in effect when these are received. Translation adjustments are reflected as additions to or deductions from the funds.

Capital expenditures are accounted for as deductions from funds and, accordingly, are not included in assets.

3. ADVANCES AND REFUNDABLE DEPOSITS

	December 31	
	1995	1994
Advances to Asian Regional Program	$259,844	$ 80,917
Advances to African Regional Program	54,406	211,368
Advances to Latin American Regional Program	17,152	26,586
Refundable deposits and others	53,655	44,140
	$385,057	$363,011

Advances to the Regional Programs were made by the Center for certain programs in the specified regions. Such advanced funds are in the custody of the assigned responsible officers. The Center maintains the records to account for actual reimbursements as reported by the Regional Program officers. The advance balances as of December 31, 1995 and 1994 were confirmed by the responsible officers.

4. RECEIPTS FOR CUSTODY

These consist of amounts received from trainees for medicine, Vitamin A Gardening Project, and field operations, less related cost and expenses.

5. RESERVES FOR EMPLOYEE BENEFITS

	December 31	
	1995	1994
Unused compensated annual leaves	$ 848,704	$ 864,020
Repatriation expenses	346,037	354,634
	$1,194,741	$1,218,654

Local employees and international staff are entitled to annual leaves of 44 days and 48 days, respectively. Employees are compensated for accumulated unused annual leaves upon resignation or termination.

The Center shall bear the transportation and relocation costs of the international staff and their immediate family upon termination of employment.

6. CORE FUND

The core fund is used exclusively in support of the Center's overall operations. Contributions and grants are subject to certain terms and conditions specified in the relevant agreements.

The details of certain changes in this fund are as follows:

	1995	1994
Other additions		
Fees for various services rendered	$ 306,849	$ 372,579
Interest earned from funds other than the contributions from U.S.A.	112,644	171,389
Food and dormitory services (net of employees' salaries and benefits of $239,636 in 1995 and $224,037 in 1994)	228,781	74,996
Training fees	11,534	10,108
Refunds of various expenditures incurred in previous years	23,972	56,995
Miscellaneous	22,634	24,644
	$ 706,414	$ 710,711

Capital expenditures

Buildings and improvements	$ 151,243	$ 75,959
Equipment and furniture	373,578	91,544
Vehicles	37,345	84,807
Books and journals	37,309	39,389
	$ 599,475	$ 291,699

Operating expenditures

Salaries	$4,063,019	$3,952,227
Wages	1,039,426	1,159,547
Employee benefits	1,784,221	1,722,720
Supplies	604,305	667,062
Travel	373,439	416,775
Utilities	257,765	271,096
Vehicle maintenance & insurance	76,505	85,665
Gasoline & diesel	32,878	23,919
Training scholarships	96,357	111,195
Postage, telephone and cable	74,414	88,604
Moving expenses	42,735	46,244
Collaborative research	13,051	15,673
International conference	23,526	23,049
Others	49,587	87,530
	$8,531,228	$8,671,306

Employee benefits include payments for the following:

	1995	1994
Contributions to retirement plans for international staff	$ 202,972	$ 197,981
Contributions to retirement savings fund for local employees	492,250	475,054

The Center has made arrangements for its international staff to be hired by the Association of International Agricultural Research Centers (AIARC) so that they may participate in suitable retirement and group insurance plans. The Center pays the entire cost of participation in these plans.

The Center has a retirement savings plan covering all local employees. The Center deposits 1/12 to 2/12 of each employee's monthly salaries, depending on service period, to a savings fund. Payments from the fund are governed by the provisions of the plan. The changes in the fund are summarized as follows:

	1995	1994
Balance, beginning of year	$3,231,356	$2,584,483
Translation adjustment	(109,095)	28,465
Contributions	492,250	475,054
Interest income	244,598	213,442
Payments	(122,775)	(70,088)
Balance, end of year	$3,736,334	$3,231,356

7. WORKING CAPITAL FUND

This fund has been established, following a common practice among international agriculture research centers. Yearly transfers are made to this fund from the core fund.

8. RESTRICTED CORE FUND

This fund is contributed by the German Agency for Technical Cooperation, and its use is restricted. The transfer from this fund to the core fund is reported as a contribution. In accordance with the agreement, effective 1995, the contribution is based on the actual disbursements of preceding year.

9. SPECIAL PROJECTS FUND

Special projects are normally based on agreed-upon budgets. Accordingly, some projects may have negative year-end balances, which shall be reimbursed in the following year.

Expenditures from this fund are subject to certain conditions and terms as set forth in agreements with the sponsors.

10. SELF-SUSTAINING OPERATION FUND

This represents the operating fund of the Center's dormitory.

11. CONTINGENCY

In 1989, the U.S. AID-supported AVRDC Vitamin A Gardening Project in Nigeria was sued by some Nigerian merchants for recovery of merchandise ordered by a U.S. Embassy employee using the Project's stationery. Most of the merchandise has been recovered by the merchants, but the lawsuit is still pending. The possible outcome of this litigation is not determinable but the Center's management believes this would not have a significant adverse effect on the Center.