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Contents

Abbreviations and Acronyms *6*

Allium Improvement *9*

Genetic resources enhancement and varietal development *10*
Genetic resources activities 10
Breeding for long bulb storage quality in onion 10
Storage studies in garlic 11
Development of high-yielding, better quality onions 12
Development of summer stress-tolerant lines 13
Breeding for stemphylium leaf blight resistance in onion 15
Improvement of garlic through clonal selections and mutation breeding 16
Improvement of shallot 18

Host-plant resistance to diseases and insect pests *19*
Second screening of onion germplasm for resistance to onion thrips 19
Effect of intercropping subterranean clover with onion on the infestation of onion thrips 19
Utilization of one-component sex pheromone for communication disruption in armyworms 20
Studies on the flying habit of beet armyworm adults 21
Screening of *Allium* germplasm for resistance to beet armyworms 22
Virus elimination and indexing of garlic and shallot 22
Host resistance to stemphylium leaf blight of bulbing alliums 23
Host resistance to purple blotch of bulbing alliums 25
Host resistance to anthracnose of bulbing alliums 26

Crucifer Improvement *29*

Genetic resources enhancement and varietal development *30*
Genetic resources activities 30
Development of heat-tolerant populations of Chinese cabbage with elongated-head type 31
Development of heat-tolerant populations of Chinese cabbage through population improvement 32
Incorporation of cytoplasmic male sterility into Chinese cabbage through backcrossing 32
Evaluation of common cabbage germplasm and development of heat-tolerant varieties/lines 33
Incorporation of TuMV resistance into inbred lines of Chinese cabbage 34
Yield trial of common cabbage varieties 34
Heat stress/tolerance in common cabbage 35

Eggplant Improvement *39*

Genetic resources enhancement and varietal development *40*
Genetic resources activities 40
Evaluation of eggplant cultivars and germplasm 40
Evaluation of germplasm for resistance to bacterial wilt 43
Breeding for bacterial wilt resistance 43

Major diseases and insect pests *44*
Screening eggplant germplasm for resistance to cotton leafhopper and cotton aphids 44
Evaluation of the stability of resistance sources to bacterial wilt 46

Strategic and/or supporting studies *47*
Variation in flower types in eggplant 47

Pepper Improvement 49

Genetic resources enhancement and varietal improvement 50
Genetic resources activities 50
Genetic resources evaluation and multiplication 51
Development of improved inbred lines 51
International Chili Pepper Nursery 53

Management of major insect pests and diseases 55
Identification of sources of resistance to broad mites 55
Resistance screening and characterization of bacterial wilt in peppers 55
Application of DNA probes and primers for the detection of *Xanthomonas campestris* pv. *vesicatoria* (Xcv) 56
Screening for resistance to viruses 57
Host resistance to phytophthora blight 58
Host resistance to anthracnose of pepper 59

Strategic and/or supporting studies 61
Genetics of resistance to major pepper diseases 61
AVNET support 61
Development of molecular markers for CVMV resistance 63

Tomato Improvement 64

Genetic resources enhancement and varietal development 65
Genetic resources activities 65
Genetic improvement of fresh market tomato 65
Genetic improvement of cherry tomato 66
Genetic improvement of processing tomato 69
Genetic improvement of tomato for tropical home gardens 70

Management of diseases 70
Identification and characterization of bacterial wilt and bacterial spot resistance in tomato 70
Ecotyping of *Ralstonia (Pseudomonas) solanacearum* isolated from tomato 71
Host resistance to black leaf mold of tomato 72
Host resistance to late blight of tomato 73
Host resistance to fusarium wilt of tomato 74
Host resistance to gray leaf spot of tomato 77
Development of multivirus-resistant tomato 77
Studies on leaf curl virus 78
Identification of molecular markers linked to heat tolerance in CLN 1639F_6 recombinant inbred lines 79
Transformation of tomato and pepper with virus resistance genes and evaluation of transformants for CMV resistance 81
Transformation of tomato plants for fusarium wilt resistance 82

Legume Improvement 85

Genetic resources activities 86
Breeding appropriate vegetable soybean 86
AVRDC soybean evaluation trial 87
AVRDC vegetable soybean evaluation trial 87
Seed multiplication of elite and Korean breeding lines 89
Evaluation of *lx lx* gene in elite lines 90
Developing insect-resistant soybeans using Brazilian lines 90
Selection of soybean for green manure 90
Effectiveness of fishbean foliage in controlling bruchids on mungbean seeds 91
Testing of various Bt strains for effectiveness against *Maruca testulalis* 92
Establishment and improvement of transformation systems for mungbean and vegetable soybean 92

Sustainable Use of Natural Resources and Inputs 94

K and NH_4 fixation and recovery 95
Effect of organic wastes on vegetable yields and soil properties 97
Enhancing biodiversity through home gardens 103
Studies on simple hydroponics 105

Overcoming Seasonal Stresses of Production 106

Overcoming water stress for summer tomato 106
Minimizing bacterial wilt damage by soil amendment 107

Management of Insect Pests and Plant Diseases 109

Testing of a nuclear polyhedrosis virus for the control of diamondback moth 109
Integrated control of crucifer insect pests 110
Evaluation of effectiveness of Bt strains against *Crocidolomia binotalis* 112
Attraction of *Hellula* and *Crocidolomia* to certain naturally occurring chemicals in crucifers 112
Mixture of urea and CaO as soil amendment to control tomato bacterial wilt 113
Biological control of tomato fusarium wilt 114

Socioeconomic Studies on Vegetables 116

Characterization of pulse supply and demand systems in Pakistan 117
Characterization of vegetables grown with field crops 119
Agricultural economics research in Asia 120

Research Support 122

Effect of food processing on iron bioavailability 122
Quality evaluation of vegetables dehydrated under low temperature and humidity 123

Human Resources Development 126

Training 126

Communication and Information 128

Information and documentation 128
Publications and communication 129

Collaborative Research and Networks 130

Collaborative Vegetable Research Program for Southeast Asia (AVNET-II) *130*
Subnetwork I - Field verification and technology packaging for selected vegetables 131
Subnetwork II - Disease and pest management 131

South Asian Vegetable Research Network (SAVERNET) *132*

Collaborative Network for Vegetable Research and Development for Central America (REDCAHOR) *135*

Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam (CLVNET) *135*

AVRDC-Asian Regional Center 136

Research activities and adaptive trials 136
Germplasm multiplication and exchange 139
Training and information exchange 139
Networking 139
Symposia and workshops 140

AVRDC-Africa Regional Program 141

Adaptation trials of tomato germplasm to the African highlands 141
Tomato multilocation evaluation trials 143
Screening ARP tomato lines for resistance to tomato mosaic virus, fusarium wilt, and root-knot nematodes 144
Field screening of tomato accessions for resistance to tomato yellow leaf curl virus 145
Field evaluation of ARP tomato lines for resistance to fusarium wilt and root-knot nematodes 145
Evaluation of tomato late blight resistance sources 145
Adaptability trials of onion germplasm under African highland conditions 146
Adaptability trials of other global crops under African highland conditions 148
Survey of major vegetable diseases occurring in East Africa 149
Effect of cultural practices and fungicide spraying for control of tomato leaf blight 149
Evaluation of some insecticides for control of diamondback moth in cabbage 150
Evaluation of fungicides for control of tomato powdery mildew caused by *Oidium lycopersicum* 150
CONVERDS training program for African researchers and extension specialists 151

Cooperative Programs 152

AVRDC-Bangladesh Agricultural Research Project *152*
Adaptive trials on selected crops 152
Protected cultivation 154
Other activities 155

AVRDC-Philippines Outreach Program *156*
Adaptive trials 156

AVRDC-ROC Cooperative Program *158*
Regional yield trials 158
Collection and evaluation of nonprincipal vegetables 160
Germplasm collection and evaluation of tropical leafy vegetables 162
Seed production and distribution 163
Other activities 163

Board 164

Staff 165

Meteorological Information, 1996 167

Crop Environment 168

Financial Statements 169

Abbreviations and Acronyms

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

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

Allium Improvement

Bulb alliums research focuses on the genetic improvement of onion (*Allium cepa*), garlic (*A. sativum*), and shallot (*A. cepa* var. *aggregatum*). The major goal of the program is to improve the productivity of these crops in the tropics by developing lines with (1) resistance to major diseases (stemphylium leaf blight, purple blotch, and anthracnose) and insect pests (thrips and beet armyworm); (2) tolerance to summer stress; and (3) improved storage quality of bulbs. The program also works on (4) virus elimination and indexing in garlic and shallot; (5) generating basic information on the effect of daylength, temperature, and flooding on growth and development; and (6) application of biotechnology in the improvement project.

During 1995 success was achieved in identifying promising onion lines for long bulb storage quality. In garlic seven clones were selected for long bulb storage quality. Summer stress tolerance (SST) was identified in seven onion genotypes and a rapid screening method was developed to screen SST at the seedling stage. Among the F_1 progenies of interspecific crosses intended to transfer stemphylium leaf blight (SLB) resistance from *A. fistulosum* to *A. cepa*, plants with fairly good fertility and resistance were identified. Resistant lines/ plants were selected in F_1 and F_2 progenies by controlled condition experiments. Male sterility identified in tropical onion line AC 26 was found to be controlled by strong cytoplasmic factors. Backcrossing was initiated to transfer male sterility in elite genotypes.

Seasonal prevalence of fungal diseases at AVRDC was determined. Preliminary screening for beet armyworm (*Spodoptera exigua*) resistance has lead to the identification of nine promising entries of *A. cepa* and *A. fistulosum* which were least damaged. Similarly screening for thrips (*Thrips tabaci*) resistance resulted in the identification of 10 resistant accessions in *A. cepa* and *A. fistulosum.*

In garlic high-yielding lines were identified among the clonally selected lines with bulb yields above 12 t/ ha. Four lines were also identified for resistance to virus diseases. Field evaluation of virus-free shallot and garlic lines was carried out with promising results.

Use of virazole treatment during meristem culture improved virus elimination frequency in garlic and shallot. RAPD markers were developed in garlic and used successfully in the phylogenetic study.

Some notable achievements during 1996 include identification of resistance sources for anthracnose disease; fairly good progress towards incorporating stemphylium leaf blight resistance in onion; development of a laboratory protocol for evaluating *Allium* plants for stemphylium leaf blight reaction; successful utilization of nursery screening methods for identifying summer stress tolerance in onion; development of high-yielding clonally selected lines in garlic; confirmation of virus resistance in four garlic lines; high bulb yields in meristem-derived virus-free garlic lines in field evaluation; and identification of sources of resistance to *Spodoptera exigua* in three *A. fistulosum* lines.

Genetic resources enhancement and varietal development

Genetic resources activities

An *Allium* germplasm collection is maintained to produce enough seed or vegetative planting material for the base and active collections; characterize accessions based on a standard set of descriptors; and distribute good quality seed or vegetative planting material to researchers in the center, other international centers, NARS, etc. The germplasm are assembled through exploration and collecting activities, and donors.

Three hundred forty-two accessions were acquired in 1996 bringing the total number of accessions in the *Allium* collection to 987 (table 1). The new acquisitions consisted of 4 species from 41 countries.

Fifty onion accessions originating from 13 countries were regenerated: 18 from bulbs and 32 from seed. Some accessions sown directly from seed flowered, but seed production was much lower compared to those produced from bulb crops. Majority produced seed. Four accessions of Welsh onions—two from Denmark and one each from Japan and Taiwan—were also regenerated. A17, a fragrant Japanese Welsh onion from Taiwan, was a good seed producer. Of 12 shallots planted, 10 produced seed.

Table 1. AVRDC *Allium* germplasm collection, 1996

Species	No. of accessions	No. acquired
A. ampeloprassum	2	1
A. cepa	357	90
A. cepa ssp. *aggregatum*	30	12
A. cepa fistulosum	23	–
A. longicuspis	3	3
A. porrum	12	–
A. sativum	467	191
A. schoenoprasum	2	2
A. tuberosum	4	–
A. sp.	87	43
Total	987	342

Only 29 onion accessions grown from seed were characterized. No variation in leaf color and flower color was observed. TA 192, TA 207, and TA 208 had unique full grown bulb shape, flower number/umbel, and leaf cross-section, respectively.

Four accessions of Welsh onion that were planted showed variation in leaf length, flower number/umbel, anther color, and scape length.

Thirty accessions of onion produced enough seed for the base collection in long-term storage and 96 accessions produced seed for the active collection in medium-term storage.

The flowering shallots will be excluded from the field genebank once they have produced enough seed for long-term storage. The two nonflowering shallots will have to be always maintained in a field genebank.

At present, 97 garlic accessions are being maintained in a field genebank which will be replanted every year.

About 334 samples of *Allium* germplasm were sent to 25 countries and territories, the AVRDC regional center and program in Thailand and Africa, including headquarters.

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

Breeding for long bulb storage quality in onion

Identification and utilization of lines with long storage quality is a major activity in the onion improvement project.

Twenty-five selected progenies previously identified for long bulb storage quality were evaluated at ambient condition (21.6–24.3°C minimum to 29.6–34.2°C maximum) in a well ventilated room in perforated plastic crates for 5 months.

Six entries had good storability (fig. 1). No sprouting losses were recorded in most of these lines except AC 172. However, rotting losses caused by black mold (*Fusarium* sp.) and bacterial (*Pseudomonas* sp.) pathogens were very high. ACC 21 had significantly low bulb rotting (37%). Total losses in the lines studied ranged from 37 to 53%, compared to the checks Granex 429 and Texas Early Grano 502, which had more than 80% losses.

Crosses were made between storable lines (TA 377, AC 49, AC 141, and AC 319) and lines with high bulb yield (Texas Early Grano 502 and TA 387) and summer stress tolerance (AC 325 and AC 429). Of 25 hybrids evaluated for 4 months under ambient conditions, 4 had less than 30% losses. Among other hybrids the losses ranged from 45 to 78%. Major losses were mainly due to rotting of bulbs. The better performing lines were used for evaluation of F_2 progenies and for selecting genotypes with combined traits.

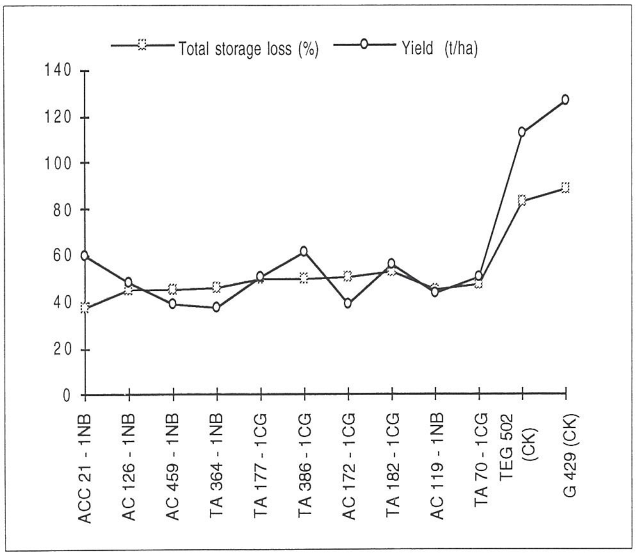

Fig. 1. Performance of selected onion lines for storage quality and bulb yield

Storage studies in garlic

Storage studies were conducted using clonal selections and germplasm lines under ambient condition for 6 months to identify lines with long storability. Of 141 clonal selections from the $IBS2Vg_2$ generation evaluated for storability 33 lines had less than 15% losses compared to check Hsi Luo which had more than 20% losses. Major losses due to rotting were recorded; sprouting losses were limited. The 20 best lines for bulb yield and storability were identified. Bulb yield in these lines ranged from 10.5 (GL 51-2) to 20.9 t/ha (GL 98-9), about 23 to 83% higher than the check.

Among the 54 clonal selections from the $IBS1Vg_3$ generation, total losses during 6-month storage ranged from 9 (GL 71-5) to 51% (GL 74-1). Fourteen selected lines had less than 15% storage losses, compared to more than 20% losses in Hsi Luo. Minimum losses were recorded in GL 71-5 (9%), followed by GL 76-2 (10%), GL 73-8 (11%), and GL 68-3 (12%). Bulb yield in these lines was higher (5.6–8.5 t/ha) than Hsi Luo's (3.8 t/ha). General yield in this experiment was low because of longer vernalization treatment of bulbs before planting.

Evaluation of 54 lines resulted in the identification of six promising lines with less than 15% losses during 6 months of storage (fig. 2). Sprouting was not observed in any of these lines and most of the losses were due to rotting of bulbs. Four of the six lines had high bulb yields ranging from 8.7 to 14.6 t/ha, which were 25% higher than Hsi Luo.

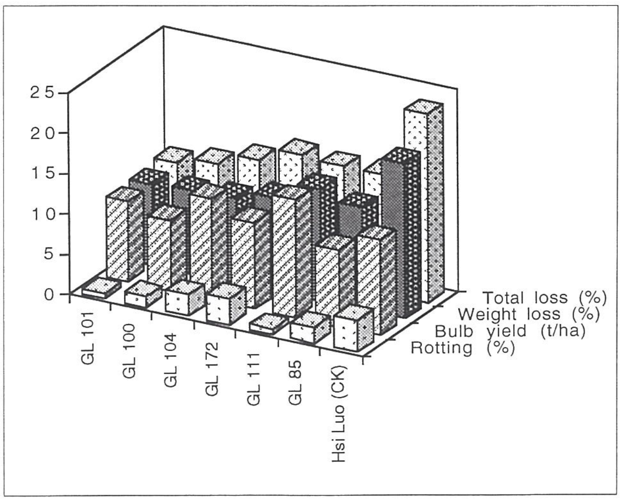

Fig. 2. Storability performance of selected garlic germplasm lines

Development of high-yielding, better quality onions

Improvement of onion lines through progeny selection

Progeny selection was carried out in 45 selfed progenies obtained from 37 breeding lines. Marketable bulb yield in these selected progenies ranged from 10 to 85 t/ha. Of these 10 promising progenies had more than 40 t/ha bulb yields (table 2). Bulb yield in three progenies was at par with the check Texas Early Grano 502; however, these progenies had significantly low percentage of split bulbs and premature bolting.

In another experiment 111 selfed progenies were evaluated in an observational row trial. Bulb yield ranged from 30 to 100 t/ha. Ten progenies with yields ranging from 61 to 113 t/ha have been selected for further evaluation. Emphasis was also given on selecting lines with low splitting tendency. The best selected progenies were TA 373-S (113 t/ha), AC 146-S (108 t/ha), TA 242-S (106 t/ha), TA 149-S (90 t/ha), and AC 132-S (88 t/ha).

In yet another experiment a total of 57 previously selected lines were evaluated and promising selections were further identified for high marketable bulb yield (TA 377-1CG, TA 215-1NB, AC 149-1CG, and TA 70-1NB) (table 3), low bolting tendency (TA 215-1NB, TA 377-1CG), and low split bulbs (AC 160-1CG, AC 429-1CG, and TA 377-1CG). Marketable bulb yield increase in the three best lines was 24–32% over the check. TA 377-1CG had the highest bulb yield, low bulb splitting and premature bolting, and long bulb storability.

Table 2. Promising selfed progenies among selected onion lines

Entry	Mkt. yield (t/ha)	Avg. bulb wt. (g)	Splitting (%)	Bolters (%)	Bulb color
AC 149-S	84.6ab	363.2b-e	8.5g-j	23.1h-m	Yellow
TA 172-S	83.6ab	306.5c-h	1.1j	4.6lm	Yellow
AC 429-S	72.6bc	286.1c-i	0.0j	6.6k-m	Yellow
AC 149-S2	57.6cd	296.7e-i	4.9ij	34.8g-k	Yellow
AC 147-S	55.3cd	323.3c-g	33.3d-j	0.0m	Yellow
TA 4-S	52.0d	201.0e-o	5.3h-j	0.0m	Yellow
AC 325-S	50.3d	690.0a	10.0g-j	23.3h-m	Yellow
AC 379-S	46.0de	185.0e-o	6.7h-j	10.1j-m	Yellow
TA 70-S	42.0d-f	226.2e-h	23.2d-j	28.0h-m	Yellow
TA 364-S	41.0d-f	205.4e-o	16.9e-j	18.9i-m	Red
TEG 502 (ck)	89.6ab	452.6b	25.8d-j	7.2j-m	Yellow
Mean	61.4	321.4	12.3	14.2	
CV (%)	23.8	49.3	73.4	25.8	

Table 3. Performance of selected onion lines for bulb yield and quality traits

Entry	Mkt. yield (t/ha)	Avg. bulb wt. (g)	Splitting (%)	Bolters (%)	Bulb color
TA 377-1CG	121.5a	243.0c-f	6.5	8.0	Yellow
TA 215-1NB	118.7a	605.8b-d	30.9	0.0	Red
AC 149-1CG	114.4ab	269.4b-e	31.7	11.5	Yellow
TA 70-1NB	92.7b-d	198.2e-i	8.4	9.5	Yellow
AC 160-1CG	92.4b-d	176.5f-j	2.4	2.5	White
AC451-1CG	89.1c-e	233.7d-g	6.9	18.0	Yellow
TA 70-1CG	84.0c-e	224.8e-h	22.2	10.0	Yellow
AC 429-1CG	71.7de	184.2f-j	3.4	18.0	Yellow
TEG 502 (ck)	92.0b-d	320.4b	4.8	3.0	Yellow
G 429 (ck)	66.0e-g	435.1a	44.7	0.5	Yellow
Mean	40.4	221.9	26.2	30.0	
CV (%)	29.0	44.9	86.2	99.6	

Hybridization and selection program

Fifty hybrids developed to combine traits such as storability, high dry matter, earliness, high yield, and others were evaluated for bulb yield and quality (fig. 3). Among these hybrids the marketable bulb yield ranged from 20 to 107 t/ha. The hybrid, TA 215 x AC 141, had 60 t/ha bulb yield and the lowest storage losses (< 20%). Other promising hybrids were TA 215 x TA 195 (107 t/ha), TA 377 x TG 502 (64 t/ha), and TA 377 x AC 325 (62 t/ha). These are also being evaluated for earliness, storability, dry matter, and other traits, and are now used for generation advancement.

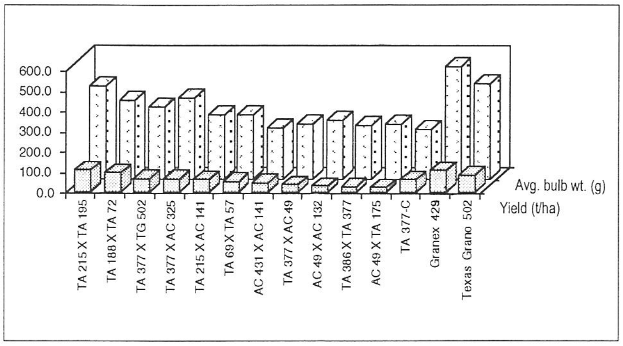

Fig. 3. Performance of promising F_1 hybrid progenies

Evaluation of F_2 progenies

Sixty-two F_2 progenies were evaluated during the winter season to identify promising selections. Of more than 200 plants selected (table 4), 20 were identified for earliness (< 100 days maturity) combined with high yield; 91 plants were selected for long storage quality and large bulbs which were free from splitting and premature bolting defects, and 35 were selected for firm bulbs.

Table 4. Promising selections made in F_2 progenies

Traits	No. plants selected	F_2 progenies
Earliness	20	AC 380-2 x TA 72
		AC 383-4 x TA 72
		AC 384-2 x TA 188
Bulb storage quality	91	AC 49 x AC 132
		AC 49 x ACC 23
		AC 50 x TA 69
		AC 384-2 x TEG 502-2
Bulb firmness	35	AC 49 x AC 132
		AC 50 x TA 60
		AC 383-3 x TEG 502-2
		AC 384-2 x TEG 502-2
		AC 431 x AC 50
		AC 442 x TEG 502-2
		AC 50 x AC 429

Development of summer stress-tolerant lines

Use of seedling screening technique for selecting for summer stress tolerance

Extremely low productivity of onion cultivars during summer is marked by high temperature (> 32°C) and prevailing photoperiod conditions (12.5 to 13.5 h daylength) in the tropics. A seedling screening technique was thus developed last year to identify better genotypes for summer stress tolerance. The technique was based on bulb diameter and leaf number at the seedling stage. Observations were recorded after 45 days in the nursery. Bulb development was ranked on a scale of 0 to 5, with 0 = no bulb development and 5 = with conspicuous bulbing.

A total of 140 breeding lines mostly originating from SST lines were evaluated at the seedling stage. Sixty lines had no bulb development (0 rating) and were identified as highly tolerant to summer stress. Among other groups 21 lines with small bulbs at seedling stage and also good SST had a rating of 1. Forty-five lines with medium bulb development and less growth after transplanting had ratings of 2 and 3. Plants with ratings of 4 and 5 generally showed poor performance in the field after transplanting.

Among 24 F_1 hybrids studied, seven did not develop bulbs at seedling stage and were considered summer stress-tolerant. All seven hybrids had one parent from the SST group (AC 47, AC 383, AC 21, AC 325, and AC 429). Six F_1 hybrids with a rating of 1 were also selected for summer stress tolerance.

In a separate study six F_2 progenies and five parental lines were evaluated for SST at the seedling stage (table 5). All the hybrids had an SST line as one of the parents. The best progenies were identified in the crosses AC 383 x AC 149, AC 425 x AC 429, and AC 429 x AC 50. In these progenies most of the plants had either no or small bulb development, and thus had SST. Other crosses, such as AC 6 x AC 149, AC 425 x AC 149, and TA 69 x AC 47 had a high percentage of plants with medium (rating: 2–3) bulb development. Among the parents, AC 149 had high sensitivity to summer stress, whereas other parental lines had high SST.

These studies, particularly those crosses involving AC 149, indicated that the gene(s) controlling summer stress tolerance are dominant.

Selections for summer stress tolerance in F_2 progenies

Twenty-three F_2 progenies with high bulb yield and quality were evaluated for summer stress tolerance. Of these four were identified as promising with higher survival rate and large bulbs. SST parents AC 6, AC 47, and AC 383 were involved in these crosses. The hybrids AC 6 x AC 149, AC 21 x AC 149, AC 383 x AC 149, and AC 47 x TA 188 had high survival rate (table 6), good plant growth, and big bulbs. Individual plants with larger bulbs of good quality were selected for seed production and further evaluation. In the crosses AC 6 x AC 149, AC 21 x AC 149, and AC 383 x AC 149 the major focus was on the selection for red as well as yellow bulbs; in the cross AC 47 x TA 188, red, yellow, as well as white bulbs were selected.

Table 5. Screening of F_2 generation plants for summer stress tolerance at seedling stage

Cross	Bulb development rating					
	Small (0 -1)		Medium (2 - 3)		Large (4 - 5)	
	No. of plants	%	No. of plants	%	No. of plants	%
AC 6 x AC 149	198	(56)	152	(49)	6	(2)
AC 383 x AC 149	210	(95)	10	(4)	1	(0.5)
AC 425 x AC 429	161	(92)	13	(8)	0	(0)
AC 425 x AC 149	154	(54)	127	(45)	3	(1)
AC 429 x AC 50	117	(80)	21	(14)	9	(6)
TA 69 x AC 47	114	(44)	101	(39)	44	(17)
AC 21	31	(78)	9	(22)	0	(0)
AC 47	226	(100)	0	(0)	0	(0)
AC 425	150	(100)	0	(0)	0	(0)
AC 429	156	(89)	20	(11)	0	(0)
AC 149 (ck)	0	(0)	0	(0)	332	(100)

Table 6. Evaluation of F_2 progenies for SST (no. of bulbs selected per category) and bulb color and size

Cross	Red		Yellow		White	
	5-6 cm	3-4 cm	5-6 cm	3-4 cm	5-6 cm	3-4 cm
AC 6 x AC 149	33	28	11	10	-	-
AC 21 x AC 149	44	18	5	-	-	-
AC 47 x TA 188	68	-	10	29	22	28
AC 383 x AC 149	60	34	5	-	16	-

Performance of elite summer stress-tolerant lines

Ten SST lines selected during the last 2 years were evaluated in summer along with check Granex 429. Bulb yield in these lines ranged from 15 (AC 425) to 29 t/ha (AC 325-1 IS), compared to 10 t/ha in the check. The best three lines, AC 325-1 IS, AC 47-1 IS, and AC 443, had more than 22 t/ha bulb yields. The yield increase in these lines ranged from 116 to 178% over Granex 429.

Breeding for stemphylium leaf blight resistance in onion

Among the prevalent diseases causing major damage to onions in the tropics, stemphylium leaf blight is economically important. Foliar losses of 80 to 90%, leading to poor bulb yield, have been reported. Resistance to SLB was located in *A. fistulosum,* a close relative of onion, and currently efforts are under way to introgress resistance genes into onion lines. This study evaluated F_1 and F_2 progenies to select desirable resistant genotypes in the field as well as under controlled conditions.

Evaluation of resistance under field conditions

Forty-eight F_1 hybrids between resistant *A. fistulosum* lines (TA 104, 108, 198, 204, and AF 468) and 31 onion lines were evaluated for stemphylium leaf blight under field conditions. All the F_1 plants evaluated for SST in all the crosses were confirmed resistant to SLB for the second year. Similarly the *A. fistulosum* lines were also found resistant. The onion lines were severely affected by SLB prevalent during the season. These results confirmed the field resistance to SLB among the hybrids, which is possibly controlled by dominant genes. Well developed bulbs were observed in three crosses (TA 198 x AC 15, TA 198 x TA 4, and TA 108 x AC 50). Two of the hybrids, AC 319 x TA 204 and AC 49 x TA 204, had good pollen fertility and seed setting.

Forty F_2 progenies were evaluated to identify useful recombinants with SLB resistance, good bulb development and fertility. Most of the progenies had variations for plant type resembling *A. fistulosum,* with very little bulb development. Useful recombinants were identified in two progenies, CF 19 (AC 50 x TA 198) and CF 46 (TA 198 x AC 50). Two plants were identified in CF 19 progeny with good bulb development, good seed-set, and vigorous and healthy tops. SLB was not observed in these plants under field conditions. Two plants with good bulbs, vigorous and healthy tops, and medium seed-set were located in the CF 46 cross. About 15 more segregants were identified in other crosses for good bulb development, healthy foliage, and fairly good seed-set.

Evaluation of resistance under controlled conditions

During the year 16 F_1 crosses and 5 F_2 progenies were evaluated along with 6 resistant (*A. fistulosum* lines) and 20 susceptible (*A. cepa* lines) parents under controlled conditions, after artificial inoculation.

***A. fistulosum* lines.** Variations were observed in the level of resistance in some of the parental lines. Two parents, TA 198 and TA 106, had 100% resistant plants (table 7). In other lines resistant plant percentage varied from 44 (TA 104) to 81% (TA 204). Resistant plants were selected for further use in the breeding program.

***A. cepa* lines.** All 20 lines were classified as susceptible.

F_1 hybrids. Disease reaction varied in the 16 F_1 hybrids. Plants that showed resistant reactions ranged from 8.3 (AC 444 x TA 204) to 88% (AF 468 x AC 8). Seven crosses had more than 50% plants with resistant reactions (table 7).

F_2 progenies. Four F_2 populations evaluated revealed the segregation ratio to be more towards resistance (table 7). Resistant plant percentage ranged from 12 (TA 108 x AC 50) to 100% (TA 198-3 x AC 50). Resistant plants were selected for further breeding work.

Table 7. **Evaluation of parents, F_1 and F_2 progenies for stemphylium leaf blight under controlled conditions**

Entries	Disease reaction (% plants)			
	R	MS	S	VS
A. fistulosum				
TA 198	100.0	0.0	0	0
TA 104	43.8	56.2	0	0
TA 106	100.0	0.0	0	0
TA 204	81.2	18.8	0	0
F_1 crosses				
CF 52 (AC 49 x TA 204)	62.5	25.0	0	12.5
CF 55 (AC 425 x TA 204)	50.0	50.0	0	0
CF 19 (AC 50 x TA 198)	50.0	50.0	0	0
FC 50 (TA 198 X TA 69)	56.2	43.8	0	0
FC 37 (TA 104 X AC 50)	83.3	16.6	0	0
FC 26 (AF 468 X AC 8)	87.5	12.5	0	0
CF 9 (AC 412-2 X AF 468-2)	75.0	18.8	6.2	0
F_2 *population*				
FC 46-13 (TA 198 x AC 50) F_2	49.9	41.6	8.3	0
CF 19-3 (AC 50 x TA 198) F_2	12.5	81.2	0	6.2
FC 45-P (TA 198-3 x AC 50) F_2	100.0	0	0	0
FC 37-2 (TA 108 x AC 50) F_2	12.4	74.9	12.4	0
CF 9-8 (AC 412-2 x AF 468-2) F_2	31.2	68.8	0	0
A. cepa — 20 lines		3.2	51.8	50.0

R = < 5% leaf area affected; MS = 6-25% leaf area affected; S = 26-50% leaf area affected; and VS = >51% leaf area affected.

Screening for resistance to anthracnose disease

Anthracnose, caused by *Colletotrichum gloeosporioides*, is one of the important diseases of onions grown in warm and wet climates. No reliable resistance source is available in onion. This study was undertaken to evaluate onion, Welsh onion (*A . fistulosum*) genotypes, and several interspecific crosses for resistance against anthracnose in field and controlled condition experiments.

Field evaluations in the last 2 years have identified two *A. fistulosum* lines (TA 198 and AF 468) as reliable sources of resistance.

Three *A. fistulosum* accessions (TA 98, TA 204, and AF 468) and 15 F_1 crosses between *A. cepa* and *A. fistulosum* lines were evaluated along with 13 onion lines under controlled conditions. A reliable source of resistance was TA 198. In this line 75% of the plants were resistant. Among other *A. fistulosum* accessions TA 204 had 69% and TA 108 had 19% plants with resistant reactions.

Among the 14 F_1 hybrids which involved *A. fistulosum* (TA 198, TA 204, or TA 108) as a parent only 5 had resistant plants up to 25%. Most of the other plants had either moderately susceptible or susceptible reactions. All the *A. cepa* lines were found susceptible. Further studies are under way to use the resistant plants.

Improvement of garlic through clonal selections and mutation breeding

Productivity of garlic in the tropics is very low (4.4 t/ha). Because of sterility garlic is propagated only vegetatively. Thus, clonal selection and mutation breeding were undertaken as part of the improvement goal for the crop.

Clonal selections. A total of 139 clonal selections in the second generation (Vg_2) of individual bulb selection group-2 (IBS2) were evaluated, along with checks Ho Mei and Hsi Luo. Bulb yield ranged from 14 (GL 51-2) to 21 t/ha (GL 98-9). Thirteen lines were identified for high bulb yield and other quality traits; the checks had bulb yields less than 12 t/ha. Increase in bulb yield among these lines ranged from 23 to 83%. Average bulb weight among the selected lines ranged from 56 (GL 65-2) to 80 g (GL 98-9), and clove number from 9.8 (GL 44-7) to 26.6 (GL 53.2).

Fifty-two selections previously identified for better performance in the second generation (Vg_2) of the individual bulb selection group-1 (IBS1) were evaluated in Vg_3 generation. Bulb yields ranged from > 3 to > 8 t/ha. Of these, 15 lines with bulb yields above 6 t/ha were further selected. The best performing lines were FG 1-2 (9 t/ha), GL 71-5 (8 t/ha), GL 76-6 (7 t/ha), and FG 1-4 (7 t/ha). Compared to check Hsi Luo the yield increase in these lines was above 92%. Average bulb weight ranged from 30 (GL 80-5) to 44 g (GL 80-5 and FG 1-6) and average clove number per bulb ranged from 7 (GL 76-6) to 13 (FG 1-8). Check Ho Mei had the highest number of cloves (16) per bulb. General yield in this experiment was low because of longer vernalization treatment of bulbs before planting.

Improving garlic through mutation breeding. Individual plants selected for bulb yield and quality traits during VgM_2 generation in the first gamma irradiation experiment (Ex-1) in Hsi Luo last year were further evaluated. In all 62 such selections derived from 0.5 K rad (22), 0.75 K rad (23), and 1.0 K rad (17) were planted in an observational row trial along with nonirradiated Hsi Luo. Bulb yield in these selections ranged from 4 to 18 t/ha. Ten promising lines were identified for high bulb yields ranging from 14 (0.5 K rad S-18) to 18 t/ha (0.5 K rad S-12). The check had a bulb yield of 11 t/ha. Yield increase in the selected mutant/variants ranged from 27 to 66% over the check. Substantial increase in average bulb weight and diameter was observed in selected progenies. Not much variation was noted in number of cloves per bulb.

Twenty-two garlic lines were irradiated last year in the second irradiation experiment (0.75 K rad and 1.0 K rad). A total of 217 plants were selected during the VgM_1 generation last year. These plants were individually planted and evaluated this year. During the early growth stage severe leaf miner infection damaged the crop. Selections were made among these progenies for resistance to leaf miner. Resistant lines identified were GL 37 VS-3, GL 44-M-2, GL 44-S-3, and GL 79 M-3. Large variations were observed in plant growth and bulb quality among the various progenies. Selection was made for better vegetative growth, bulb quality, resistance to leaf miner, stemphylium leaf blight, and viruses. Selections made in the progenies of lines GL 44, GL 51, GL 75, and GL 79 were highly promising for yield and bulb quality traits.

Germplasm evaluation. One hundred and thirteen lines were evaluated for yield and bulb quality traits along with check varieties. Bulb yield ranged from 2 (GL 189) to 17 t/ha (GL 156). Among these 35 lines had bulb yields less than 5 t/ha, 42 lines had 5–10 t/ha, 22 lines had 11–14 t/ha, and 10 lines had 15–17 t/ha. Highest bulb yield was recorded in GL 156 (17 t/ha) followed by GL 157, GL 34, and GL 44. The check Hsi Luo had a bulb yield of 15 t/ha. Among these lines the average bulb weight ranged from 61 (GL 98) to 80 g (GL 123), and clove number ranged from 8 (GL 157) to 30 (GL 50). The newly collected lines—GL 156, GL 157, GL 170, GL 121, and GL 123—performed well; however, variations in plant growth and bulb size were observed in these lines.

Resistance to virus diseases in garlic

Virus diseases cause extensive yield losses in garlic. This study identified clonal selections for resistance to viruses.

Garlic clones (GL 42-2-E, GL 49-3-2, GL 50-3-1, GL 98-6, and GL 98-9) previously identified for resistance to virus diseases were again evaluated. These lines were planted along with highly susceptible lines to allow transfer of viruses from natural populations. The results confirmed the previous findings, since the lines displayed negative reaction to onion yellow dwarf virus

(OYDV), garlic common latent virus (GCLV), and shallot latent virus (SLV) through ELISA.

In GL 42-2-E all the six plants had negative reactions to OYDV, LYSV, and GCLV. The plants had no visible virus symptoms on the leaves, which confirmed last year's findings. This line had medium size bulbs with 35 g average bulb weight.

Nine selected clones of GL 98 were evaluated and of these six displayed negative reactions to OYDV, SLV, and GCLV; three clones reacted negatively to OYDV and SLV. Visible virus symptoms were mild in all these lines. Bulb size in these clones was large, with an average weight of more than 60 g, making the clones promising for commercial use. Among other lines GL 49-3-2 and GL 50-3-1 both had negative reactions to OYDV, GCLV, and SLV. Mild symptoms were observed in these plants. Average bulb weight was above 50 g in both clones.

In the mutation breeding experiment five mutants/variants (GL 49-0.75 K rad S-1-1, S-2-1, VS-9-1, Bulk-1, GL 44-0.75 K rad M-1-1) negative to the presence of viruses were isolated in the Ex-2-VgM_2 generation of gamma ray-treated lines. These plants showed mild visual symptoms of virus infection. All four plants from line GL 49 (at 0.75 K rad) had negative reactions to OYDV, GCLV, and SLV, and GL 44 plants had negative reactions to SLV and GCLV. The only resistant plant identified in a previous mutation experiment, Hsi Luo 0.5 K rad 12-1, was confirmed resistant to SLV and GCLV.

Improvement of shallot

Evaluation of shallot lines for yield and quality

Twenty promising shallot lines previously selected for high bulb yield were evaluated during winter through bulb planting. Their bulb yields ranged from 4 to 27 t/ha. Eleven lines performed well with yields above 20 t/ha (fig. 4). Among these S 25, S 31, and S 2 had yields above 25 t/ha, showing an increase of more than 100% over the check S 28. Among the selected lines average bulb weight ranged from 88 (S 11) to 132 g (S 25), number of bulblets per plant from 11 (S 36) to 23.5 (S 10), and average bulblet weight from 4.3 (S 11) to 8.9 g (S 36).

In another experiment 29 shallot lines propagated through true seed were evaluated in a replicated trial during winter. Seedlings were raised in the nursery and after 45 days planted in the field. Check S 28 was planted through bulbs for comparison. In general the lines matured about 10 to 15 days later and some lines showed variations in bulb color and bulblet number and size. S 31-C and S 25 had fairly good uniformity. Fig. 5 shows that all these lines had high bulb yields ranging from 17 (S 31-C) to 25 t/ha (S 35-C). Check S 28 had 27 t/ha. Bulblet number ranged from 5.0 to 8.8 and average bulblet weight from 6.3 to 25.2 g among selected lines. Further selections were made for bulb quality traits for use in seed production and evaluation.

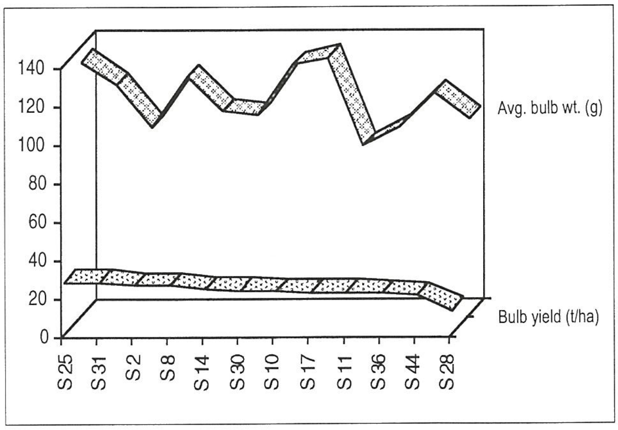

Fig. 4. Evaluation of promising shallot lines planted through bulbs

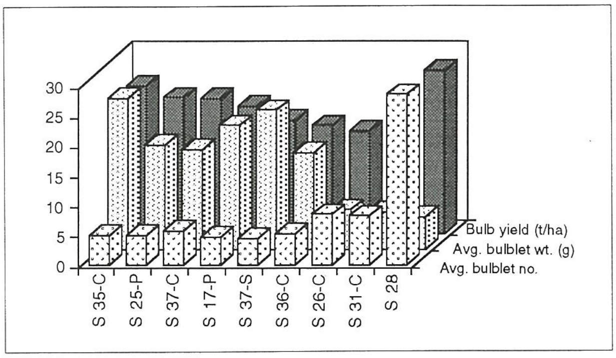

Fig. 5. Evaluation of promising shallot lines propagated through true seed

Host-plant resistance to diseases and insect pests

Second screening of onion germplasm for resistance to onion thrips

Onion thrips, *Thrips tabaci*, is the most destructive pest of onion throughout tropical to subtropical Asia. It is difficult to control by conventional means since it remains hidden between leaf sheaths and away from contact with insecticides. To combat this pest, AVRDC is working on host-plant resistance breeding. A single-replicate screening of part of AVRDC's *Allium* germplasm conducted in early 1995 resulted in the selection of 10 accessions with moderate to high levels of resistance. A greenhouse experiment was conducted in late 1995 and early 1996 to screen these promising accessions and select entries with consistently high levels of resistance.

Seed of 12 accessions including two susceptible checks were sown in specialized seedling-raising trays containing soil-compost mixture in a greenhouse for 8 weeks. The trays were then moved into an insectary room where onion thrips were maintained on onion plants. Each accession was planted in four randomly selected rows. Starting 2 weeks after initial exposure of plants to onion thrips, each plant was observed once a week for onion thrips damage and rated on a 0–5 scale.

One of the two susceptible checks, TA 254, was always the most damaged in all seven observations (table 8). TA 189, TA 243, and TA 385 were consistently the least damaged entries throughout the season. These entries represent an important source of moderate level of resistance to onion thrips. The stability of resistance will be tested under field conditions.

Effect of intercropping subterranean clover with onion on the infestation of onion thrips

Onion thrips larvae and adults feed on the foliage of onion, scratching away the epidermis, thus, reducing bulb onion yield and quality, and marketability of Welsh onion. At present, farmers use pesticides to combat this pest. None of the chemicals, however, give satisfactory control unless they are sprayed frequently. The pest is especially serious in dry weather. Dutch researchers have observed that planting subterranean clover in the vicinity of leek (*Allium porrum*) reduces infestation of western flower thrips, *Frankliniella occidentalis*, on leek. The effect of intercropping onion and subterranean clover on thrips damage was investigated in a greenhouse experiment.

Table 8. Damage to various *Allium* accessions by onion thrips, greenhouse experiment, AVRDC, 1995–96

Acc. no.	Damage rating through observations						
	2 Feb.	9 Feb.	16 Feb.	1 March	8 March	15 Marc h	22 March
AF 465	1.8	2.3	2.7	3.2	3.7	3.7	3.4
AC 430	1.2	1.5	1.8	2.9	3.2	3.8	3.7
AC 448	1.3	1.6	1.9	3.0	3.5	3.6	3.4
TA 178	1.8	2.3	2.4	3.8	4.0	4.1	4.0
TA 189	1.0	1.0	1.5	2.1	2.5	2.8	2.8
AF 2	1.8	2.5	2.4	2.9	3.3	3.5	3.1
TA 210	1.8	2.2	2.1	3.3	3.6	3.6	3.6
AF 218	1.9	2.5	2.4	3.0	3.5	3.7	3.2
TA 243	1.1	1.3	1.5	2.2	2.5	3.1	3.0
TA 385	1.3	1.6	1.6	2.3	2.5	3.1	2.8
TA 254	1.9	3.1	3.0	3.7	4.2	4.6	4.3
AC 004	1.6	2.2	2.2	3.0	3.6	3.5	3.4
LSD (5%)	0.4	0.5	0.4	0.5	0.4	0.3	0.4

Seeding date: 23 October 1995; data are means of 4 replicates.

Damage rating: 0 = no damage, 1 = up to 20% leaf area damaged, 2 = up to 40% leaf area damaged, 3 = up to 60% leaf area damaged, 4 = up to 80% leaf area damaged, and 5 = up to 100% leaf area damaged.

Sixty medium-size clay pots filled with soil mixture were placed in a greenhouse room. Seed of subterranean clover were planted on one side of each of 30 pots. At 0, 10, and 30 days after clover planting, bulb onion was planted on the other side in five pots each and Welsh onion in the remaining five pots. In 30 check pots, only Welsh onion was planted in five pots and bulb onion in the remaining five pots. All in all there were six groupings. The potted plants were maintained in the greenhouse away from any onion thrips source, for at least 4 weeks after last planting date. Later the pots were moved in a *Thrips tabaci* room where the pest was maintained on onion plants for 2 weeks. Each bulb onion or Welsh onion plant was observed for thrips damage once a week for 3 weeks. Thrips damage was rated on a scale of 0 to 5 where 0 = no damage and 5 = 100% leaf area damaged by thrips (table 8).

When both subterranean clover and onions were planted simultaneously, no difference in insect damage was observed in the sole onion crop or onion-clover intercrop. When onions were planted 30 days after subterranean clover, thrips damage was evident in only one observation. When onion was planted 10 days after clover, however, significantly less damage was observed in intercropped Welsh onion than in sole Welsh onion in all three observations. A similar but not so striking difference was also observed in bulb onion.

Utilization of one-component of sex pheromone for communication disruption in armyworms

Beet armyworm (*Spodoptera exigua*) and common armyworm (*Spodoptera litura*) are destructive pests of onion and several other crops in Asia. In onion, the insect larva feeds on foliage, and mostly remain concealed inside the tubular leaves. This makes it difficult to control by conventional insecticide use. Indiscriminate use of insecticides has also resulted in the pest becoming resistant to several commonly used chemicals. AVRDC is, therefore, working on alternate control measures with minimal chemical pesticide use.

Published reports indicate that effective disruption of mating communication can be achieved by the use of only one of the four components of the sex pheromone of beet armyworm in crops like tomato, alfalfa, and cotton. In this experiment, one chemical (Z, E)-9, 12-tetradecadienyl acetate, which is also found in the sex pheromone of common armyworm, was tested to find out whether it can cause mating communication disruption in both armyworm species in the field.

Two 30 x 20 m parcels of land located about 100 m apart were worked into 0.75-m-wide beds. Five-week-old onion seedlings were transplanted as a single row on the top of each bed. Two weeks after transplanting, one pheromone release station—a 1-m-high pole with an attachment for the capillary tube containing pheromone at the top—was erected at the junction of a 4-m grid in one parcel. The other parcel was maintained as a check. The sex pheromone component was dispensed in three 2-mm-diam polyethylene tubes, each containing 100 µg of chemical, which was replenished from time to time. The height of the pole above the ground was adjusted periodically so that the tubes remained at least 10 cm above the plant canopy. The onion crop was grown using standard crop protection practices, except that no pesticide was used to control insect pests.

Once a week, starting 1 day before initiation of pheromone treatment, three traps—one laced with complete sex pheromone of beet armyworm, one with the sex pheromone of common armyworm, and the third without any pheromone—were placed in both fields in late evening, and the number of adults caught in each was recorded next morning. Simultaneously, starting 3 weeks after initiation of pheromone treatment, four 3-m-long rows were randomly selected in each field and each plant in each row was observed for armyworm damage. The damage was scored on a 0–5 scale (0 = no damage and 5 = up to 100% damaged leaf area). The mean damage score of plants in treated and check parcels was compared by student's *t* test.

Prior to initiation of pheromone treatment in both fields large numbers of adult armyworms of both species were trapped (table 9). As soon as the single-component pheromone treatment was initiated, no armyworm adults were attracted to pheromone-baited traps. Similar results were obtained when instead of pheromone, traps were baited with three virgin females of individual armyworm species. The armyworm adults were unable to find virgin females for mating in the one-component pheromone-treated area. There was, however, no significant difference in armyworm damage to onion plants between the check and treatment fields when insect damage to plants was evaluated. This could be due to migration of mated female armyworm moths from the neighboring area. The pheromone is not effective against female moths. If all farmers in a community use this method rigorously in all crops that are reported to be hosts of armyworms, it is possible to obtain adequate control of the pest in small fields.

Table 9. Trapping of beet and common armyworm male adults by sex pheromone traps placed in two onion (var. California 303) fields, AVRDC, autumn-winter 1995–96

Date of observation	No. of adults trapped per trap overnight			
	Check field		CD field[a]	
	exigua	*litura*	*exigua*	*litura*
27 Nov. 95	72	16	44	18
7 Dec.	68	18	0	0
14 Dec.	34	25	0	0
21 Dec.	37	18	0	0
28 Dec.	40	29	0	2
4 Jan. 96	31	9	2	1
11 Jan.	18	19	0	1
18 Jan.	52	13	2	1
25 Jan.	16	10	2	0
1 Feb.	9	9	8	0
8 Feb.	14	1	5	1
16 Feb.	18	6	2	0

[a] CD = communication disruption by the use of high concentration of a single component sex pheromone (Z9,E12-14:OAc) initiated on 30 November 1995; 100 µg chemical in polyethylene tube was placed just above plant canopy at the junction of a 4 x 4 m grid.

Studies on the flying habit of beet armyworm adults

Insecticides keep both larval and pupal stages of beet armyworm from attack by natural enemies and potential pathogens. In an earlier study the use of a high concentration of one-component sex pheromone drastically reduced the potential mating of adults in a treated field. However, migration of mated females from neighboring areas still caused heavy pest damage in pheromone-treated area. To devise a method that will reduce migration of beet armyworm female adults, especially mated ones, into the onion field, the height above ground level at which the insect adults fly was determined to erect suitable barriers.

A 0.05-ha parcel of land planted to onion was used. Six 4.5-m-high wooden poles were erected 3 m apart on the periphery of the field, with three poles facing north and three south. At 1, 2, 3, and 4-m points above the ground, 21.5 x 21.5 cm white paper boards coated with Tangle foot glue were posted. The number of male and female beet armyworm adults stuck on each board were recorded twice a week. The boards were replaced when moderate amounts of scales or dust covered the sticky surface. Seven observations were recorded between 12 January and 5 February.

Two-thirds of adults were trapped at a height of 1 m above the soil surface and a total of more than 90% were trapped at 1 and 2 m above the soil surface (table 10). At 3 and 4-m heights the number of adults trapped decreased drastically. The proportion of females trapped at various heights was identical to the proportion of total number of adults trapped. No female adult was trapped at 4-m heights.

Since it is the migration of females, especially mated females, that initiate insect infestation, a 2-m high barrier around the planted area is recommended. The utilization of a nylon net barrier could be economical as one IPM tool.

Table 10. Beet armyworm adults captured in sticky traps placed at various heights in the field, AVRDC, spring 1996

Trap height (m)	No. of adults	% adults trapped	% females trapped
1	17.8	66.4	68.4
2	6.8	24.4	26.3
3	2.7	7.8	5.3
4	0.7	1.4	0.0
LSD (5%)	3.5	11.3	18.5

Trap size: 21.5 x 21.5 cm white boards; observation dates: twice a week from 12 January to 5 February. Data are totals of 7 observations.

Screening of *Allium* germplasm for resistance to beet armyworm

Two screening trials were conducted to identify sources of resistance to beet armyworm in *Allium*. In one trial part of AVRDC's germplasm accessions was evaluated in a single replicate test; a second screening was conducted on selected germplasm that showed moderate to high levels of resistance during 1994–95 to further confirm the resistance.

Preliminary screening. Seed of 123 germplasm accessions were sown in seedling flats and the seedlings were raised in a greenhouse for 6 weeks. Seedlings of each accession were transplanted in individual 2-m-long plots in the field. The planted area was divided into two portions confined by two 13-m-long x 10-m-wide x 2-m-high nylon net cages. Each portion of the planted area had onion cultivars Granex 429 and Fragrant as susceptible checks. Six weeks after transplanting, 100 pairs of beet armyworm adults were released inside each cage. Once every 2 weeks thereafter, insect damage was observed on each plant and rated on a 0– 5 scale (0 = no damage and 5 = up to 100% leaf area affected).

Among 123 accessions screened, AC 490, AC 492, AC 683, AC 688, AC 1293, AC 1699, and FC 37 were the least damaged in all four observation dates. The two susceptible checks were equally greatly damaged in all four screenings in both cages. The resistant entries need to be screened in multireplicate tests under heavier pest population pressure to confirm their resistance.

Second screening. Nine potentially resistant and six susceptible accessions were planted inside identical sized field cages as described earlier. The plot size, method of planting, initiation of insect infestation, and evaluation procedures for resistance were the same as in the preliminary screening except that each accession was transplanted in four randomly selected plots, with each plot being one replicate. AF 204, AF 218, and TA 246 were the significantly least damaged entries in all four observations (table 11). Susceptible TA 241 and TA 392 were the most damaged entries.

Table 11. Beet armyworm larval feeding damage on various *Allium* accessions, second screening, AVRDC, spring 1996

Accession no.	Damage rating in screenings			
	First	Second	Third	Fourth
AC 029	1.4	1.7	1.9	3.0
AC 058	1.2	1.6	1.6	2.6
AC 145	1.5	1.6	1.8	2.9
AF 465	1.3	1.5	1.6	1.6
AF 218	1.3	1.4	1.4	1.7
AF 204	1.3	1.4	1.3	1.5
TA 243	1.2	1.4	1.4	1.9
TA 246	1.2	1.4	1.4	1.6
TA 385	1.2	1.4	1.4	1.9
TA 174	1.3	1.5	1.6	2.4
TA 200	1.4	1.6	1.7	3.0
TA 228	1.4	1.6	2.0	3.2
TA 241	2.0	2.3	3.2	4.8
TA 392	1.6	1.9	2.1	3.3
TA 395	1.3	1.5	1.7	2.6
LSD 5%	0.2	0.2	0.5	0.6

Sowing date: 24 October 1995, Transplanting date: 12 December 1995
Observation dates: 4, 11, 18, and 25 March 1996.
Data are means of four replicates.

Virus elimination and virus indexing of garlic and shallot

Routine virus elimination and indexing for garlic and shallot continued. Eight shallot and 74 garlic lines completed the second growth cycle in 1996, bringing the total number of virus-free garlic to 196 and virus-free shallot to 25 lines (table 12).

Table 12. **Summary of virus elimination (Ve) and virus indexing (Vi) of garlic and shallot, up to November 1996**

Crop	Year	No. of lines subjected to Ve[a]	No. of lines completed Vi[b] 1st cycle	2nd cycle
Garlic	1994	163 (group 1)	34	16
	1995	- (group 1)	129	106
		74 (group 2)	-	-
	1996	- (group 1)	-	26
		- (group 2)	74	48
		52 (group 3)	2	-
Total		289	239	196
Shallot	1994	17 (group 1)	16	2
	1995	- (group 1)	1	15
		8 (group 2)	-	-
	1996	- (group 2)	8	8
		3 (group 3)	-	-
Total		28	25	25

[a] Garlic group 1: accessions from Thailand (17), France (9), Philippines (40), India (6) Indonesia (19), Dominican Republic (11), Malaysia (4), Argentina (2), Brazil (15), Taiwan (40); group 2: China (10), Germany (11), Egypt (1), India (1), Indonesia (6), Nepal (3), Philippines (6), Thailand (3), Vietnam (1), Taiwan (32); group 3: Dominican Republic (12), USA (1), Guatemala (2), Malaysia (2), China (1), India (1), Burma (1), Thailand (10), Vietnam (1), Taiwan (21); Shallot group 1: Indonesia (9), Philippines (1), Thailand (7); group 2: Philippines (4), Thailand (3),Vietnam (1); group 3: Malaysia (2), USA (1).

[b] First growth cycle: ELISA 0, ELISA 1, and ELISA 2 tests completed. ELISA-negative plants were then subjected to the second growth cycle; Second growth cycle: ELISA 3 test completed and found negative.

Virus indexing efficiency could be improved by using two monoclonal antibodies developed by the Biologische Bundesanstalt (BBA) in Braunschweig, Germany: SYSV MabIH_2, which is specific for the shallot strain of shallot yellow stripe virus (SYSV), and MbFV 4H4, which is specific for the shallot strain of the miteborne filamentous virus (MbFV). Neither could be detected with polyclonal antibodies. The use of the antiviral agent virazole in the tissue culture medium has now become routine because it enhances virus elimination efficiency in both garlic and shallot.

An additional virus test, electron-microscopic examination of ELISA-negative grown-out plants, was used at the end of the second growth cycle in the screenhouse. With this test it is possible to detect new viruses and strains for which no serological detection methods are presently available. ELISA-negative shallot plants were found to be free of virus under the electron-microscope. However, 54% of 109 ELISA-negative garlic plants tested were found to still contain virus. The particles found were filamentous rods (700-800 nm length) which possibly represent particles of a new Asian MbFV.

The yield of the virus-free clone of cultivar Black Leaf grown for the third season in the field continues to be considerably higher than that of the nonmeristemmed field-propagated clone (table 13). Yield increase averaged 253% despite some reinfection with virus, particularly with OYDV and MbFV. This is comparable to an average of 130% yield increase obtained in the second growth cycle in the field last year and an average of 17% in the first growth cycle 2 years ago.

Table 13. **Yields of meristem-derived virus-indexed plants of cultivar Black Leaf grown for the second season in AVRDC fields,1996**

Line[a]	Yield (g/plant) With cage	Without cage
Breeder's field[b]		
M_1F_3	54.5 (429)[c]	57.1 (301)
M_2F_3	37.3 (262)	46.0 (224)
F	10.3	14.2
CV	19.3	14.9
LSD	14.9	13.2
Pathology field[d]		
M_2F_3	63.2 (196)	69.8 (229)
F	24.0	20.0
CV	9.2	10.8
LSD	20.7	10.6

[a] F = nonmeristemmed, nonvirus-indexed, field-propagated clone of cv. Black Leaf; M_1F_3 = meristem 1 of cultivar Black Leaf, grown for 3 seasons in the field; M_2F_3 = meristem 2 of cultivar Black Leaf, grown for 3 seasons in the field.

[b] No garlic, shallot, or onion grown nearby; previous crop = rice.

[c] Numbers in parentheses are % yield increase over the field-grown clone.

[d] No garlic, shallot, or onion grown nearby; previous crop = *Crotalaria* sp.

Host resistance to stemphylium leaf blight of bulbing alliums

Stemphylium leaf blight, caused by *Stemphylium vesicarium*, has been recognized in recent years to be one of the most important if not the most important foliar pathogen on onion and garlic. Control is chiefly through the use of fungicides, because no resistant varieties have been identified. The objectives of this study were (1) to determine the seasonal occurrence and relative importance of SLB, (2) to evaluate the field reactions of *Allium* lines to SLB, (3) to refine a laboratory protocol for evaluating SLB reactions of *Allium* plants, and (4) to evaluate fungicides for their efficacy against SLB.

Seasonal occurrence and relative incidence of fungal foliar diseases. Monthly plantings of onion, garlic, shallot, and Welsh onion made year-round were monitored monthly for the occurrence and relative incidence of SLB. Among all diseased leaves examined over the yearlong period, 69% were infected by *Stemphylium vesicarium*, 10% by *Colletotrichum gloeosporioides*, 8% by *Puccinia allii*, and 6% by *Alternaria porri*. SLB was the predominant disease throughout the year, but it was most prevalent from December to May, occurring on all four crops.

Field evaluation for SLB resistance. A total of 154 onion entries were evaluated (table 14). Four *A. cepa* entries and a single *A. fistulosum* entry were rated very resistant. Twenty entries were rated resistant. Of 249 garlic entries evaluated for their SLB reactions (table 15), seven were rated very resistant and 15 entries were rated resistant.

Table 14. Stemphylium leaf blight reactions of onion entries to natural inoculum in a field planting at AVRDC, winter/spring, 1995–96

Project[b] - Field #14	Number of entries in each category[a]					Total entries
	VR	R	MR	S	VS	
Onion, Hybrids - Group I	0	0	3	3	2	8
Onion, Heat-tolerant Lines	0	0	0	1	7	8
Onion, Selfed Lines - Group I	1[c]	9[c]	9	14	12	45
Onion - Group I	1[d]	2[d]	8	12	3	26
Onion - Group II	2[e]	7[e]	14	18	16	57
Onion Storage Trial (1995–1996)	0	2[f]	2	4	2	10
Total	4	20	36	52	42	154

[a] VR = No symptom; R = ≤ 5% leaf area affected; MR = 6–25% leaf area affected; S = 26–50% leaf area affected; and VS = >50% leaf area affected.

[b] Onion Breeding Unit designations.

[c] VR = [AC 380-2 N-S, *A. fistulosum*]; R = AC 119 C-S, AC 325 self, AC 325 S_2, AC 325 P-S, AC 431 (R) S_2, AC 449 self, TA 26 self, [TA 203 self, *A. fistulosum*], TA 364 self.

[d] VR = AC 119; R = 451, AC 364.

[e] VR = AC 431, TA 69; R = AC 172, TA 69, TA 176, TA 178, TA 182, TA 370, TA 379.

[f] R = AC 169, AC 319.

Table 15. Stemphylium leaf blight reactions of garlic entries to natural inoculum in a field planting at AVRDC, winter/spring, 1995–96

Project[b] - Field #32	Number of entries in each category[a]					Total entries
	VR	R	MR	S	VS	
Flowering, Clonal Sel. 1994-Cycle-2	0	0	6	38	18	62
Common, Clonal Sel. 1994-Cycle-2	0	3[c]	7	25	40	75
Flowering, Germplasm Eval. - Group I	6[d]	1[d]	17	0	0	24
Common, Germplasm Eval. - Group II	0	3[e]	18	7	0	28
Common, Germplasm Eval. - Group III	1[f]	8[f]	16	15	0	40
Early, Germplasm Eval. - Group IV	0	0	9	11	0	20
Total	7	15	73	96	58	249

[a] VR = No symptom; R = ≤ 5% leaf area affected; MR = 6–25% leaf area affected; S = 26–50% leaf area affected; and VS = >50% leaf area affected.

[b] Onion Breeding Unit designations.

[c] R = GL 34-2, GL 98-6, GL 98-1.

[d] VR = FG 1, FG 2, GL 31, GL 55, GL 83, GL 169; R = GL 67.

[e] R = GL 17, GL 69, GL 120.

[f] VR = GL 33; R = GL 18, GL 50, GL 109, GL 151, GL 153, GL 156, GL 158, GL 215.

Laboratory protocol to evaluate SLB reactions. These studies were conducted at 22±2°C. During the first 36 h after inoculation, the plants were kept in the dark at 100% RH to maintain leaf wetness. Thereafter, the growth room was lighted for 14 h/day and the RH was maintained at 90–95%. Disease severity ratings (DSR) on susceptible onions increased sharply with increasing conidial concentrations from 5×10^3 to 5×10^4, then increased only slightly from 5×10^4 to 2.2×10^5. DSRs on the resistant onion were much lower overall, but the DSR increased significantly ($P < 0.05$) from the 1×10^5 to the 2.2×10^5 conidial concentrations. An inoculum concentration of 1×10^5 was chosen for the routine SLB screening protocol.

DSRs among age groups (30, 40, and 50 days after sowing) for each cultivar varied slightly, but there was no evidence of a trend for a change in cultivar response based on seedling age.

Laboratory evaluation for SLB resistance. Among the first set of entries evaluated, *A. cepa* lines were susceptible or very susceptible and *A. fistulosum* lines were moderately resistant or resistant. The moderately resistant and resistant SLB reactions of F_1 and F_2 populations derived from crosses between *A. cepa* and *A. fistulosum* clearly showed that the SLB resistance of *A. fistulosum* is an inherited trait.

Fungicidal control of SLB in the field. Seven fungicide treatments were evaluated for their control of SLB in the field at AVRDC (table 16). All fungicide treatments provided a significant ($P < 0.05$) level of protection based on area under disease progress curve (AUDPC) values. The iprodione and the mancozeb + iprodione treatments were superior to all other treatments.

Table 16. Fungicidal control of Stemphylium leaf blight on onion cultivar Superex W, AVRDC, 1995–96

Treatment[a]	Yield (t/ha)	AUDPC
Mancozeb + Iprodione	182.1	123.3
Chlorothalonil + Iprodione	141.2	154.3
Iprodione, 23% FP	178.8	114.8
Diphenconazol, 10% W.P.	166.2	159.9
Chlorothalonil, 75% W.P.	146.0	207.4
Mancozeb, 80% W.P.	157.5	177.5
Prochloraz, 50% W.P.	159.6	203.4
Control	125.1	290.3
LSD ($P < 0.01$)	16.9	27.6

[a] Fungicidal applications made at 2-week intervals.

Host resistance to purple blotch of bulbing alliums

Purple blotch (PB) of *Alliums*, caused by *Alternaria porri*, occurs worldwide on most cultivated *Alliums*. It is most severe in areas with hot, humid climates. Control is chiefly through the use of fungicides. Although some resistance has been reported in onions, there seems to be no useful resistant varieties available. This study aimed to determine the seasonal occurrence and importance of PB relative to other foliar pathogens and to develop a laboratory protocol to evaluate *Allium* plants for their PB reactions.

Monthly plantings of onion, garlic, shallot, and Welsh onion made year-round at AVRDC were monitored monthly as they matured for the occurrence and relative incidence of PB and other fungal foliar diseases. Purple blotch was found on all four crops examined for fungal foliar pathogens, but it constituted only about 6% of the total leaf lesions caused by fungal pathogens. It was most prevalent from June to October, but was not the predominant foliar disease during that period.

Fifteen *Allium* lines and crosses were evaluated by the following protocol: 46-day-old greenhouse-grown plants were atomized to the point of runoff with a 1×10^4 conidia/ml suspension from isolate *Ap*-33 of *A. porri*. The inoculated plants were incubated in the dark for 36 h at 25±2°C and 100% RH to maintain leaf wetness. The RH was then reduced to 98% and the plants provided a 14 h/day photoperiod. Disease severity ratings were made 7 days after inoculation. No accession was rated resistant among the entries. Three were rated moderately resistant, eight susceptible, and four very susceptible (table 17). Clearly good disease development was obtained using this protocol. It

Table 17. Evaluation[a] of *Allium cepa*, *A. fistulosum*, and F_1 populations for purple blotch reactions in laboratory inoculations[b]

Entry	No. of plants	No. of plants at each DSR[c] 1	2	3	4	5	Mean DSR	Disease reaction[d]
AC 531	24				1	23	4.96	VS
Granex 429	24					24	5.00	VS
AC 443 (OP)	24				1	23	4.96	VS
CF 19	24		8	15	1		2.71	MR
FC 39	24		4	13	3	4	3.29	S
FC 41	24		14	7	2	1	2.58	MR
FC 26 (18)	23		2	17	4		3.09	S
SL 179	22		5	11	2	4	3.23	S
CF 54	21		2	4	2	13	4.24	VS
CF 57 (4)	23		2	10	3	8	3.74	S
FC 66	23	1	2	10	1	9	3.65	S
AF 468	21	1	1	9	8	2	3.43	S
TA 198	24	4	3	16		1	2.63	MR
TA 204	20		2	12	1	5	3.45	S
TA 108	17		1	8	6	2	3.53	S
TA 108 (ck)	6		1	2	1	2	3.67	S
TA 198 (ck)	6		1	4	1		3.00	MR
AC 47 (ck)	6			3		3	4.00	S
Granex 429 (ck)	6				1	5	4.83	VS
TG 502 (ck)	6				1	5	4.83	VS
SL-745 (ck)	6			2		4	4.33	VS

[a] Greenhouse-grown plants were inoculated 14 October and the disease response evaluated 7 days later.

[b] Inoculum from *Alternaria porri* isolate *Ap*-33, 1 x 10^4 conidia/ml. Growth room conditions: 25±2°C continuous; plants held in the dark at 100% RH for the first 36 h after inoculation, thereafter with a 14 h/day light period at 98% RH.

[c] Disease severity rating scale of 1 to 5. DSR of 1 = no symptom, 2 = ≤5%, 3 = 6–25%, 4 = 26–50%, and 5 = >50% of the leaf area affected.

[d] Disease reaction categories are based on mean DSRs. Mean DSRs of 1 = very resistant (VR), 1.1–2.0 = resistant (R), 2.1–3.0 = moderately resistant (MR), 3.1–4.0 = susceptible (S), and 4.1–5.0 = very susceptible (VS).

is not yet known if disease severity is too great to allow distinguishing useful sources of resistance, and more important to accurately distinguish intermediate reactions of plants among breeding populations.

Host resistance to anthracnose of bulbing alliums

Onion anthracnose, caused by *Colletotrichum gloeosporioides*, causes extensive losses in onions grown during warm wet weather. Its control is primarily through the application of fungicides. This study (1) determined seasonal occurrence and relative importance of anthracnose, (2) evaluated onion lines in the field and in the laboratory for anthracnose reactions, and (3) developed a laboratory protocol for evaluating anthracnose reactions of onion plants.

Seasonal prevalence of anthracnose. Monthly plantings of onion, garlic, shallot, and Welsh onion made at AVRDC were monitored monthly for the occurrence and relative incidence of anthracnose from November 1995 through October 1996. Among all diseased leaves examined over the yearlong period, 10% were infected by *Colletotrichum gloeosporioides*. Anthracnose incidence was greatest from June to November when it was a major disease on all four crops.

Field evaluation for anthracnose resistance. In the first evaluation on 7 August, 20 onion and Welsh onion entries were assessed for their reactions. TA 198 was rated very resistant and three entries (TA 104, AF 468, and AF 558) were rated resistant. In the second evaluation on 7 November, a total of 311 entries were assessed for their reactions (table 18). Eight entries were rated very resistant—TA 104,

Table 18. Anthracnose reactions of onion and Welsh onion entries to natural inoculum in a field planting, AVRDC, summer/fall 1996[a]

Project - Field #32	Number of entries in each category[b] VR	R	MR	S	VS	Total entries
Summer 1996 (I) - Group I	0	0	1	2	19	22
Summer 1996 (I) - Group II	1[f]	0	0	2	44	47
Summer 1996 (I) - Group III	8[g]	1[g]	2	9	80	100
Summer 1996 (I) - Group IV[c]	0	1[h]	2	2	34	39
Summer 1996 (II) - Group I[d]	0	0	5	3	13	21
Summer 1996 (II) - Group II[e]	0	0	4	17	61	82
Total	9	2	14	35	251	311

[a] Transplanted 15 August and evaluated 7 November.
[b] VR = No symptom; R = ≤ 5% leaf area affected; MR = 6–25% leaf area affected; S = 26–50% leaf area affected; and VS = > 50% leaf area affected.
[c] F_1 and F_2 population.
[d] Promising lines and new germplasm.
[e] Heat-tolerant lines (F_2 & F_3) and new germplasm.
[f] VR = AF 468 (*A. fistulosum*).
[g] VR = TA 104, 105, 106, 108, 198, 204, AF 438, and AF 468; R = TA 188 self (*A. fistulosum*).
[h] R = OC15-P = AC 50 x AC 429 F_2 OP.

105, 106, 108, 198, 204, AF 438, and AF 468. TA 188 self and AC 50 x AC 429 F_2 OP were rated resistant.

Laboratory protocol to evaluate anthracnose reactions. These studies were conducted in a growth room maintained at a constant temperature of 28±1°C. During the first 36 h after inoculation, the plants were kept in the dark at 100% RH to maintain leaf wetness. Thereafter, the growth room was lighted for 14 h/day and the RH was maintained at 98±2%. Disease severity ratings for the three plant age groups were not significantly different with the susceptible bulbing onions Granex 429 and Granex PRR (table 19). However, DSRs among age groups of the resistant Welsh onion Feast (*A. fistulosum*) were significantly different with each of three *C. gloeosporioides* isolates. The Feast plants inoculated at 43 and 53 DAS gave significantly higher DSRs than 63-day-old seedlings. These results suggest that the minimum seedling age for assessing anthracnose resistance is about 60 days.

Laboratory evaluation for anthracnose resistance. The first set included *A. cepa* lines, *A. fistulosum* lines, and interspecific crosses (table 20). A single entry, TA 198, was classified as resistant, and three entries, FC 43(3), CF 55, and SL 181(5), were classified as moderately resistant with DSRs of 2.8–

Table 19. Effects of plant ages and isolates of *Colletotrichum gloeosporioides* on anthracnose expression (Disease severity rating)[a] in onion and Welsh onion

Cultivars[b]	Plant age (days)[c]	Isolates Cg-183	Cg-184	Cg-184
Granex 429	43	5.0a A[d]	5.0a A	4.0a B
	53	5.0a A	4.8a A	3.5a B
	63	4.8a A	4.8a A	3.8a B
	Mean	4.9(a) A	4.9(a) A	3.8(b) B
Granex PRR	43	5.0a A	5.0a A	4.8a A
	53	5.0a A	5.0a A	4.5a A
	63	-	-	-
	Mean	5.0a A	5.0a A	4.7(a) B
Feast	43	3.9a A	4.0a A	2.8a B
	53	2.5b AB	3.2b A	1.6b B
	63	1.7c B	2.0c A	1.6b B
	Mean	2.7(b) B	3.1(b) A	2.0(c) B

[a] Plants inoculated 19 August (1 x 10^6 conidia/ml) and evaluated 26 August; DSR based on a scale of 1 to 5 in which 1 = no symptom; 2 = < 5% leaf area affected; 3 = 6–25% leaf area affected; 4 = leaf area affected; and 5 = > 50% leaf area affected.
[b] Granex 429 and Granex PRR are *A. cepa* bulbing onions; Feast is an *A. fistulosum* Welsh onion.
[c] Seed sown 17 June (63-day-old); 27 June (53-day-old); and 7 July (43-day-old).
[d] Mean separation in columns, a-c; in rows, A-B; and mean of means in columns (a-c).

Table 20. Evaluation of onion accessions, *A. fistulosum* lines, and breeding populations for their anthracnose reactions[a] in laboratory inoculations[b]

Entry	No. of plants at each DSR[c]					Mean	Disease
	1	2	3	4	5	DSR	reaction[d]
CF 19		1	2	5		3.5	S
FC 37			4	12		3.8	S
CF 16			3	12	1	3.9	S
FC 41			6	9	1	3.7	S
CF 54		1	7	7	1	3.5	S
CF 51		1	4	3		3.3	S
FC 47			2	6		3.8	S
FC 44				8		4.0	S
FC 39			3	13		3.8	S
CF 59			1	11	4	4.2	VS
FC 46				4	12	4.8	VS
FC 43 (3)		1	6	1		3.0	MR
FC 26 (8)-P		1	3	4		3.4	S
FC 66			8	6	2	3.6	S
CF 55		4	11	1		2.8	MR
SL 181 (5)		2	4	2		2.9	MR
SC 179			6	8	2	3.8	S
G 429				4	4	4.5	VS
TA 198	2	4	2			2.0	R
AF 468			7	1		3.1	S
SL 724					8	5.0	VS
TA 204				8		4.0	S

[a] 57-day-old plants were inoculated 20 August and the disease response evaluated 7 days after.
[b] Inoculum from *Colletotrichum gloeosporioides*, isolate Cg-184 (1 x 10^6 conidia/ml).
[c] Disease severity rating scale of 1 to 5. DSR of 1 = no symptom, 2 = < 5%, 3 = 6–25%, 4 = 26–50%, and 5 = > 50% of leaf area affected.
[d] Disease reaction categories are based on mean DSRs. Mean DSR of 1 = very resistant (VR), 1.1–2.0 = resistant (R), 2.1–3.0 = moderately resistant (MR), 3.1–4.0 = susceptible (S), and 4.1–5.0 = very susceptible (VS).

3.0. All other entries were classified as susceptible or very susceptible. The second evaluation included six onion F_2 populations, all of which gave very susceptible reactions (data not shown). In the third evaluation, a total of 18 onion accessions were assessed for their anthracnose reactions both in the laboratory and in the field (table 21). DSRs from the laboratory and the field were highly correlated (r = 0.82), except for some very susceptible entries; the DSRs were consistently higher in the laboratory evaluations. These results suggested that disease pressure was too high with this protocol to permit identification of some useful sources of anthracnose resistance.

Table 21. Evaluation of onion accessions for their reactions to anthracnose in laboratory inoculations and in the field

Entry	Laboratory[a]		Field[b]	
	DSR[c]	Disease reaction[a]	DSR[c]	Disease reaction[d]
AC 320	4.8	VS	4.5	VS
AC 323	4.8	VS	4.5	VS
AC 324	5.0	VS	5.0	VS
AC 327	5.0	VS	-	-
TA 108	4.0	S	3.0	MR
AC 325	5.0	S	3.8	S
AC 427	5.0	VS	5.0	VS
AF 468	4.8	VS	2.5	MR
TA 204	2.2	MR	1.3	R
TA 104	4.8	VS	3.0	MR
TA 198	2.1	MR	1.3	R
AC 47 (seed lot #247)	5.0	VS	3.5	S
AC 47 (seed lot #745)	5.0	VS	4.0	S
TA 211	5.0	VS	5.0	VS
AC 37	4.9	VS	4.3	VS
AC 444	5.0	VS	4.3	VS
AC 54	5.0	VS	3.7	S
TA 189	5.0	VS	4.8	VS

[a] 51-day-old plants were inoculated 12 September with isolate *Cg*-184 (1 x 10^6 conidia/ml) and the disease response evaluated 7 days after.
[b] 81-day-old plants were inoculated 7 October with isolate *Cg*-184 (1 x 10^5 conidia/ml).
[c] Disease severity rating scale of 1 to 5. DSR of 1 = no symptom, 2 = <5%, 3 = 6–25%, 4 = 26–50%, and 5 = >50% of leaf area affected.
[d] Disease reaction categories are based on mean DSRs. Mean DSR of 1 = very resistant (VR), 1.1–2.0 = resistant (R), 2.1–3.0 = moderately resistant (MR), 3.1–4.0 = susceptible (S), and 4.1–5.0 = very susceptible (VS).

Crucifer Improvement

The goal of crucifer improvement is to develop heat-tolerant, high-yielding, and early maturing Chinese cabbage (*Brassica rapa* ssp. *pekinensis*)and common cabbage (*B. oleracea* ssp. *capitata*) varieties with disease and stress tolerance, suitable for growing in the tropics and subtropics.

The crucifer breeding program succeeded in breeding heat-tolerant Chinese cabbage varieties, which enable production of this crop under the hot-wet climate of the tropics and subtropics. In the hope of breeding heat-tolerant varieties through a similar breeding protocol, common cabbage was added as a principal crop in 1992. Common cabbages are produced in the highland tropics, and moderately heat-tolerant hybrids are supplied by several seed companies. The seeds of these hybrids are often inordinately priced.

In 1995, results of the monthly planting of several common cabbage varieties defined constraints in summer common cabbage production: low heading ability, small head formation, and high incidence of diseases and insects.

From a collection of 45 commercial cabbage varieties, 8 were selected for their high-yielding ability during the hot-wet season. A backcross breeding project was initiated to incorporate turnip mosaic virus (TuMV) resistance, which was identified in two lines of Chinese cabbage by their immune responses to five known strains of the virus, into elite lines of heat-tolerant Chinese cabbage. To develop inbred lines with elongated head conformation, 196 plants were selected from three segregating populations for their head shape and heat-tolerance.

To further enhance the level of heat tolerance in 9 composite populations 100 plants were selected from a total of 1685 plants to form a source population for a recurrent selection program, which was proposed to substitute for composite population strategy. The backcross program for the introduction of *ogura* cytoplasmic male sterility (CMS) into Chinese cabbage was proposed to be terminated, since no progress has been achieved for many years in finding plants without chlorosis symptom under low temperature conditions. New sources of CMS are needed.

Major activities in 1996 focused on (1) development of elongated-head type Chinese cabbage, (2) improvement of heat tolerance in Chinese cabbage through population improvement, (3) introduction of cytoplasmic male sterility and turnip mosaic virus resistance into Chinese cabbage, (4) evaluation of common cabbage varieties for early flowering and heat tolerance, and (5) physiological study on heat stress and tolerance in common cabbage.

Genetic resources enhancement and varietal development

Genetic resources activities

The *Brassica* germplasm collection of AVRDC consists of 1510 accessions (table 1) 14 of which were acquired during the year (table 2).

Thirty-six accessions of the *Brassica rapa* group were regenerated. Of the total 33 came from China, 1 from Taiwan, 1 from Thailand, and 1 is of unknown origin. In common cabbage, 5 black rot-resistant lines from the USA, 5 varieties from China, and 1 each from Brazil, Japan, and USA, were regenerated at the Mei-fong farm of National Taiwan University. All 13 accessions produced seed; the amount harvested depended on the number of plants that germinated and that reached the reproductive phase.

So far, 315 accessions have been completely characterized for vegetative and reproductive traits. Only 108 accessions have been characterized for flower and silique traits. A summary of the characterization of the 36 accessions regenerated in 1995–96 is shown in table 3.

Five hundred and sixty-two accessions have been regenerated, 549 (98%) of which have enough seed for long-term preservation.

Eighteen countries and territories received 249 out of 405 samples of crucifer germplasm. The rest went to the regional center in Thailand, the regional program in Africa, and headquarters. Samples were used by Center scientists for summer leafy vegetable production trials; cool season observation, TuMV strain confirmation, summer planting, purity testing, evaluation for heat tolerance; for control in screening for black rot resistance, and for TuMV inoculum production.

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

Table 1. AVRDC *Brassica* germplasm collection, 1996

Species	No. of accessions
B. juncea	36
B. napus	9
B. oleracea	7
B. oleracea var. *alboglabra*	10
B. oleracea var. *botrytis*	6
B. oleracea var. *capitata*	17
B. oleracea var. *gongyloides*	1
B. rapa	859
B. rapa var. Chinese cabbage	22
B. rapa var. Saishin	1
B. sp.	542
Total	1510

Table 2. *Brassica* germplasm acquired in 1996

Acc. no.	Variety name	Species	Origin
TB 641	-	Chinese kale	Malaysia
TB 642	Kailan	Cauliflower	Malaysia
TB 643	75-2c	Cauliflower	India
TB 644	234-S	Cauliflower	India
TB 645	235-S	Cauliflower	India
TB 646	Pant Shubhra	Cauliflower	India
TB 647	Tsao Muam Pai	C. cabbage	China
TB 648	Chu Tung Pai	C. cabbage	China
TB 649	Fan Hsin Huang	C. cabbage	China
TB 650	Fan Hsin Pai	C. cabbage	China
TB 651	Shu Hsin Ching Pai Kuo	C. cabbage	China
TB 652	Fan Hsin Huang	C. cabbage	China
TB 653	Tung An Pai Tsai	C. cabbage	China
TB 654	Chang Pu Wan Sheng Hei Yeh	C. cabbage	Taiwan

Table 3. Flower and silique traits of 36 accessions of *Brassica* regenerated in 1995–96

Trait	Value
Flowering behavior	annual
Flowering stalk color	green
Petal color	yellow
Flower stalk bloom	absent
Silique length (cm)	2.18-5.45
Silique width (cm)	0.55-0.74
Beak length (cm)	0.37-1.85
Silique color	green
Silique attitude	erect
Silique hairiness	absent
Silique shattering	low
No. of seeds/silique	11.3-28.2
Silique carination	keel absent

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

One of the major obstacles 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 popularize this crop in many tropical countries. To develop inbred lines, S5 (selfed) seed were produced from 1995 selections and evaluated in mid- to late summer to select the most heat-tolerant plants with elongated-head type.

Plants with medium-long to long head conformation were found in all batches (table 4). In the families derived from 77-35, however, only a few lines showed elongated head shape. Several lines derived from cylindrical type and 77-27 showed medium-long or long head conformation, and some lines showed the typical shape of Michihili or laxa types. The heat tolerance level, as estimated from percent heading, was low in the population derived from cylindrical type and 77-35. Four out of 16 and 5 out of 23 families showed less than 10% heading rate, respectively. In the families derived from 77-27, only 3 out of 67 families showed less than 10% heading rate, and 24% of the families showed over 80% heading rate.

Table 4. Summary of heat tolerance level and performance of families with elongated head shape from three different populations, summer 1996

Origin	Maturity[a]	% heading[b]	Head length[c]	Uniformity[d]
Cylindrical type	ML-L	0–75 (31)	M-L	2-5
77-27	M-L	0–100 (56)	S-L	2-5
77-35	M-L	0–90 (41)	S-L	4-5
ASVEG #1 (ck)	VE	100	S	5

[a] E = early; ME = medium early; M = medium; ML = medium late; L = late; VE = very early.
[b] Numbers in parentheses are average percent heading of the population.
[c] S = short; M = medium; ML = medium long; L = long.
[d] 1 = poor; 5 = excellent.

Except for a few families, all the rest showed an acceptable level of uniformity. One or two generations of inbreeding should be enough to generate inbred lines. A total of 16 families were selected from the three populations for their heading conformation, heat tolerance, and general performance. Plants with many leaves were visually selected for generation advance. The selected plants were moved to the screenhouse for vernalization and pollination.

Combinations between families of cylindrical type and Chang Puh line CT1-32 were evaluated for their performance during the hot-wet season (table 5). All the combinations showed elongated head formation and large plant weight. None of the combinations, however, yielded more than ASVEG #1 largely due to relatively small head size. The combinations were also heavily infected by softrot. None of the combinations showed ideal medium-long head conformation and sizable head.

Table 5. Horticultural characters of F_1s between elongated lines and Chang Puh in summer 1996

Combination	Plant wt. (g)	Head wt. (g)	Yield (t /ha)	DAT[a]	Head length (cm)
95688-3 / CT1-32	2,477b	1,140c	19.0bc	46b	22.5a
95694-1 / CT1-32	2,812ab	1,486ab	22.2b	45b	22.7a
95694-2 / CT1-32	2,841ab	1,362abc	22.7b	47b	22.7a
95694-3 / CT1-32	2,631ab	1,092c	6.0d	50c	22.7a
95695-5 / CT1-32	2,378b	1,368abc	22.8b	45b	21.3a
95697-2 / CT1-32	2,708ab	1,489ab	15.9c	46b	22.8a
95699-4 / CT1-32	3,028a	1,617a	22.8b	47b	22.7a
ASVEG #1 (ck)	1,915c	1,225bc	32.7a	36a	16.8b

Sown on 12 August and transplanted on 3 September.
Mean separation within column by DMRT at P = 0.05.
[a] Days to maturity from transplanting.

Development of heat-tolerant populations of Chinese cabbage through population improvement

Composite populations were initially made in 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 #1, and semitropical type, according to head shape, hairiness, and other horticultural characteristics. The composite populations were further developed by mass selection for eight generations. Another class of population was generated after three generations of mass selection by bulking equal amounts of selfed seed in each generation.

Beginning 1996, a population improvement strategy was initiated to further enhance heat tolerance level of populations of these two classes while maintaining variation of head shape in the population. The populations were surveyed for early maturity during the hot-wet season. The seed were sown on 5 August and transplanted to the field on 23 August. The populations, which consisted of approximately 600 plants were surveyed two to three times for their earliness and head shape.

A large variation in heat tolerance, head shape, and midrib shape was observed in each population (table 6). With such a level of variation, each population was considered appropriate as the base population for population improvement. Around 100 plants from each population were selected for breeding manipulation. Selection was primarily based on maturity. Head shape was considered as a second criterion when the selected plants were outnumbered. The generation from the selected plants is being advanced during the cool season according to each of the breeding schemes.

Incorporation of cytoplasmic male sterility into Chinese cabbage through backcrossing

The previous cytoplasmic male sterility backcross breeding project was terminated because of the development of leaf chlorosis under low temperature conditions. To develop a simple and a stable system of hybrid seed production, however, a new source of CMS is being sought for.

A CMS accession, NY8481, was acquired from Cornell University. The accession was synthesized by protoplast fusion between *ogura* CMS and a normal plant to produce a CMS line which does not exhibit chlorosis under low temperature. During the summer season, plants were induced to flower and kept in a growth chamber maintained at 22°C. During or after the vernalization period at 4°C, all the plants did not show chlorosis, but showed typical male sterility of *ogura* CMS. Wide variation was observed in leaf morphology, flower size and color among the plants, but all plants produced seed normally. To introduce the male

Table 6. Properties of base population and number of selected plants from each population

Population[a]	Proportion matured on[b]					HS[c]	Head shape of[d] selected plants	Total no.	No. of selected
	30 DAT	35 DAT	40 DAT	45 DAT	50 DAT				
Bulk; Chang Puh	3.8	27.3				17.8	**DC**, D, CP, EDC	611	128
Bulk; ASVEG #1	1.7	27.5	29.5			7.1	**DC**, EDC, EA, A	589	144
Bulk; Late mature		0.9	14.3	29.4		2.4	**EDC**, DC	582	114
Mass; Chang Puh	0.7	14.1	18.4			1.2	**DC**, EDC, A, L	581	120
Mass; ASVEG #1	0.5	16.6	31.8			4.1	**DC**, EDC, EA, A	584	110
Mass; Late mature			5.3	13.4	18.1	20.3	**EDC**, DC, L	580	107
ASVEG #1	10	83	6.7					120	-

[a] Bulk: Population consisted of bulked seeds of selfed progeny; Mass: Population originated from mass selection.

[b] Difference between the sum and the unity is the proportion that matured later than the last survey.

[c] Proportion of nonheading (heat-sensitive) plants.

[d] Bold faced type is majority. A = ASVEG #1, CP = Chang Puh, D = depressa, DC = depressa x cylindrica, E = elongated, L = laxa.

sterility trait into heat-tolerant Chinese cabbage, crosses between the line and four heat-tolerant lines were made. A total of 599 seed were produced from the crosses (table 7) and the progenies were raised for selection of seed plants for backcrossing. Progenies from white-flowered plant showed severe lobation and wax deposition on leaves.

Table 7. Production of F_1 seed between CMS line NY8481 and several heat-tolerant lines

	Recurrent parent			
CMS line	CT1-32	N4-2	O-2	180
NY8481 (Yellow flower)	177	90	90	190
NY8481 (White flower)	40	-	-	80

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

The acceptable common cabbage variety for summer cultivation in the tropics should have high heading ability, high-yielding potential (large head formation), short growing period, and high resistance to softrot and blackrot. In addition to these, low chilling requirement for vernalization is needed to ensure seed production. Thus, common cabbage collections were evaluated for heat tolerance and easy flowering under natural conditions.

Cabbage lines derived from 23 accessions were observed for their flowering response under natural conditions during the 1995–96 winter. The lines were sown on 15 November 1995 and transplanted on 19 December. Lines derived from variety Yehshern flowered and produced seed successfully, but lines derived from Probhati, an early flowering cabbage that produces seed in Bangladesh, flowered late and failed to produce seed. Two local varieties and two breeding lines acquired from the Taiwan Seed Improvement and Propagation Service (TSIPS, formerly TSS) flowered earlier than Probhati, but not early enough to ensure seed production.

To characterize flowering and devernalization in cabbage, stumps of five varieties (KK-Cross, KY-Cross, Choon Chiou, Zhong Gan #8, and Probhati) were vernalized in a 5°C cold chamber. The plants were sown on 15 November 1995 and transplanted on 19 December. The treatment was initiated on 26 March 1996, and the stumps were treated up to a maximum length of 35 days. After the treatment, plants were kept in a growth chamber maintained at 22°C and 16-h photoperiod. Bolting and flowering were surveyed until 7 June, but, even after long vernalization, only Probhati showed bolting and flowering. The result suggested that cabbage needs a fairly long duration of vernalization for bolting and flowering.

Forty-six cabbage varieties were grown in the field during the summer-wet season observation trial. Headed varieties matured from 47 to 91 days after transplanting (DAT). Twenty-five varieties had more than 80% harvest rate. The heaviest heads were obtained from KS-Cross from Seoul Seeds (Korea) with an average head weight of 906 g. The top five varieties were KS-Cross, KK-Cross, Summer Queen, KY-Cross, and Choon Chiou. They yielded 24–19 t/ha and exhibited perfect heading and harvest rates.

Several varieties produced small heads of approximately 400 g, but showed perfect heading rate under hot-wet conditions (table 8). Some

Table 8. Performance of small-headed cabbage varieties in 1996 hot-wet season[a]

Variety	Source	DAT[b]	Head wt. (g)	Yield (t/ha)[c]
Golden Cross 40	Takii Seeds, Japan	47	407	10.9
T-621	Takii Seeds, Japan	62	398	10.6
BSS 50	Bejo Seeds, Netherlands	56	332	7.7
V 0410	S & G Seeds, Netherlands	52	376	10.0
Alaska Cabbage	Takii Seeds, Japan	55	145	3.9
KK-Cross (ck)	Takii Seeds, Japan	59	868	23.2

[a] Sown on 17 June and transplanted on 16 July.
[b] Days after transplanting to harvest.
[c] Yield was based on spacing of 50 x 50 cm.

varieties matured earlier than the check, KK-Cross. Adaptability and yield potential of this group should be explored under tropical and subtropical conditions utilizing a closer planting density.

Incorporation of TuMV resistance into inbred lines of Chinese cabbage

To identify more resistant material against TuMV, a total of 82 new introductions were screened against C5 or a mixture of five TuMV strains (table 9). Fifteen accessions showed highly resistant or immune responses against the strain in both visual ratings and ELISA test. Four of the resistant accessions were immune or resistant to the mixture of five TuMV strains. Ten common cabbage lines were screened for resistance to C2 and C4, and all were found to be resistant.

In an attempt to develop TuMV-resistant lines, a backcross breeding scheme was initiated to incorporate the resistance gene(s) of BP 58 and BP 79, which were previously identified as resistant to all known TuMV strains, into two heat-tolerant lines, B 18 and E 9. Backcross progenies of BC_3 and BC_1 were screened against C1 + C5 strain mixture (table 10). The resistant plants will be further backcrossed to recipient lines.

Table 9. Summary of 1996 TuMV resistance screening

Strain	Total no. lines screened	No. lines resistant	No. lines heterogeneous for resistance
C_5 (singly)	106	15[a]	7
C_2+C_4 (mixed)	10	10[b]	-
$C_1+C_2+C_3+C_4+C_5$ (mixed)	4	3[c]	1

[a] CAAS 1, 2, 4, 13, Shern Yang, Jin Hybrid G55, 75, 80, Beijing #70, 75, Chin Huai 169, Shuang-Chin 156, Hybrid M4 (Fujou), Sin-Kong-Bin 65 (Choang Nong) Lu Bao.

[b] Common cabbage: Shiafong #1, KK-Cross, Zhong Gan #8, Taiwu, Probhati, Choon Chiou, Copenhagen Market 55 days No. 1, Delicious, KS Green, Summer Sea YR.

[c] CAAS #4, CAAS #2, CAAS #13.

Table 10. Screening results of backcross population against TuMV C1+C5 strain mixture

Pedigree	Description	Elisa reaction[a]
(BP 58-3/B 18)/B 18^3	BC_3F_1 (RP1)	30/40
[(BP 58-3/B 18)self]/B 18	BC_1F_2 (RP1)	225/285
[(BP 79-3/B 18)/B 18^3]self	BC_3F_2 (RP1)	287/288
(BP 58-3/E 9)/E 9^3	BC_3F_1(RP2)	9/47
[(BP 58-3/E 9)self]/E 9	BC_1F_2 (RP2)	156/300
(BP 79-3/E 9)/E 9	BC_1F_1 (RP2)	1/60
B 18	Recurrent parent 1 (RP1)	23/23
E 9	Recurrent parent 2 (RP2)	24/24
BP 58-3	Resistant check	0/19
BP 79-3	Resistant check	0/14
B 96	Susceptible check	23/23

[a] No. of positive reactions / No. of tested plants.

Yield trial of common cabbage varieties

A series of plantings of several selected common cabbage varieties was conducted to select the best parents for breeding a heat-tolerant variety. Probhati was included along with six moderately heat-tolerant and two heat-sensitive varieties. The varieties were planted four times during the hot-wet season and once in the cool-dry season (May, June, July, August, and November).

The varieties sown in June showed the highest heat stress (fig. 1). The lowest head weight, heading rate, and yield (data not shown), and highest incidence of softrot and longest days to maturity were observed in the June sowing. June to August seemed to be the most heat stressful period. For heat tolerance screening, therefore, sowing of trials should be carried out in June. In this planting date, two heat-sensitive varieties and Probhati showed very low head weight and heading rate (< 30 %), and the highest incidence of softrot.

KK-Cross had the highest head weight in all sowing until August, while Probhati showed extremely low head weight in all plantings. In the June sowing, the head weights of KK-Cross and Probhati were 776 g and 161 g, respectively (table 11). Probhati and the heat-sensitive varieties matured about 10 days later than the other varieties. Both KK-Cross and Shiafong #1 were selected as a source of heat tolerance and other characteristics.

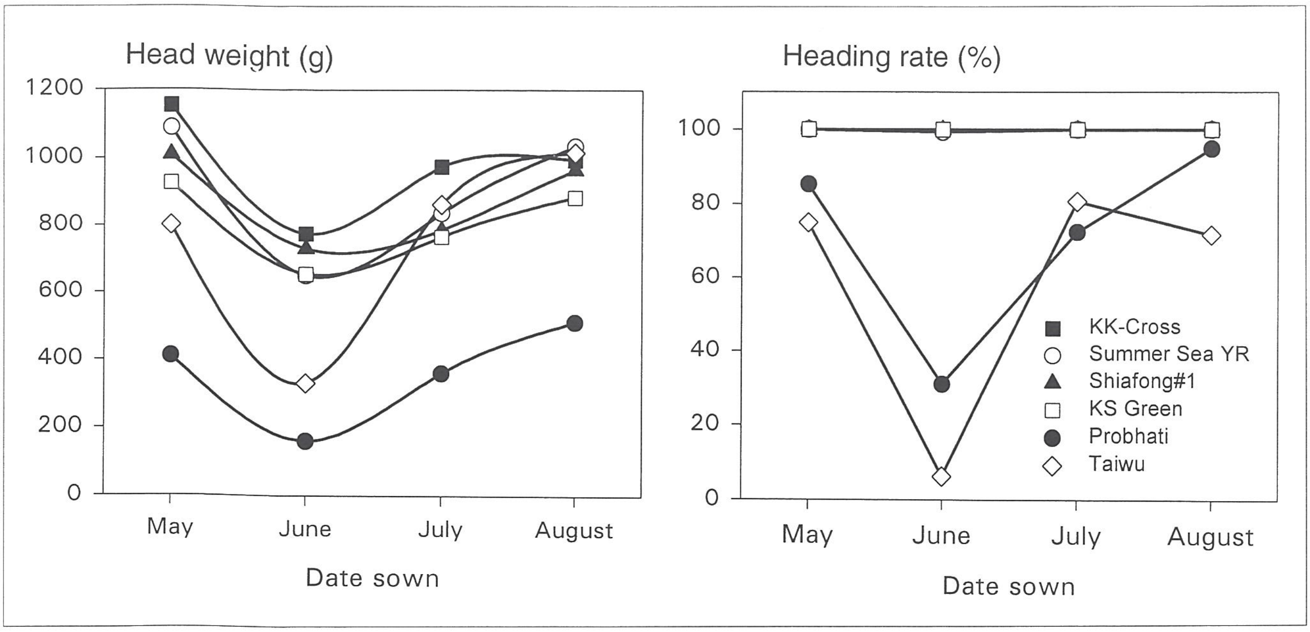

Fig. 1. Head weight and heading rate of common cabbage sown at different times

Table 11. Performance of several common cabbage varieties in June planting, 1996

Variety	DAT[a]	Heading rate (%)	Head wt. (g)	Softrot (%)	Yield (t/ha)
KK-Cross	56ab	100a	776a	68d	6.2de
Shiafong #1	56ab	100a	732ab	33ab	11.2ab
Zhong Gan #8	66c	87b	382d	55cd	3.3ef
Taiwu	70d	6d	331d	47bc	0.5f
Probhati	67c	32c	161e	36ab	0.9f
Choon Chiou	56ab	100a	637b	67d	5.6de
Delicious	57ab	100a	495c	19a	10.3abc
KS Green	55a	100a	656b	32ab	12.1a
Summer Sea YR	56ab	99a	651b	57cd	7.2cd

Sown on 17 June and transplanted on 11 July.
Mean separation within columns by DMRT at P = 0.05.
[a] Days after transplanting to harvest.

Heat stress/tolerance in common cabbage

This study investigated the growth and development of heat-tolerant and sensitive cabbage varieties under high temperature conditions and genetic diversity/similarity with RAPD analysis.

First experiment. Seed of Shiafong #1, KK-Cross, Zhong Gan #8, Taiwu, and Probhati were transplanted on 15 May, 13 June, 11 July, and 19 August. Three plants each were sampled at 0, 20, 40, and 60 DAT and at the final harvest. Fresh weights of various plant parts, i.e., head, stem, leaf, and petiole were recorded. Mean minimum and maximum temperatures and total precipitation during the experimental period ranged from 22.9 to 32.9°C and 86 to 629 mm, respectively.

Second experiment. DNA of 10 cabbage varieties for the study on heat tolerance was extracted. RAPD analysis was conducted with 16 microsatellite primers and 7 random decamers purchased from the University of British Columbia. DNA amplification was carried out in either Perkin Elmer Cetus DNA thermocycler model 480 or Thermolyne thermocycler. The amplification program for microsatellite primers was: 3 cycles of 94°C for 1 min, 50°C for 1 min, and 72°C for 2 min, followed by 40 cycles of 94°C for 30 sec, 50°C for 30 sec, and 72°C for 1 min, ended by 72°C for 10 min. For the random decamers the program was the same except that the annealing temperature was reduced from 50 to 40°C. Amplification products were resolved electrophoretically on a 2.0% agarose gel. To analyze genetic similarity among cabbage varieties polymorphic fragments were scored 1 for the presence or 0 for absence of a fragment. Only major fragments were scored in the data analysis. Genetic similarity was analyzed with the computer program NTSYS-pc ver. 1.80. Similarity matrices using simple matching coefficients were calculated and subjected to cluster analysis by unweighted pair group method analysis (UPGMA) and principle component analysis (PCA).

Among five varieties investigated, KK-Cross showed the most stable heading character, followed by Shiafong #1 and Zhong Gan #8 (fig. 2). Two typhoons came at the end of July and the beginning of August. Under natural stress conditions KK-Cross seemed to be the best variety in terms of heat and flooding tolerance. Shiafong #1 produced marketable heads, but was not so tolerant to high soil moisture.

KK-Cross and Shiafong #1 tended to have wider petiole base than the other varieties (fig. 3). Length of petiole was longest in Taiwu and shortest in Probhati. The wide petiole base may indicate a better translocation channel, especially under stress conditions. Since heading under high temperature conditions is related to the efficient acropetal translocation of water and inorganic nutrients for photosynthesis and water balance, it is reasonable for high-yielding KK-Cross and Shiafong #1 to have both high blade biomass and wide petiole base. The ratio of stem weight/head weight seemed to decline in cool temperature planting (fig. 4), and this ratio tended to be lower in heat-tolerant varieties than in sensitive ones. Reduction in sink demand might be the cause of photosynthate accumulation in the stem under high temperature conditions as well as in the heat-sensitive varieties.

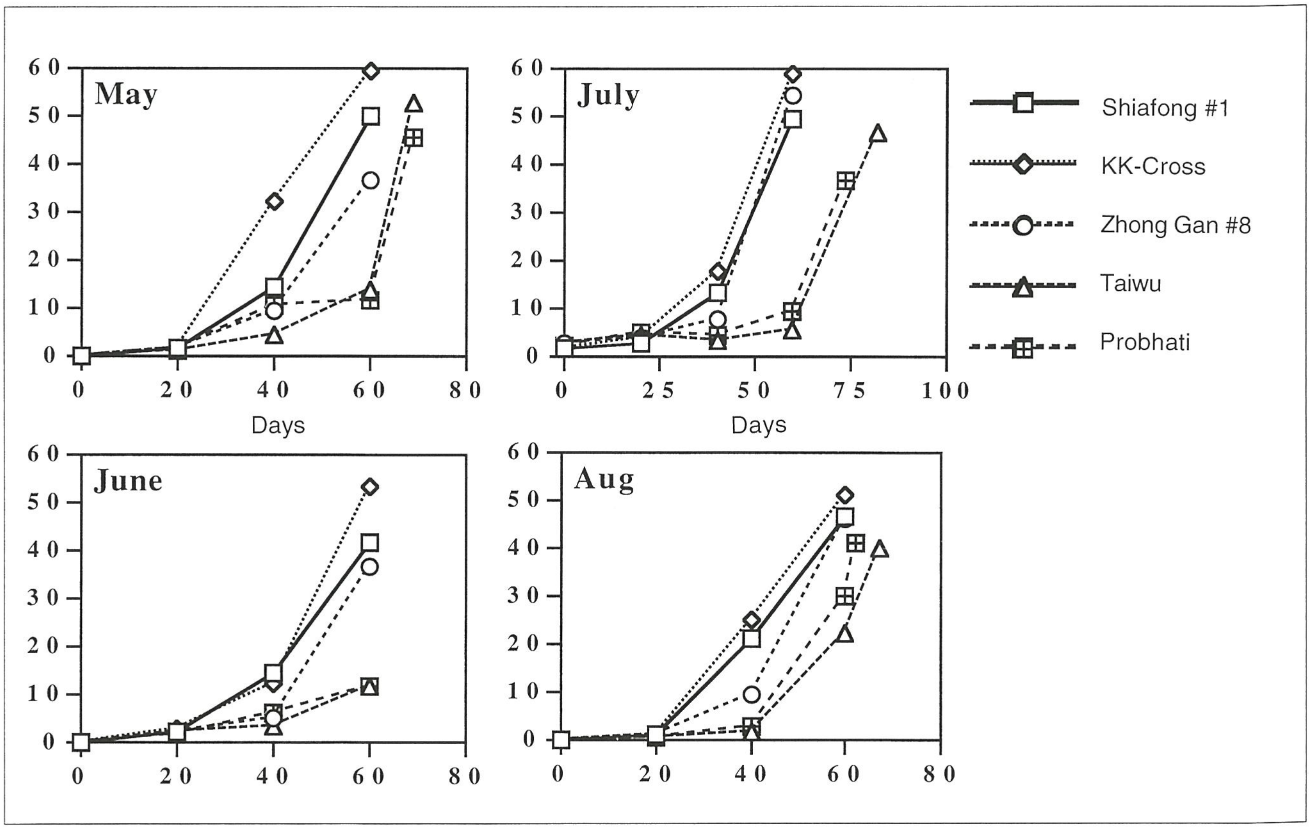

Fig. 2. Harvest index of 5 cabbage varieties planted in May, June, July, and August

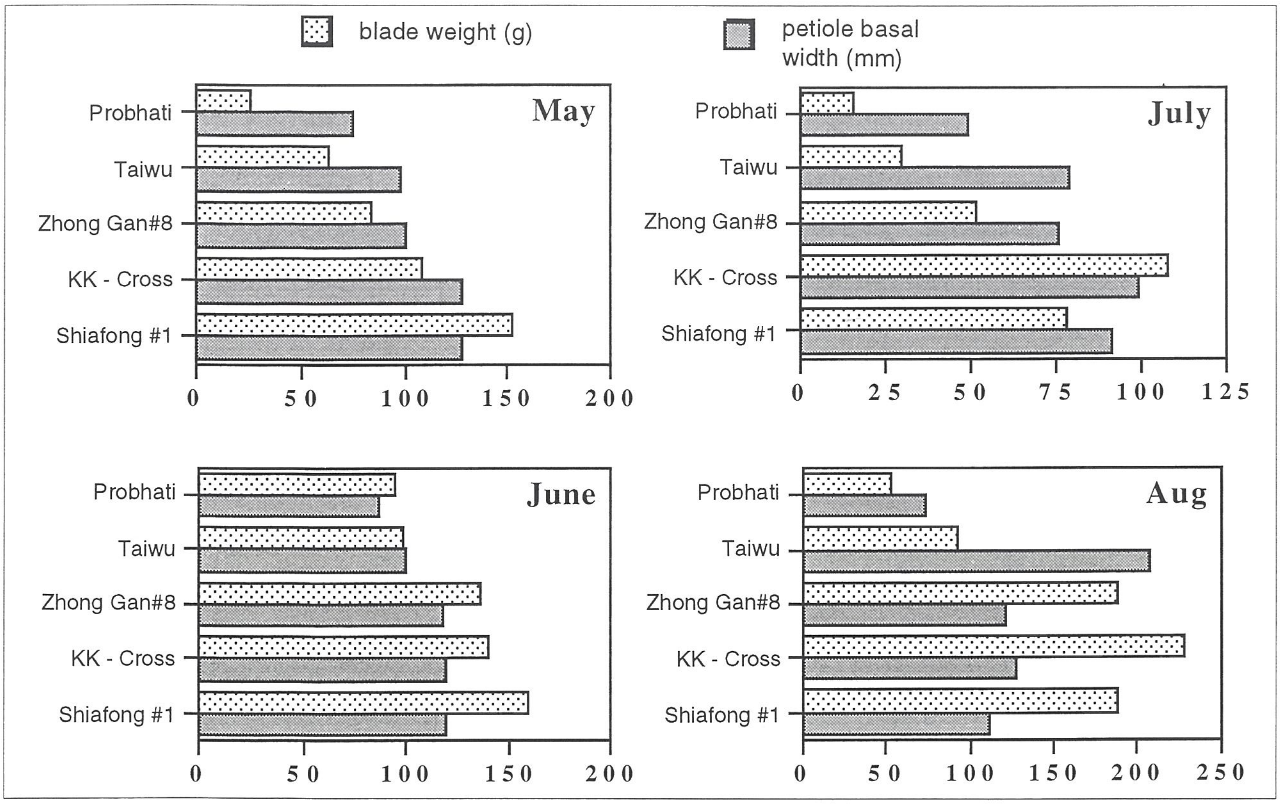

Fig. 3. Leaf blade fresh weight and basal petiole width of 5 cabbage varieties at 20 days after transplanting

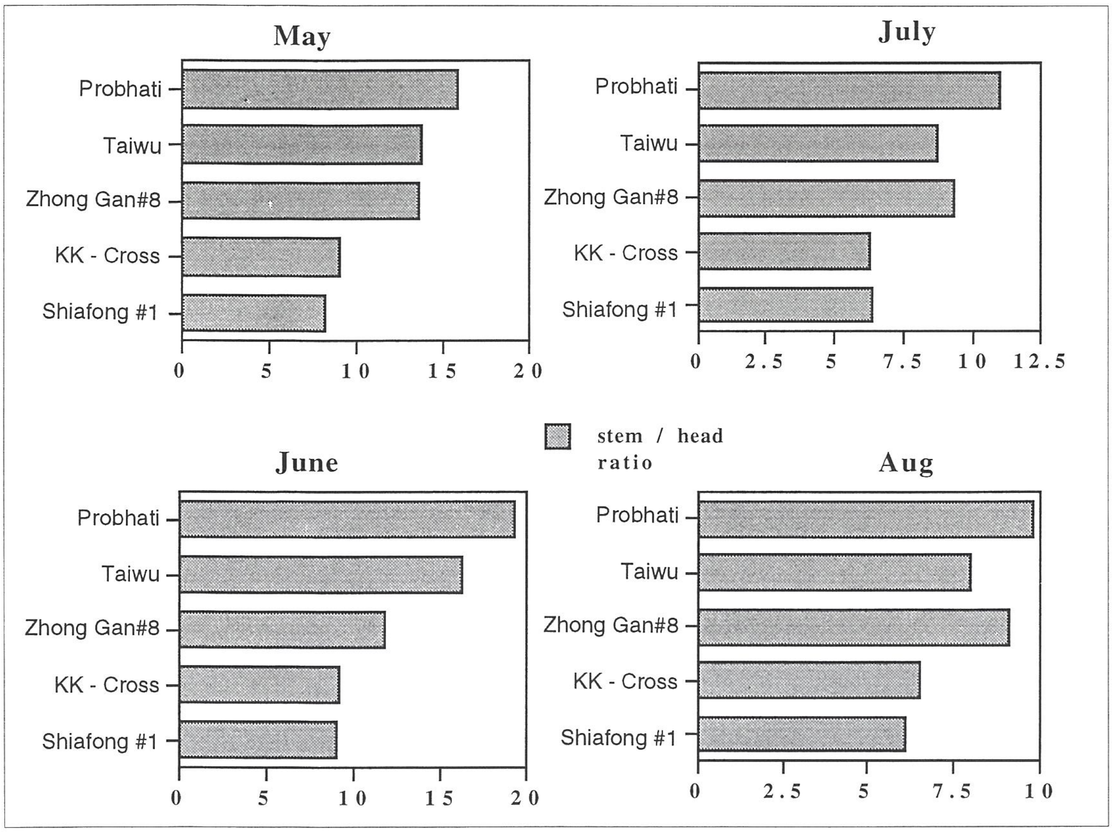

Fig. 4. Stem/head ratio (% of fresh weight) of 5 cabbage varieties at the final harvest, i.e., 55–69, 60, 56–82 and 49–70 DAT for May, June, July, and August plantings, respectively

The RAPD profile of 10 cabbage varieties was quite polymorphic. The similarity matrices based on 71 bands produced by 23 primers ranged from 0.394 to 0.718 (table 12). The closest varieties were KK-Cross (Takii, Japan)/Zhong Gan #8 (CAAS, China) and Zhong Gan #8 (CAAS, China)/Choon Chiou (Taiwan), with a similarity level of 0.718. The most distant varieties were Probhati (Bangladesh)/ Summer Sea YR (Japan) and KK-Cross (Takii, Japan)/Delicious (Watanabe, Japan) with a similarity level of 0.394.

Two subgroups, Shiafong #1 (Taiwan)/Taiwu (Taiwan) and KS Green (Japan)/Summer Sea YR (Japan), have similarity levels of 0.66 and 0.69, respectively.

Table 12. Similarity matrix of 10 cabbage varieties

	Shiafong #1	KK-Cross	Zhong Gan #8	Taiwu	Probhati	Choon Chiou	Copenhagen Market	Delicious	KS Green	Summer Sea
Shiafong #1	1									
KK-Cross	0.62	1								
Zhong Gan #8	0.65	0.72	1							
Taiwu	0.66	0.59	0.62	1						
Probhati	0.55	0.56	0.56	0.41	1					
Choon Chiou	0.62	0.58	0.72	0.62	0.51	1				
Copenhagen Market	0.63	0.62	0.62	0.63	0.49	0.62	1			
Delicious	0.52	0.39	0.48	0.58	0.46	0.62	0.46	1		
KS Green	0.54	0.55	0.63	0.51	0.51	0.55	0.59	0.51	1	
Summer Sea	0.59	0.63	0.55	0.54	0.39	0.49	0.56	0.45	0.69	1

Eggplant Improvement

Eggplant (*Solanum melongena*) is a common vegetable crop grown in nearly all types of gardens and production systems in the subtropics and tropics. Its growth duration is relatively long, hence, it is subject to a number of constraints. AVRDC added eggplant as one of the principal crops in 1992. The improvement goal for eggplant is to develop stable and high-yielding varieties/lines with improved fruit quality attributes and integrated pest management for major diseases and insect pests, such as bacterial wilt *Ralstonia (Pseudomonas) solanacearum*, phomopsis blight (*Phomopsis vexans*), fruit and shoot borer (*Leucinodes orbonalis*), and cotton leafhopper (*Amrasca biggutulla biggutulla*) with emphasis on host resistance/tolerance and biological control in the tropics and subtropics.

In 1995, germplasm collection, multiplication, and characterization continued, and a worldwide collection of eggplant varieties was assembled.

Observational and elite variety trials were conducted on 152 entries to identify desired genotypes for use in the improvement program or for recommendation to the national agricultural research systems (NARS). A large diversity in yield, horticultural characteristics, and fruit quality was observed in the observation trial, while significant differences in marketable yield among the entries were observed in the elite variety trials.

Sources of bacterial wilt resistance were further evaluated to confirm their resistance. Of more than 200 eggplant accessions screened, six showed consistently low disease indices in both greenhouse and field trials.

A field screening protocol for bacterial wilt was developed and adopted.

Center entomologists developed a semisynthetic diet for the mass production and rearing of eggplant fruit and shoot borer, the most destructive pest of eggplant in Asia. The diet is being evaluated in the laboratory.

Research activities in 1996 focused on (1) germplasm collection, regeneration, characterization, and preservation, (2) evaluation of germplasm and elite varieties, (3) identification of new sources of resistance to bacterial wilt, (4) evaluation on the stability of bacterial wilt resistance sources, (5) development of bacterial wilt-resistant lines and varieties, and (6) screening germplasm for resistance to leafhopper and cotton aphid (*Aphis gossypii*).

Genetic resources enhancement and varietal development

Genetic resources activities

Sixteen eggplant accessions were acquired in 1996 bringing the total number of accessions in the eggplant collection to 2246. The new acquisitions include one each of *S. mammosum* from Taiwan (planted as an ornamental) and *S. viarum* from India (a wild species reported resistant to eggplant fruit and shoot borer), 12 *S. melongena*, and 2 *Solanum* sp. The total collection now includes 42 species from 60 countries.

A total of 60 *Solanum melongena* accessions from 14 countries were regenerated in fall 1995.

Sixty-six accessions including variants of the same accessions were characterized. Most of the accessions germinated in 4–5 days. Highest 100-seed weight (0.8 g) was noted in Badinjan from Iran. Highest number of locules/fruit (10) was in S 399 from Canada, while highest number of fruit/plant (80) was observed in S 362 from India.

To date 413 accessions (18%) have been regenerated. Seventeen percent have enough seed for the base collection.

A total of 782 samples were sent to 32 countries and territories. Center scientists requested 276 samples for bacterial wilt screening, grafting, and screening and germplasm evaluation for resistance to fruit and shoot borer.

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

Evaluation of eggplant cultivars and germplasm

New collections of eggplant cultivars and germplasm were tested in the field to observe their general performance.

Observation trial

An observation trial consisting of 121 entries including six check varieties was planted in the field without replication. These entries included 25 commercial cultivars from the USA, Japan, Taiwan, and other countries, and 90 germplasm accessions mainly from India, Turkey, and China. The entries were planted in a single-row plot of 9 m^2 consisting of 12 plants with 1.5 x 0.5 m spacing.

Yield and horticultural characteristics among entries varied widely (fig. 1). Entries had mainly purple fruits with cylindrical or oval and round shapes. One hundred entries matured in 90–100 DAT. The yields in the first 2 months ranged from 4 to 84 t/ha with a mean of 49 t/ha. Sixty entries (50%) yielded above 50 t/ha. Cica, a phomopsis blight-resistant variety from Brazil, gave the highest yield. About 60% of the entries produced 20–40 fruit per plant, and 59% had fruit weights in the 100–200 g range. Genotypes with desirable traits such as early maturity (S 195, Early Bird, Orient Express), erect plant with fewer branches (S 248 sib, S 357A, S 357B), and high yield potential (S 195, S 172, S 174) were identified.

Elite variety trial

Three elite variety trials (EVT) were conducted in 1995–96. The experimental design was randomized complete block design (RCBD) with four replications. 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. The same entries consisting of 19 cylindrical fruit type (CF) varieties and 21 round fruit type (RF) varieties were used in both 1995 summer and autumn trials. In the 1996 spring trial, 38 entries including 24 CF and 13 RF types were evaluated.

In each EVT within the same fruit type, differences in marketable yield among the entries were significant. Generally, yield in the autumn crop was higher than that in summer and spring (table 1). In summer, the plants produced less branches, lower

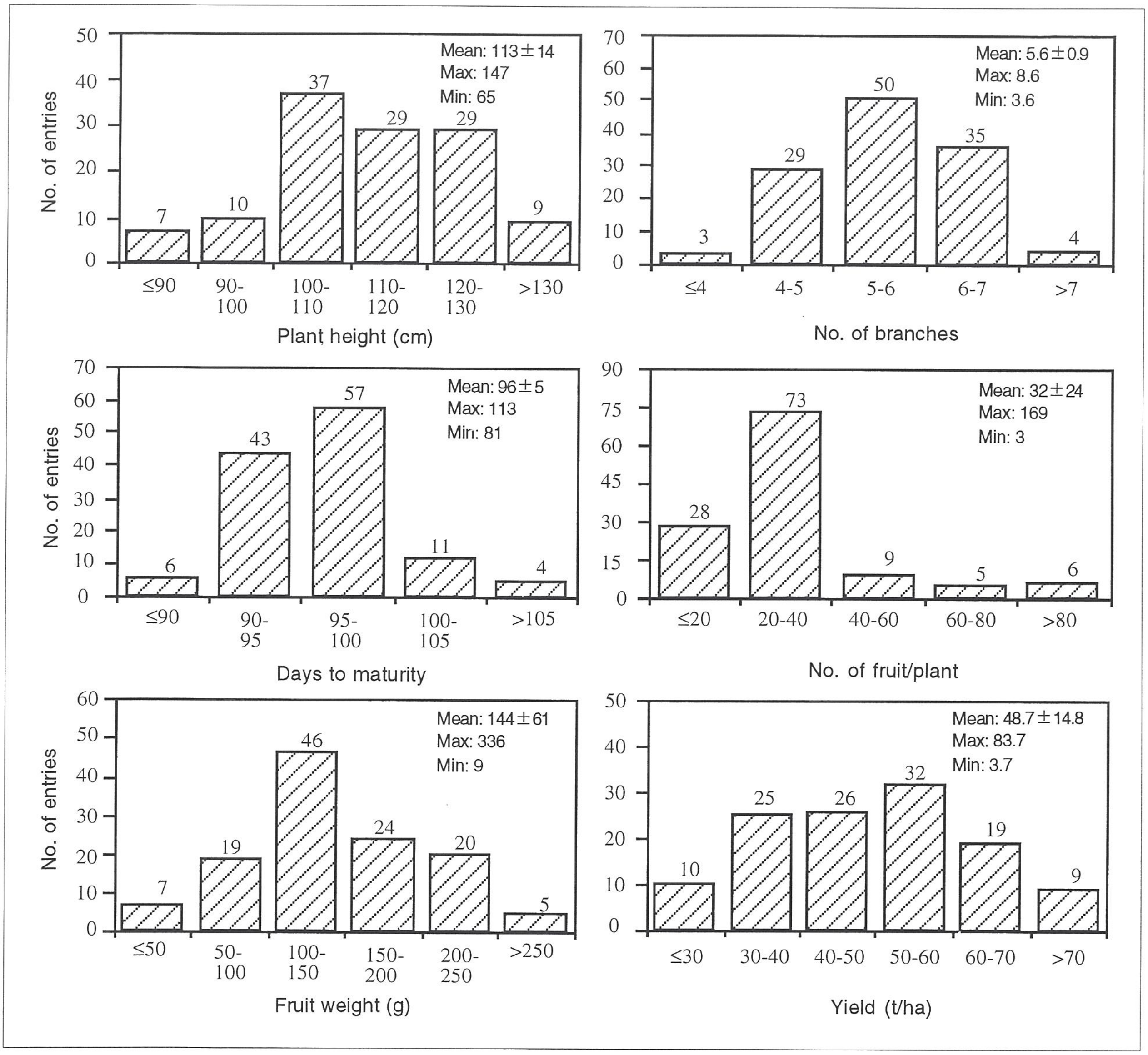

Fig. 1. Distribution of horticultural characteristics among 121 eggplant entries

Table 1. Mean yield and horticultural characters of eggplant varieties in various seasons, EVTs, 1995-96[a]

Trial season	Fruit type[b]	Mean mkt. yield (t/ha)	Plant height (cm)	No. of branches	Days to maturity	No. of fruit/plant	Fruit wt. (g)
Summer 1995	CF	22.6	87	5.9	77	25	76
	RF	23.0	94	5.8	78	16	152
Autumn 1995	CF	44.6	100	7.1	126	41	89
	RF	52.8	106	7.1	127	29	184
Spring 1996	CF	25.5	117	6.8	87	27	78
	RF	28.6	108	6.4	77	23	128

[a] No. of entries: summer and autumn 1995: 19 (C) 21(R); spring 1996: 24(C) 13(R).
[b] CF = cylindrical type, RF = round or teardrop type.

number of fruit per plant, and a smaller fruit size, and the fruit matured in a shorter time resulting in lower yields compared to that of the autumn crop.

For the CF type, average yields were 23, 45, and 26 t/ha, while for the RF type, mean yields were 23, 53, and 29 t/ha for summer, autumn, and spring trials, respectively. The best yielders in summer, autumn, and spring were CF: Swallow Med Long F_1 (28 t/ha), White Eggplant (54 t/ha), and Niu-chiao (40 t/ha); RF: BB-13-1 (33 t/ha), Othello F_1 (70 t/ha), and Pant Rituraj (42 t/ha), respectively. In the same crop seasons, the yields of the check Pingtung Long (CF) were 22, 42, and 25 t/ha, respectively. Marketable yields were highly associated with maturing time, number of fruit per plant, and fruit weight.

Eggplant yields varied with varieties and crop seasons. Based on 1995–96 trials, eggplant produced the best and stable yield in autumn crop. Irrespective of types and varieties, the mean yield in autumn was 49 t/ha compared to 23 t/ha in summer and 27 t/ha in spring. Generally, yield variations among the crop seasons were observed in most of the EVT entries. Niu-chiao, a variety introduced from China, produced stable yields over different seasons (fig. 2). The high autumn yield was attributed to the plants producing more branches and fruit, and maturing in a longer time with larger fruit sizes compared to other seasons. In addition, a stability analysis of 29 varieties in three seasons in 1995 indicated that 21 varieties exhibited good stability in yields with their regression coefficient (b) within b = 1.0±0.3 (fig. 3).

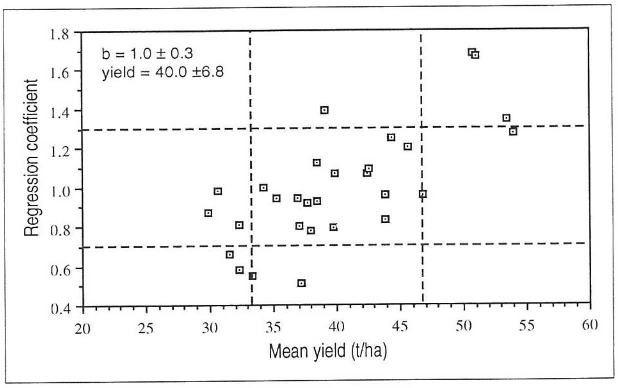

Fig. 3. Relationship of regression coefficients and mean yields of 29 eggplant varieties in 3 seasons

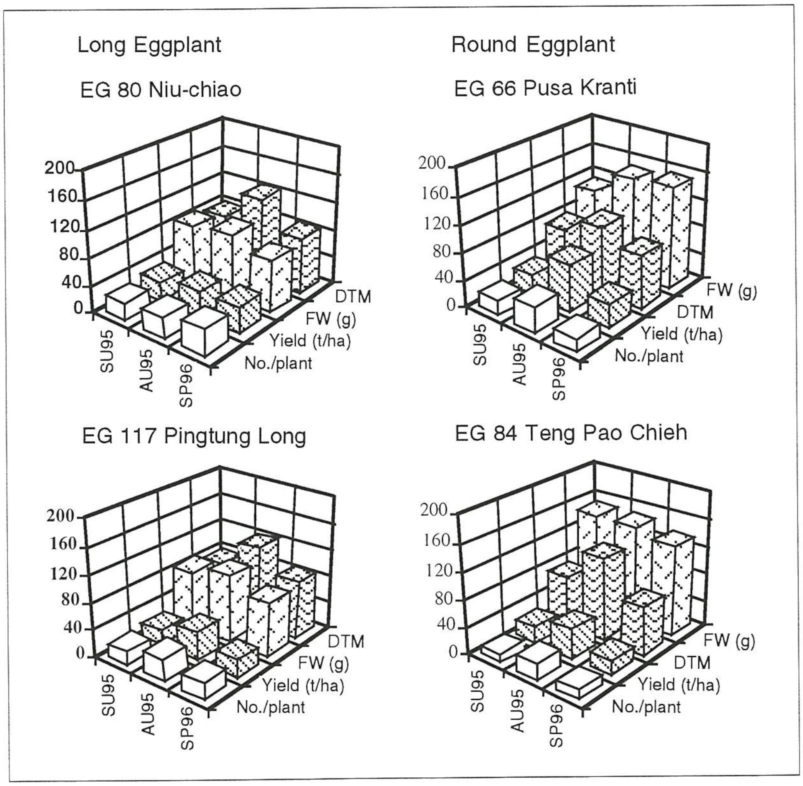

Fig. 2. Performance of 4 eggplant varieties in 3 growing seasons

Evaluation of germplasm for resistance to bacterial wilt

More than 300 accessions of eggplant were screened for bacterial wilt resistance (BWR) in the past three years. Among these, 17 accessions have been identified and confirmed to have a high level of resistance under both greenhouse and field conditions. These resistant sources were collected from Indonesia, India, Italy, Malaysia, Netherlands, and Thailand.

Breeding for bacterial wilt resistance

Selection for bacterial wilt resistance in hybrid progenies

Eight F_2 populations of eggplant crosses were screened for BWR at seedling stage in the greenhouse using the soil drenching with root-severing method. A total of 4293 symptomless seedlings (71%) were transplanted in the disease nursery for further selection of earliness, plant type, fruit appearance, yield potential, and others. At fruiting stage, individual plants were selected among surviving plants of the populations. About 85% of the field-planted plants or 60% of total plants remained symptomless in the field at the end of the trials (table 2). Among them, 218 plant selections (6%) with good horticultural characteristics were advanced to the next generation (F_3).

Twenty-two F_3 lines derived from three crosses were also screened for BWR in the greenhouse. Among 2069 plants, 1617 plants (78%) were identified as symptomless at seedling stage (table 3). At the termination of the trials, about 60% (1179 plants) of the total populations were symptomless in the field. A total of 108 plants (9%) were selected from these symptomless plants for advancement to F_4 generation.

Table 2. Results of screening and selection for bacterial wilt resistance in eggplant F_2 populations

Pedigree		Greenhouse (no. of plants)		Field (no. of plants)		
		Screened[a]	Symptomless	Planted	Symptomless	Selected
CSB 28	F_2 (EG 117/S 1BWR)	576	314	311	236	18
CSB 30	F_2 (EG 117/S 66BWR)	96	41	41	24	4
CSB 42	F_2 (EG 117/EG 014)	958	612	605	427	32
CSB 43	F_2 (EG 117/EG 026)	960	705	703	609	56
CSB 46	F_2 (EG 117/EG 124)	767	555	546	477	30
CSB 47	F_2 (EG 117/EG 125P)	924	750	736	657	22
CSB 48	F_2 (EG 117/EG 125W)	821	621	608	529	10
CSB 49	F_2 (EG 014/EG 117)	959	748	743	679	46
Total		6061	4346	4293	3638	218

[a] Inoculated with PSS97 by soil drenching.

Table 3. Results of screening and selection for bacterial wilt resistance in eggplant F_3 populations

Pedigree		Greenhouse (no. of plants)		Field (no. of plants)		
		Screened[a]	SL[b]	Planted	SL	Selected
CSB 8-1 to CSB 8-11 (11 lines)	F_3 (EG014/S1BWR)	1019	750	676	429	71
CSB 10-1 to CSB 10-10 (10 lines)	F_3 (EG014/S66BWR)	957	783	757	703	37
CSB 20-2	F_3 (EG037/S56B)	93	84	80	47	0
Total		2069	1617	1513	1179	108

[a] Inoculated with PSS97 by soil drenching.
[b] SL = symptomless.

Development of eggplant varietal hybrids and their reaction to bacterial wilt

Twenty-four promising varieties (S, susceptible to bacterial wilt) and six bacterial wilt-resistant varieties (R) were used as parents to develop varietal hybrids. Six bacterial wilt-resistant varieties were EG 192 (Arka Neelkantha), EG 193 (Arka Nidhi), EG 194 (BB-1), EG 203 (Surya), S 7 (MTE 2), and S 64 (Jackpot). A total of 92 hybrids including 78 of S x R cross combinations and 14 of R x R crosses were made. These hybrids were subjected in greenhouse inoculations to bacterial wilt pathogen (PSS 97) at seedling stage. After 30 days of inoculation (DAI), the reactions of the hybrids to bacterial wilt were classified based on % wilt of plants.

Forty-one out of the 92 varietal hybrids exhibited a high level of BWR with less than 10% wilted plants (table 4). Among the 41 resistant hybrids, 14 had 0% wilt including 7 hybrids from R x R cross combinations. The reactions of varietal hybrids to bacterial wilt varied with the parental combinations particularly for S x R crosses. In general, the R x R cross combinations gave a resistant reaction. Moreover, EG 193, EG 194, and EG 203 are good resistance sources for use as parents in developing hybrids with BWR. A yield trial of some selected varietal hybrids is being conducted in the field.

Table 4. Reactions of eggplant variety hybrids to bacterial wilt

BW-resistant	No. of	Bacterial wilt reaction[a]			
parent	crosses	R	MR	MS	S
EG 192	24	9	7	5	3
EG 193	19	11	6	2	0
EG 194	9	4	3	2	0
EG 203	12	6	3	2	1
S 7	17	7	4	5	1
S 64	11	4	6	1	0
Total	92	41	29	17	5

[a] R: resistant; MR: moderately resistant; MS: moderately susceptible; S: susceptible.

To improve bacterial wilt resistance of three landraces, Pingtung Long, Pusa Purple Long, and Uttara, crosses were made between them and EG 14, a resistant variety. Three backcrossings were made to their respective recurrent parents. Information on the mode of inheritance of BWR is expected to facilitate the development of resistant varieties. A genetic study of BWR was initiated 2 years ago using three resistance sources. Possible cross combinations of F_1, F_2, and backcrosses were developed. Evaluation of bacterial wilt reaction for F_1, F_2, and backcrosses was partially done in the greenhouse. A complete report of the genetic study will be given in 1997.

Major diseases and insect pests

Screening eggplant germplasm for resistance to cotton leafhopper and cotton aphids

In most Asian countries, aside from the fruit and shoot borer, *Leucinodes orbonalis*, the cotton leafhopper, *Amrasca biguttula biguttula*, is considered a major insect pest of eggplant. It causes serious damage as a pest and as a vector of plant diseases.

To combat this pest, AVRDC is evaluating its eggplant germplasm collection to identify resistance sources. The collection, consisting of more than 500 cultivated and wild germplasm accessions, was tested for resistance to cotton leafhopper and cotton aphid under field conditions. Selected plant parameters that could influence leafhopper resistance were also studied. Seed were sown in small plastic cups that contained a mixture of sterile soil and rice hull. Seedlings were grown inside the greenhouse and watered daily prior to transplanting. Five-week-old seedlings were used for transplanting in 1.5-m beds in a 2-ha field. Test accessions were planted between rows of susceptible Pingtung Long as insect source rows to obtain high and uniform distribution of leafhopper and aphid. A visual damage rating scale of 0–5 (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) and actual counts of insects per plant were used to assess resistance. The damage rating of the different accessions was subjected to a statistical analysis based on mean ($\bar{x}$) and standard deviation (SD). Accessions with insect damaged leaf area of less than $\bar{x}$ - 2SD were rated as highly resistant, those between $\bar{x}$ - 1SD and $\bar{x}$ - 2SD as moderately resistant, those between $\bar{x}$ and $\bar{x}$ - 1SD as possessing low levels of resistance, and those with more than $\bar{x}$ as susceptible.

Among 519 accessions screened in the field, 19 and 28 showed high levels of resistance to cotton leafhopper and cotton aphid, respectively.

The *Solanum* accessions which showed high levels of resistance to cotton aphid are shown in table 5.

Initial aphid damage symptoms included yellowing and curling of leaves. Some plants, specially the most susceptible ones, had grayish to blackish sooty mold on the leaves.

Damage due to leafhopper was observed as early as 58 DAT and increased rapidly until 97 DAT. As expected, the different *Solanum* accessions showed variable resistance to leafhopper attack in three observation dates.

Several accessions were found to have consistently high resistance to the leafhopper in all three observation dates (table 6). All of these accessions were wild *Solanum* species. At least seven cultivated *Solanum* accessions (S 127, 135, 132, 133, 145, 149, 158) from the Philippines showed moderate levels of resistance. These accessions have acceptable horticultural characteristics and therefore have good potential as parent materials. Some accessions showed high levels of resistance to both cotton aphid and cotton leafhopper infestation under field conditions (table 7).

Table 5. *Solanum* accessions which showed high level of resistance to *A. gossypii* infestation under field conditions, AVRDC, 1995–96[a]

Acc. no.	Species	Pedigree name	Origin
TS 26	*torvum*	-	Malaysia
TS 42	unidentified[b]	Terong Dayak	Malaysia
TS 43	unidentified	Dayak Eggplant	Malaysia
TS 41	unidentified	-	Malaysia
TS 37	unidentified	-	Malaysia
TS 54	*macrocarpon*	-	Malaysia
TS 51	*petinatum*	Petinatum	Malaysia
TS 207	*pseudocapsicum*	-	Malaysia
S 140	*melongena*	Talong	Philippines
S 166	*indicum*	Ma-wang	Thailand
S 267	unidentified	Islampuri	Bangladesh
S 328	*melongena*	Lamba Kala	Bangladesh
S 349	*melongena*	Gole Begun	Bangladesh
TS 206	*pseudocapsicum*	-	Malaysia
TS 2020	*melongena*	Makhuea Proa	Thailand
TS 2051	*melongena*	Makhuea Khuen	Thailand
TS 2063	unidentified	Makhuea Krob	Thailand
TS 2091	*melongena*	Makhuea Yaao	Thailand
TS 2154	*stramonifolium*	Ma-uk	Thailand
TS 2155	*melongena*	Makhuea khun	Thailand
TS 2161	unidentified	Makhuea	Thailand
TS 2162	unidentified	Makhuea Tole	Thailand
TS 2168	unidentified	-	Thailand
TS 2183	unidentified	Makhuea Puang	Thailand
TS 2191	unidentified	Makhusading	Thailand
TS 2160	unidentified	Makhuea Tole	Thailand
TS 2093	unidentified	Makhuea Yaao	Thailand
TS 2090	unidentified	Makhuea Krob	Thailand

[a] Transplanting date: 4 October; Observation date: 27 October 1995.
[b] Unidentified: Wild *Solanum* species.

Damage rating was positively and significantly correlated with the total number of cotton leafhoppers on selected resistant and susceptible *Solanum* accessions in all three observations (r = 0.984, r = 0.976, and r = 0.961, P = 0.01, and df = 13). Of the different plant parameters (i.e., leaf area, leaf thickness, leaf toughness, leaf color, leaf shape, trichome density, trichome length, degree of leaf waxy coating, moisture and dry matter content, fruit shape and color, flower color, number of thorns, stem color, internode length, petiole length and diameter, and leaf shape) studied, only the length of internode was negatively and significantly correlated with resistance to the cotton leafhopper (r = -0.890, r = - 0.846, r = -0.890, P = 0.01, and df = 13). The shorter the internode, the greater the level of resistance.

Table 6. *Solanum* accessions which showed high level of resistance to *A. bigguttula bigguttula* damage in all three screenings, AVRDC, 1995–96[a]

Acc. no.	Species	Pedigree name	Origin
TS 13	unidentified[b]	Santok	Malaysia
TS 26	*torvum*	-	Malaysia
TS 40	unidentified	-	Malaysia
TS 41	unidentified	-	Malaysia
TS 42	unidentified	Terong Dayak	Malaysia
TS 43	unidentified	Dayak Eggplant	Malaysia
TS 46	unidentified	-	Malaysia
TS 206	*pseudocapsicum*	-	Malaysia
TS 207	*pseudocapsicum*	-	Malaysia
TS 1947	*indicum*	Maweang	Thailand
TS 2086	unidentified	Makhuea Krob	Thailand
TS 2180	unidentified	Makhuea Puang	Thailand
TS 2199	*indicum*	Maweang	Thailand
TS 2168	unidentified	-	Thailand
TS 2173	unidentified	Maok	Thailand
S 267	unidentified	Islampuri	Bangladesh
S 273	unidentified	Jangti	Bangladesh
-	*macrocarpon*	-	India
S 166	*indicum*	Maweang	Thailand

[a] Transplanting date: 4 October; Observation dates: 1 and 15 December 1995 and 9 January 1996.
[b] Unidentified: Wild *Solanum* species.

Table 7. *Solanum* accessions which showed high levels of resistance to *A. bigguttula bigguttula* and *A. gossypii* infestation under field conditions, AVRDC, 1995–96[a]

Acc. no.	Species	Pedigree name	Origin
TS 26	*torvum*	-	Malaysia
TS 41	unidentified[b]	-	Malaysia
TS 42	unidentified	Terong Dayak	Malaysia
TS 43	unidentified	Dayak Eggplant	Malaysia
TS 206	*pseudocapsicum*	-	Malaysia
TS 207	*pseudocapsicum*	-	Malaysia
TS 2168	unidentified	-	Thailand
S 166	*indicum*	Ma-wang	Thailand
S 267	unidentified	Islampuri	Bangladesh

[a] Transplanting date: 4 October; Observation dates: For leafhopper resistance - 1 and 15 December 1995, and 9 January 1996. For aphid resistance - 27 October 1995.
[b] Unidentified: Wild *Solanum* species.

Evaluation of the stability of resistance sources to bacterial wilt

Seventeen accessions resistant to bacterial wilt were selected from previous seedling screening trials conducted under eggplant improvement. To evaluate the stability of the bacterial wilt resistance, evaluation trials were conducted by three methods: (1) seedling screening in the screenhouse with strain Pss97 (SH); (2) field screening at AVRDC by transplanting Pss97-inoculated seedlings (AVRDC); and (3) field screening in a naturally infested field at the Taiwan Seed Improvement and Propagation Service, Taichung (TSS).

Symptoms other than wilting were observed in all the test entries except in the three susceptible ones, such as necrosis on leaves, yellowing, stem splitting, and defoliation.

Percentage of wilted plants at the end of the trial are shown in table 8. Mean percentage of wilted plants of each entry ranged from 1 to 21% over three trials. EG 219, EG 203, and EG 192 had the lowest % wilt and the most stable resistance to bacterial wilt (table 8).

The mean % wilt for the trials were 22, 21, and 17%; the final % wilt of Bonne, the susceptible check, were 100, 100, and 96% for SH, AVRDC, and TSS trials, respectively. Thus, colonization frequency could be positively correlated with disease pressure. Based on the combined analysis of variance, the variables entry, trial, as well as entry x trial were significant. However, the effect of the trial was not significant when only data from SH and AVRDC trials were included in the combined analysis. This could be due to the use of Pss97 as inoculum in both trials.

Table 8. Mean % wilt of eggplant entries evaluated for bacterial wilt reaction in 2 field trials and 1 screenhouse trial

Acc. no.	Variety name	Origin	% wilt[a]	*t* test[a]
EG 219	BB44	India	1	g
EG 203	Surya	India	1	g
EG 192	Arka Shirish	India	1	g
TS 69	Gelatik	Indonesia	3	fg
EG 193	Arka Nidhi	India	3	fg
TS 90		Indonesia	3	fg
EG 195	BB49	India	3	fg
TS 3		Malaysia	4	e-g
TS 47A		Malaysia	4	e-g
TS56B	Terong Hijau (R)	Indonesia	4	e-g
TS 7	MTE2	Malaysia	6	ef
TS 87	Glatik	Indonesia	8	d-f
EG 190	SM6-6	India	9	c-e
EG 191	Arka Keshav	India	12	b-d
TS 75		Thailand	13	bc
EG 014	Slim Jim	Italy	15	bc
TS 64	Jackpot	Netherlands	21	b
EG 064	Pusa Purple Long (S)	India	96	a
EG 120	Bonne (S)	Taiwan	99	a
EG 048	Black Beauty (S)	USA	100	a

[a] % wilt means are actual values. Analysis of variance and mean separation were conducted using transformed data by arcsin of the square root.

Isolation of the pathogen from the collar or lower stem part was conducted for nine selected resistant entries (EG 219, EG 203, EG 192, TS 69, TS 3, TS 47A, TS 56B, TS 7, and EG 190) at the end of each trial. *Ralstonia (Pseudomonas) solanacearum* was isolated from all the nine selected lines at the end of the SH and AVRDC trials. The colonization frequency was much lower in the TSS trial and the pathogen can only be isolated from plants of EG 203, EG 192, and TS 69. The range of colonization frequency was 67 to 100%, 33 to 79%, and 0 to 11% for the SH, AVRDC, and TSS trials, respectively.

Strategic and/or supporting studies

Variation in 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 (SSF) has a rudimentary ovary which does not develop into a fruit. Selection of a genotype with stable and high numbers of long-styled flowers (LSF) may increase fruit setting and yield. Flowering in six eggplant genotypes, EG 81, EG 117, S 10, S 49, S 64, and S 93, was investigated in the greenhouse. Plants were grown in 30-cm pots, with six plants for each variety. Dates of flowering, flower abortion, and flower types were recorded daily during the 12-week period after the first flowering.

The number of open flowers varied with genotypes from 20 to 77 per plant. A large variation was found among the genotypes in percentages of long-styled and short-styled flowers. The LSF percentages ranged from 71 to 99%, while the SSF ranged from 1 to 29% (table 9). EG 81, a variety from China, had the highest percentage of LSF. EG 117 (Pingtung Long) and S 49 also exhibited a high proportion of LSF. In contrast, two varieties, S 10 (from Fiji) and S 93 (from Indonesia), had a high percentage of SSF.

Differences in flower abortion among genotypes and between flower types in each variety were remarkable. For LSF, 8 to 55% (mean = 30%) of open flowers aborted; while for SSF, about 55 to 100% (mean = 84%) of open flowers aborted depending on the variety (table 9). The flower abortion occurred 4.9-6.0 days and 6.0–6.7 days after flowering for SSF and LSF, respectively. In some varieties, the SSF either aborted totally or set few fruits which dropped prematurely. Therefore, genotypes with stable high numbers of LSF may increase fruit setting and yield.

Table 9. Percentages of long-styled and short-styled flowers and flower abortion of six eggplant genotypes

Acc. no.	Variety	Flower				
		open flowers		aborted		Days to abortion
		no.	%	no.	%	
Long-styled flower						
EG 81	Pai Chieh Tzu	57.4	99	4.4	8	6.0
EG 117	Pingtung Long	59.4	95	28.0	47	6.1
S 10	Sitara	45.4	71	25.0	55	6.5
S 49		18.0	92	4.6	25	6.7
S 64	Jackpot	29.8	82	6.2	21	6.7
S 93	Kopek	61.8	80	18.0	29	6.0
Short-styled flower						
EG 81	Pai Chieh Tzu	0.8	1	0.8	100	5.2
EG 117	Pingtung Long	3.0	5	2.4	80	5.1
S 10	Sitara	18.4	29	16.2	88	5.4
S 49		1.6	8	1.6	100	6.0
S 64	Jackpot	6.6	18	5.2	79	5.1
S 93	Kopek	15.0	20	8.3	55	4.9

The number of open and aborted flowers in both LSF and SSF during the six 2-week periods are given in fig. 4. Generally, the number of LSF increased as plants became older. In most of the test varieties, more than 50% of the total LSFs opened during the 7–10 weeks after first flowering. Varieties with high numbers of LSF, such as EG 81 and S 49, produced completely no SSF during the first 8 weeks after flowering. On the contrary, genotypes with high numbers of SSF, such as S 10 and S 93, bore SSF throughout the flowering period.

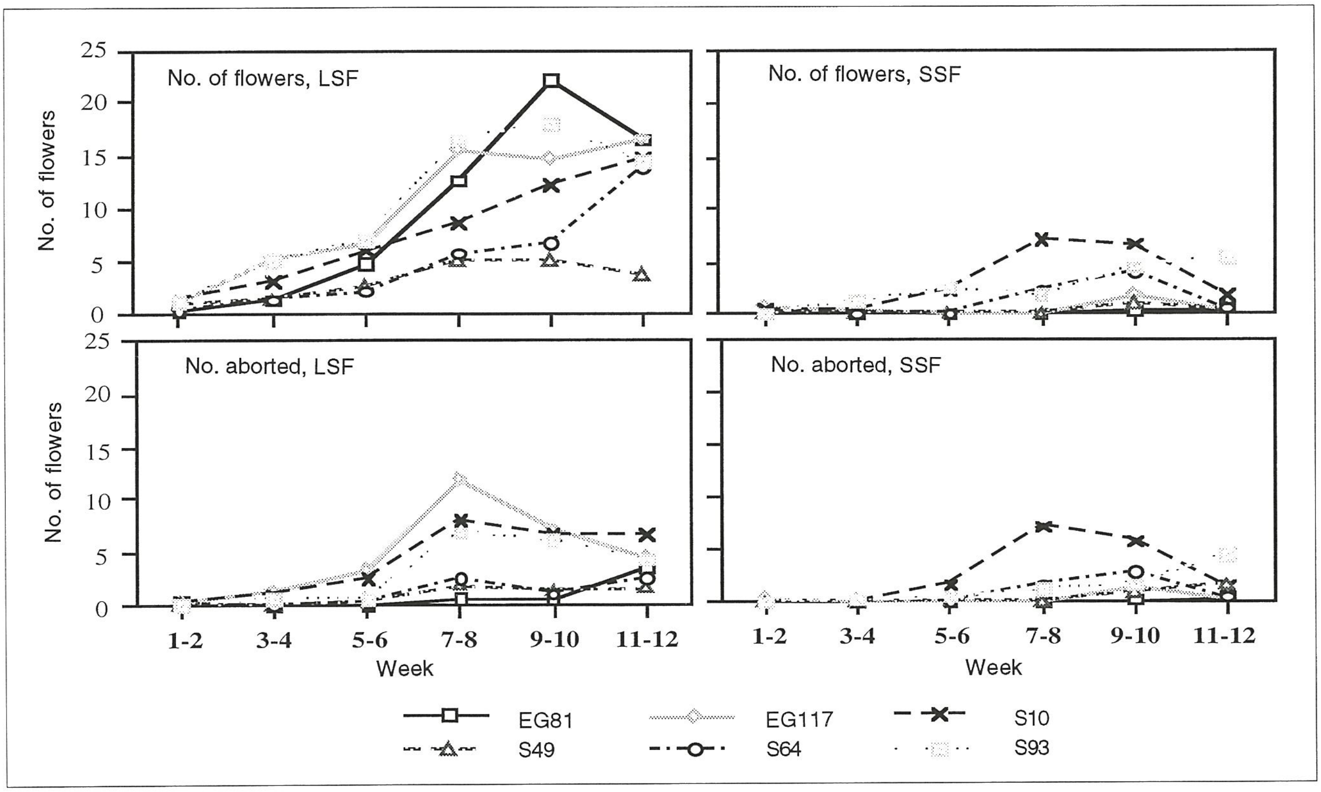

Fig. 4. No. of long- and short-styled flowers and their abortion during the 12-week period after flowering in six genotypes

Pepper Improvement

The goal of the pepper project is to enhance pepper yield and quality in existing production areas and to promote its adaptation to new regions in the hot, humid tropics.

In 1995, more than 200 sweet pepper and 100 hot pepper F_2 populations underwent selection during the hot, rainy season for combined resistance to bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*), *Phytophthora capsici*, and chili veinal mottle virus (CVMV). Inheritance studies seemed to indicate that one dominant and one recessive gene conferred CVMV resistance in Perennial and one dominant gene in PSP-11, whereas two recessive genes conferred resistance to pepper veinal mottle virus (PVMV) in both parents.

The International Chili Pepper Nursery (ICPN) 5 trial, formerly INTHOPE, consisting of 20 lines and landraces was assembled and seed sets were sent to 22 countries for testing. Some entries possessed resistance to potato virus Y (PVY), CVMV, tobacco mosaic virus (TMV), anthracnose, and/or *P. capsici*.

CVMV, cucumber mosaic virus (CMV), PVY, and the tobamoviruses tomato mosaic virus (ToMV), TMV, and pepper mild mottle virus (PMMV) were found to be the most important viruses in Asia, but tobacco etch virus (TEV), pepper mottle virus (PeMV), and tospoviruses, which are important in the Western hemisphere, were shown to be of minor importance.

Resistance to the Taiwan strains of CMV and CVMV has been confirmed in several lines and additional sources of resistance to the major viruses were identified in the AVRDC germplasm collection. The presence of at least seven strains of CVMV and five strains of CMV in Asia has been established.

Distinct responses by some phytophthora blight resistance sources to different *P. capsici* isolates from Taiwan suggested the occurrence of pathotypes. Detection of seedborne *X. campestris* pv. *vesicatoria* is important to avoid distribution of the pathogen by seed. PCR was found to be more sensitive, specific, and timesaving than the conventional seed detection method by direct plating on semiselective media.

A search for molecular markers linked to CVMV resistance was initiated. Several RAPD markers loosely linked with CVMV resistance were identified. Several agrotransformed chili and sweet pepper plants (R_0) harboring a truncated CMV RNA-2 replicase gene were generated, some of which were found resistant to a local pepper strain of CMV.

Project activities for 1996 include genetic resources enhancement, varietal improvement, management of major pests and diseases, and strategic and supporting studies, such as inheritance studies and the search for molecular markers linked to important characters.

Genetic resources enhancement and varietal improvement

Genetic resources activities

AVRDC's *Capsicum* germplasm collection now totals 6857 accessions, with 22 accessions of 3 species acquired in 1996 (table 1). The collection consists of 8 species. Of the total, 119 (2%) have been identified as F_1s and will be excluded from the active collection.

A total of 288 accessions were regenerated at headquarters in 1995–96 and 300 at the University of the Philippines Los Baños (UPLB). Of these, 283 accessions were characterized following the International Plant Genetic Resources Institute (IPGRI) standard set of descriptors.

Only 248 accessions produced enough seeds for the base and active collections. Thirty-five produced only a few seeds while five accessions had no seeds.

A total of 4136 seed samples were sent to 48 countries and territories, 298 to the AVRDC regional center in Thailand, and 31 to the regional program in Africa. Headquarters scientists also used samples for hybridization, germplasm evaluation, screening for fusarium wilt, PVMV, and watermelon silver mottle tospovirus (WSMV), grafting trials, and gene transformation.

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

Table 1. The AVRDC pepper germplasm collection, 1996

Species	No. of accessions	No. acquired
C. annuum	4,103	13
C. baccatum	359	3
C. chacoense	30	–
C. chinense	380	3
C. eximium	4	–
C. frutescens	365	–
C. praetermissum	4	–
C. pubescens	25	–
C. sp.	1,587	3
Total	6,857	22

Establishing the AVRDC *Capsicum* germplasm core collection. In collaboration with UPLB, an AVRDC capsicum germplasm core collection was developed. The core was formed by (1) calculating ratio variables such as leaf length/leaf width, (2) eliminating outliers for the different ratio variables, (3) cluster analysis on ratio variables of the remaining accessions, (4) selecting representative accessions for each cluster based on nominal and ordinal variables, and (5) including accessions with extreme quantitative traits not contiguous with the rest. Step 3 grouped the accessions based on quantitative traits. At least one representative was taken from each cluster. Steps 4 and 5 included several qualitative traits.

A core based on the preceding procedure was formed for each of the following species: *annuum, baccatum, chinense, frutescens,* and unclassified accessions. For each species, two cores were formed: CORE 1 and CORE 2. CORE 1 is based on procedures 1 to 4. CORE 2 attempted to include all the traits present in the species in the accessions nominated to the core. The result is that CORE 2 includes all accessions listed in CORE 1 plus additional accessions. CORE 1 (11% of the original) is smaller than CORE 2 (15% of the original). CORE 1 is suggested to be used unless the researcher is interested in particular gene combinations. If for some reason the accession nominated to the core is not available, an alternate accession from the same subcluster can be used. All accessions of species with only a few were included in the core.

The core is not final. It was based only on accessions characterized at AVRDC headquarters and excludes accessions with missing data. As further characterization takes place and more data become available the accessions in the list will change. The core is intended for use by germplasm evaluators. In the future, only accessions in the CORE will be included in the active collection.

Genetic resources evaluation and multiplication

The pepper breeding germplasm collection was found to contain many accessions with few seeds and/or poor germination. Therefore, a portion (635 accessions) was multiplied in six different nurseries for future use. In some cases, the seed amount obtained was < 5 g and those accessions will be multiplied again next year. A total of 53 accessions were lost because the seeds failed to germinate. A rapid, cheap, easy to evaluate germination test is needed to determine the % germination of pepper seeds. Of several methods tested, sterile vermiculite gave the best results in terms of speed, cost, ease, and repeatability. The protocol developed is as follows: sow 25 pepper seeds 1 cm deep in a 3-cm diam sterile plastic pot with a hole in the bottom for optimum drainage. Use sterile vermiculite as the planting medium and keep the pots at 24–26°C. Water daily and record the number of plants that emerge at 21 days after sowing. Convert to % germination by multiplying by 4.

Over 1000 accessions were tested for % germination using the sterile vermiculite test. Seeds that were up to 10 years old were tested to estimate the length of time pepper seeds could be stored without losing their viability. Over 60% of the lines had >80% germination. Pepper seeds can thus be stored 10 years without losing viability (up to 95% germination) under AVRDC's storage conditions.

Data on % seed germination and seed quantity were placed into a spreadsheet file for easy retrieval and updating. In addition, guidelines on seed increase amounts were set at 5 g (minimum amount needed) and 50 g (maximum amount needed) of any given accession.

At the same time a database was created for 635 accessions containing information on plant and fruit characters, including fruit type and color, species, maturity, etc. for each accession. A wide range of variation for fruit traits (length, width, and weight) was observed: fruit length varied from 0.6 to 18.1 cm; fruit width from 0.2 to 8.6 cm; and fruit weight from 0.1 to 228.9 g. Means were 7.3 cm, 2.5 cm, and 31.3 g, respectively for fruit length, fruit width, and fruit weight.

Because fruit type varies tremendously in pepper and it is difficult to visualize fruit type from phenotypic data, a computerized photo/slide database was begun for the 635 accessions with slides/pictures representing the major fruit types.

A large observation nursery (1400 accessions) mainly comprising of *C. annuum*, *chinense*, *frutescens*, and a few *chacoense*, and *pubescens*, was grown during the hot, rainy season and characterized for several traits, including heat and flood tolerance, species, and fruit type. Thirty-one accessions had good summer survival (a combination of heat/flood tolerance, mite resistance, and virus tolerance), and 36 had fair summer survival. These will be tested again next year to confirm their good summer survival.

As part of efforts to characterize the Center's *Capsicum* germplasm collection, molecular markers (RAPDs) are being used to characterize a set of 150 phenotypically diverse accessions (several different fruit types and six different species represented). These were sent to the University of Wisconsin for RAPD analysis and the work is ongoing.

Development of improved inbred lines

The pepper breeding activities were reorganized and the research thrusts prioritized. Four market types were identified as highest priority: small (5 x 0.8 cm) chili, medium (10 x 1.0 cm) chili, large (15 x 1.4 cm) chili, and medium (8 x 8 cm) sweet bell. Fifty percent of breeding resources will be allocated to the medium chili type, with equal amounts of resources allocated to the other three types. Abiotic and biotic stresses were rated for severity in AVRDC target areas (Asia and Africa) and the most severe stresses (anthracnose, CMV, CVMV, mites, thrips, and flood tolerance) will receive the highest priority.

F_2 seeds from 200 F_1 hybrids carrying resistance to CMV, CVMV, and PVY were obtained for sowing in the F_2 nursery.

The CVMV backcross activity continued with another backcross to the recurrent parents. Segregation ratios of resistant (R): susceptible (S) varied widely depending on the recurrent parent, from mostly resistant to mostly susceptible. This indicates that more than a single dominant gene was involved and/or that some of the recurrent parents were already resistant to CVMV. All 21 recurrent parents of the backcrossing program were tested for resistance: 10 were susceptible and were successfully backcrossed; most are at the BC_4 stage. The 11 remaining partially or completely resistant parents were dropped from the backcrossing program.

Initial crosses in a backcrossing activity to transfer male sterility (both genic and cytoplasmic) and PMMV resistance into tropical chili lines were made successfully in three to four lines chosen as recurrent parents.

To determine the optimum time of year to make selections a selection experiment was initiated in spring by growing ~250 F_2 plants from the cross Perennial/Cheongryong and selecting the best 10% (~25 plants) based on plant phenotype at flowering. Selfed seeds were then obtained from each selected plant. The second stage of selection in the F_2 selection experiment was made in summer. Selfed seeds were also obtained from each selected plant.

Crosses were made among CMV-resistant lines selected from multilocation screening and between CMV- and CVMV-resistant lines to try to generate lines with resistance to multiple strains of CMV and lines with multiple virus resistance, respectively. Recurrent selection for CMV and CVMV resistance was initiated as well.

The pedigree selection program included 1643 F_2 populations (20 plants/population), 1600 F_3 families (10 plants/family), 1130 F_4 families (10 plants/family), and 510 F_5 families (10 plants/family) which were grown in the summer for pedigree selection. Most plants in the pedigree selection nurseries died, but ~20% survived. The best plants were selected at flowering and controlled self-pollinations were made by bagging individual branches with unopened flowers.

Selfed seeds of 308 plants from three populations designated as hot pepper 1 (HP1), sweet pepper 1 (SP1), and sweet pepper 2 (SP2) were obtained for progeny testing, evaluation and selection during the hot, rainy season. Most plants died, but ~5% survived. The best plants were selected at flowering and controlled self-pollinations were made. All selected plants were planted again in fall 1996 for the next generation of pedigree selection.

Three sets of 100 F_3 families with small chili fruit type were sent to cooperators in Thailand and Malaysia for evaluation. The Thai cooperator indicated that several families had good plant and fruit type and would be acceptable in Thailand.

Phytophthora is a major constraint to chili production in Bhutan. Initial crosses were made between a Bhutanese landrace Sha Ema and two sources of phytophthora blight resistance, PI 201234 and Criollo de Morelos 334, to begin backcrossing resistance into Sha Ema. In addition, a few crosses were made for flood tolerance, mite resistance, pimento fruit type, plant ideotype, high capsaicin, very large fruit type, aphid resistance, anthracnose resistance, and fruit color.

Definition of optimum cultural practices was begun, focusing on optimum plant density and weed control methods. The problem of weed control during the summer season was addressed by multiple strategies including the use of plastic mulch to cover the beds, spraying a nonselective herbicide in the furrows, and hand weeding around the plants. Other strategies that could be tested include use of pre- and postemergence herbicides and use of a brush cutter.

Seed extraction of sweet peppers is laborious and should be done shortly after harvest or the fruits begin to spoil. For chili peppers, controlled tests indicated that drying the fruits at 40°C for 7–10 days followed by seed extraction could be done with no loss in % germination. This does not work for sweet peppers because of their higher moisture content. Controlled tests indicated that laborious hand extraction of seeds can be replaced by use of a small hand-operated grinder (for small samples) or a large electric grinder (for large samples) followed by several washes of water to separate the seeds and fruits with no loss in % germination. After extraction, seeds can be dried in a forced-air dryer at 20°C in either net bags or manila envelopes with no loss in % germination.

Pure line selection was initiated during the hot, rainy season on approximately 200 landraces/lines that showed good summer survival. Self-pollinated seeds were harvested from 186 landraces/lines; these were sown in fall for further selection/purification. The best lines in the hot, rainy season came from Sri Lanka, India, Malaysia, Thailand, and U.S.A.

International Chili Pepper Nursery

The International Hot Pepper Network (INTHOPE) was renamed as International Chili Pepper Nursery (ICPN) to conform with international standards for naming nurseries. The nursery was reorganized and prioritized by defining the target environment as the hot, rainy season and standardizing the number of entries at 20. The ICPN feedback form was also simplified to encourage more feedback. The data from ICPN 5 were summarized and mailed to each cooperator who grew the nursery, along with an invitation to receive ICPN 6.

Eighteen entries and two checks were selected for inclusion in ICPN 6. One AVRDC pure line selection from the Szechwan landrace #1 (PP 921206) was included. Shipment of ICPN 6 seeds began in February. The ICPN 6 nursery was tested for resistance to viruses (CMV, CVMV, PVY, TMV, ToMV, and PMMV), bacterial wilt, bacterial spot, phytophthora, and anthracnose in collaboration with the Plant Pathology Unit. The nursery was grown in a replicated field trial at AVRDC with 10 weekly harvests. The ICPN 6 plant, fruit, and chemical composition traits are shown in table 2 and disease screening results in table 3.

PBC 556B and PBC 972 showed good resistance to one or more diseases. PBC 972 was chosen as the check for the medium (10 x 1.0 cm) chili fruit type based on its overall performance for disease resistance, plant and fruit traits, and fruit chemical composition. No new sources of resistance were identified for CMV, CVMV, or PMMV. For the other diseases, at least one line was identified that was as resistant as the resistant check.

The ICPN entries could be grouped into three maturity classes: early (anthesis occurred before 74 DAS), medium (between 77 and 89 DAS), and late (after 95 DAS). Visual scores estimate a variety's adaptation to the AVRDC environment. Late varieties were generally unadapted to the AVRDC environment as shown by their relatively high visual scores (>3.8). The most adapted variety appeared to be PBC 739 (Lueng 8) from Thailand (1.3). Plant height at anthesis was negatively correlated with visual score, and it appeared that the combination of early anthesis date and tall plant height at anthesis can be used to predict adaptation.

Most entries had relatively small fruits (<6 cm long). Capsaicin (a measure of pungency) showed a slight and nonsignificant correlation with fruit size in these entries ($r = -0.14$, $p = 0.28$). Relatively high CVs were observed for anthesis date, fruit weight, and capsaicin content. These traits are known to be sensitive to environmental interactions. For example, in ICPN 5, check PBC 137 was reported to have 2.2 mg/g capsaicin, compared to 0.4 mg/g in ICPN 6.

Table 2. ICPN 6 plant and fruit traits and chemical compositions

Entry no.	PBC no.	Anthesis date (DAS)	Plant ht. (cm)	Visual score (1-5)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Dry matter (%)	Cap (mg/g)	Oil (%)	Sugar (%)
1	PBC 137 (ck)	73	36	3.5	3.6	0.6	1.0	25.5	0.4	15.2	15.6
2	PBC 142 (ck)	72	33	3.8	3.8	0.7	1.1	22.7	2.2	14.0	16.4
3	PBC 206	95	22	5.0	2.5	1.0	1.1	—	—	—	—
4	PBC 316	71	33	4.0	3.7	0.9	1.4	23.4	2.8	17.1	10.7
5	PBC 364	71	35	4.0	2.0	1.1	1.2	17.0	0.8	10.4	21.4
6	PBC 367	71	36	3.0	6.0	0.4	1.8	21.9	2.1	13.1	17.7
7	PBC 368	73	40	2.8	9.1	0.5	1.4	22.1	3.0	14.3	17.9
8	PBC 404	84	31	4.0	2.4	0.7	0.6	28.0	1.2	15.4	9.2
9	PBC 497	98	17	5.0	1.4	0.6	0.3	21.2	1.5	13.4	13.8
10	PBC 556B	97	34	4.0	2.8	0.7	0.8	23.4	1.7	15.1	12.4
11	PBC 559	99	29	3.8	1.9	0.5	0.7	22.2	4.5	19.7	12.0
12	PBC 585	77	43	2.5	4.3	0.7	1.4	22.3	1.9	13.0	21.7
13	PBC 586	72	38	3.3	5.2	0.7	1.5	23.4	1.8	12.8	20.7
14	PBC 601	71	36	3.0	8.3	0.9	3.4	15.9	1.6	9.1	22.3
15	PBC 634	71	36	3.0	4.5	1.2	2.7	19.7	0.3	11.7	23.3
16	PBC 714	71	32	3.8	4.3	1.0	1.7	—	—	—	—
17	PBC 739	89	48	1.3	5.8	1.0	3.3	20.5	3.2	16.3	22.3
18	PBC 972	78	45	2.8	8.3	1.1	5.9	17.0	0.6	11.6	26.2
19	PBC 973	73	41	3.0	6.9	1.4	6.7	14.0	1.7	9.9	24.8
20	PP921206	71	34	3.3	6.5	0.7	2.2	18.8	0.7	8.5	18.6
Mean		78	35	3.4	4.7	0.8	2.0	21.0	1.7	13.3	18.4
Range		71–99	22-48	1.3-5.0	1.4-9.1	0.4-1.4	0.3-6.7	14-28	0.3-4.5	9-20	9-26
DMRT		6	7	0.7	1.2	0.1	1.0	2.1	1.8	1.7	2.3
CV (%)		34	12	11	15	10	28	4	33	5	5

Table 3. ICPN 6 disease screening results for bacterial wilt (BW), bacterial spot (BS), cucumber mosaic virus (CMV), chilli veinal mottle virus (CVMV), potato virus Y (PVY), tomato mosaic virus (ToMV), tobacco mosaic virus (TMV), pepper mild mottle virus (PMMV), anthracnose (A, *Colletotrichum gloeosporioides*), and Phytophthora (PC, *Phytophthora capsici*)

Entry no.	PBC no.	BW	BS	CMV	CVMV	PVY	ToMV	TMV	PMMV	A	PC
1	PBC 137	23[a]	3.1	H (92)[b]	—	S	R	R	S	68	100
2	PBC 142	50	19.5	H (58)	H (21)	S	S	S	S	84	79
3	PBC 206	100	27.5	S	S	R	R	R	S	64	100
4	PBC 316	26	13.3	H (25)	H (20)	R	S	S	S	87	100
5	PBC 364	67	7.6	S	S	H (84)	S	S	S	82	100
6	PBC 367	3	26.8	S	S	R	S	S	S	12	92
7	PBC 368	14	7.8	H (42)	H (61)	R	S	S	S	44	100
8	PBC 404	14	60.4	H (57)	S	S	S	S	S	25	68
9	PBC 497	93	25.1	H (67)	S	R	R	R	S	67	100
10	PBC 556B	59	16.6	H (58)	S	S	R	R	S	3	100
11	PBC 559	70	29.5	H (83)	S	R	R	R	S	0	100
12	PBC 585	7	27.2	H (33)	H (16)	R	S	S	S	61	96
13	PBC 586	24	20.5	H (83)	H (36)	R	S	S	S	70	92
14	PBC 601	6	39.5	H (57)	S	R	S	S	S	93	100
15	PBC 634	3	14.3	H (33)	H (28)	H (82)	S	S	S	69	96
16	PBC 714	88	8.2	S	S	R	S	S	S	96	0
17	PBC 739	9	23.2	H (53)	H (68)	R	S	S	S	51	87
18	PBC 972	1	7.6	H (63)	S	R	S	S	S	8	100
19	PBC 973	0	10.9	H (83)	S	H (45)	S	S	S	50	100
20	PP921206	6	80.1	H (66)	S	H (15)	S	S	S	87	100

[a] H(25) means the entry was heterogeneous and 25% of the plants tested were susceptible; R means all plants tested were resistant, and S means all plants tested were susceptible.

[b] Numbers refer to % susceptible plants.

Management of major insect pests and diseases

Identification of sources of resistance to broad mites

The broad mite, *Polyphagotarsonemus latus*, is a destructive pest of chili pepper throughout Asia. Its nymphs and adults suck the sap from young succulent leaves, and as a result, the leaves become crinkled and eventually wither. Loss of buds and leaves leads to stunted growth, and delayed flower and fruit production, which can result in drastic yield loss. At present farmers use large quantities of chemical pesticides to combat this pest, which leads to increased cost of production and environmental pollution.

In 1996, resistance screening of the AVRDC germplasm collection was initiated. Six seedlings per accession were placed in individual pots in a greenhouse room where the temperature was maintained at 26–30°C and where a few broad mite-infested chili pepper plants were maintained as infestation source. The mites readily migrated from infested plants to the young leaves of the test accessions. The plants were observed weekly and damage was assessed on a scale of 0 to 5, where 0 = no symptom of broad mite damage on any leaves; 1 = bronzing followed by crinkling of freshly emerged leaves; 2 = crinkling of new leaves followed by crinkling and elongation of older leaves; 3 = symptoms of necrosis on the growing point and dropping of old leaves; 4 = heavy necrosis of growing point; and 5 = heavy necrosis of the growing point and defoliation of infested plants.

Three batches of germplasm were screened. Each batch was evaluated for damage three or four times and the observation which had the highest average damage rating was used to assess the resistance. The ratings were subjected to a statistical analysis based on mean ($\bar{x}$) damage rating and standard deviation (SD). Accessions with damage rating of less than $\bar{x}$ – 2SD were rated as highly resistant; those between $\bar{x}$ – 1SD and $\bar{x}$ – 2SD, as moderately resistant; those between $\bar{x}$ and $\bar{x}$ – 1SD, possessing low level of resistance; those between $\bar{x}$ and $\bar{x}$ + 2SD, susceptible; and those that had a rating of more than $\bar{x}$ + 2SD, highly susceptible.

From the first batch of 123 accessions three highly resistant accessions (PBC 115, 116, and 117) with a damage rating of 0.8, 1.0, and 1.0, respectively, and three moderately resistant accessions (PBC 85, 118, 164) with ratings of 1.2, 1.3, and 1.3 were obtained.

From the second batch of 54 accessions, three (PBC 288, 292, 323) were rated as highly resistant with damage ratings of 1.0, 1.8, and 1.8, respectively.

The third batch of 150 accessions suffered excessive damage from broad mite infestation. Although nine accessions were classified as highly resistant, their overall damage ratings were considerably higher than those of the other two batches. The damage ratings of the least damaged accessions of this batch (PBC 629, PBC 648, and PBC 660) were 2.3, 1.6, and 2.4, respectively. The damage rating of susceptible entries was 5.0.

The most promising entries selected from these screenings will be reevaluated in replicated tests to confirm their resistance and characterize the resistance mechanism.

Resistance screening and characterization of bacterial wilt in peppers

A total of 17 pepper lines resistant to bacterial wilt were selected from previous seedling screening trials. The stability of the bacterial wilt resistance was evaluated by three methods: (1) seedling screening in a growth room at 28°C (GR); (2) field screening at AVRDC by transplanting inoculated seedlings (AVRDC); and (3) field screening in a naturally infested field at Taiwan Seed Improvement and Propagation Service, Taichung (TSS). Symptoms other than wilting, such as necrosis on leaves, yellowing, and defoliation, were observed in most of the entries tested. Data on percentage of wilted plants at the end of the trials enabled differentiation among the entries. The % wilt means were 21, 15, and 11 and the final % wilt of C 00835, the susceptible check, were 100, 100, and 85 for GR, AVRDC, and the TSS trials, respectively. Thus, the disease pressure was lower in the naturally infested field at TSS. Based on combined analysis of variance, the variables of entry and trial are significant, but not the interaction.

Among the entries tested, only PBC 385 did not show symptoms in the three trials (table 4). Isolation of the pathogen from the collar or lower part of the stem was attempted for nine resistant entries (PBC 375, PBC 384, PBC 385, PBC 473, PBC 535, and PBC 631) at the end of each trial. *Ralstonia solanacearum* was isolated only from six of the nine selected lines, i.e., PBC 066, PBC 204, and PBC 1347. Colonization was 61 to 100%, 60 to 100%, and 0 to 39% for the GR, AVRDC, and TSS trials, respectively.

Application of DNA probes and primers for the detection of *Xanthomonas campestris* pv. *vesicatoria (Xcv)*

To determine the efficiency of seed transmission of Xcv, seedlings of Early Calwonder (ECW) were planted under three environments: (1) sowing in vermiculite and placing them in the growth room at 28°C with overhead water sprinkling for 30 sec every 3 h; (2) raising seedlings in flats in the greenhouse and moving them outdoors 3 weeks after sowing (29 August); and (3) raising seedlings in the greenhouse and transplanting to the field 3 weeks after sowing. Four seed lots were used in this experiment: ECW-C (harvested from healthy plants), ECW-1 (seeds of ECW-C coated with 10^3 cfu/g seeds), ECW-2 (seeds of ECW-C coated with 5×10^5 cfu/g seeds), and ECW-SH3 (harvested from fruits showing bacterial spot symptoms on 3 to 6% of the fruit surface). Coating of the ECW-1 and ECW-2 seed with bacteria was done using an Xcv suspension in 1% carboxymethyl cellulose.

Table 4. Mean % wilt of pepper entries evaluated for bacterial wilt reaction in 2 field trials and 1 growth room trial, 1996

Code	Variety name	Origin	Type	% wilt	LSD
Susceptible ck	C 00835	Hungary	Wax	96.0[a]	a[a]
PBC 650	Sinagtala	Philippines	Sweet	39.4	b
PBC 1350	KingGumGoChu	Korea	Chili	36.9	bc
PBC 404	PL-38475	Nigeria	Chili	36.4	bc
PBC 717	Sheetal-51	India	Chili	30.5	bcd
PBC 495	Perennial	India	Chili	26.7	cd
PBC 518	PSP-11	India	Chili	21.4	d
PBC 067	MC 5	Malaysia	Chili	6.9	ef
PBC 1347	R1-26(17)	Malaysia	Chili	6.1	e
Resistant ck	MC4	Malaysia	Chili	3.6	efg
PBC 384		Malaysia	Chili	3.4	efg
PBC 743	Chinda 2	Thailand	Chili	2.7	efg
PBC 473		Indonesia	Chili	1.6	efg
PBC 204	Cili Langkap	Malaysia	Chili	1.6	efg
PBC 066	MC 4	Malaysia	Chili	1.6	efg
PBC 375	Paris Minyak	Indonesia	Chili	1.1	fg
PBC 535	IR	Indonesia	Chili	1.1	fg
PBC 631	CA 8	Sri Lanka	Sweet	0.9	efg
PBC 385		Malaysia	Chili	0.0	g

[a] Wilt % means are actual values. Analysis of variance and mean separation were done using transformed data by arcsin of the square root. Ranking of wilt % means and the transformed data was different.

Contamination with Xcv did not affect the germination percentage. No symptoms were observed in the outdoor and field trials from 29 August to 15 October (table 5). In the growth room where the environment was most conducive to infection, symptoms were observed on seedlings of ECW-1 (7% incidence) and ECW-2 (19% incidence), but not on seedlings of ECW-SH3.

Three seed treatments reported in the literature for eradicating Xcv from tomato and pepper seeds were compared: (1) fermentation in 1.3% (v/v) acetic acid for 4 h; (2) soaking in 1.25% Clorox for 10 min; and (3) fermentation followed by Clorox treatment. Germination of ECW seeds was not affected by any of these treatments. Based on PCR detection, the three treatments were shown to eradicate Xcv on seed lots ECW-SH3, but not on ECW-1 or ECW-2. Since the population of Xcv present in naturally contaminated seed lots is similar to that in ECW-SH3, these treatments can be recommended for practical use.

Table 5. Incidence of bacterial spot on pepper seedlings grown from seed lots contaminated with *Xanthomonas campestris* pv. *vesicatoria* (Xcv) under infection-conducive environment

Seed lot[a]	Germination	Xcv[b]	PCR[c]	Disease[d]
ECW-C	91%	0	-	0
ECW-1	97%	10^3	+	7%
ECW-2	92%	5×10^5	+	19%
ECW-SH3	not tested	0	+	0

[a] Seed of Early Calwonder (ECW) were harvested from fruit of healthy plants (ECW-C) and from fruit showing symptoms on 3 to 6% of the fruit surface (ECW-SH3). Seed lots of ECW-1 and ECW-2 were prepared by coating seeds of ECW-C with Xcv in 1% carboxymethyl cellulose.

[b] Amount of Xcv (cfu/g seeds) determined by plating seed extracts of ECW-C, ECW-1, and ECW-2 on 523 medium; seed extract of ECW-SH3 was plated on Tween B medium.

[c] Detection of Xcv was conducted by amplification of seed extracts with the primer pair RST 9 and RST 10, which is specific for Xcv strains of the A group.

[d] Disease incidence was recorded at 20 DAS in the growth room at 28°C with water sprinkling for 30 sec every 3 h.

Screening for resistance to viruses

Routine resistance screening was conducted for CMV, CVMV, PVY, ToMV/TMV, and PMMV. Of a total 379 entries screened, 4 lines with CMV resistance (PBC 621, 534, 323, 634), 6 lines with CVMV resistance (PBC 146, 450, 371, 518, 365, VC 183a), 22 lines with PVY resistance (PBC 323, 316, 367, 368, 497, 559, 585, 586, 601, 714, 739, 972, 206, 345, VC 6a, 8a, 12a, 15a, 25a, 31a, 43a, 214a), and 11 lines with TMV/ToMV resistance (PBC 323, 497, 556B, 559, VC 13a, 15a, 60a, 100a, 175a, 178a, 182a) were identified. The resistance of these lines will be confirmed.

The resistance to CVMV of 22 selections (C 00265, C 01509, C 01664, VC 16a, 40a, 41a, 33a, 36a, 208, 58a, Taiwan 83-168, Huareua Ubon, Chau Maukau, I-13-4-1, PBC 522, 521, 122, 149A, 370, 524, 523, 142A) screened previously was confirmed.

Similarly the resistance of 12 CMV-resistant selections (VC 41a, VC 16a, VC 185, Hybrid Huareua, PBC 370, 549, 521, 569, 463, Punjab Guch Hadar, Punjab Surkh, VR 53-3/93 S-1) screened previously was also confirmed.

Thus, sufficient sources of resistance to the major pepper viruses are now available for improvement purpose. In most lines the resistance has been fixed. Heterogeneity of the accessions and outcrossing has been a major problem in fixing resistance in the past. However, with careful controlled self-pollination outcrossing could be minimized. Since strains of CMV as well as CVMV have been reported, it is important to subject these resistant lines to multilocational screening.

Two *Capsicum chinense* lines (PI 152225 and PI 159236) have been reported to be resistant to tomato spotted wilt tospovirus. However, only PI 152225 was found resistant to the Taiwan WSMV tospovirus.

Host resistance to phytophthora blight

Phytophthora blight (PB) of pepper, caused by *Phytophthora capsici*, has a wide geographic distribution. It is associated with warm wet periods in high rainfall areas and with irrigation water in arid areas. Thus, it is a problem in diverse agroecosystems. Pepper lines with varying levels of resistance have been reported, but high levels of resistance have not been incorporated into many useful varieties. Inheritance of resistance has not been clearly established. The objectives of this study were (1) to evaluate entries in the ICPN 6 for their PB reactions, (2) to reevaluate resistant lines with apparent *P. capsici* pathotypes, and (3) to assay breeding populations for their PB reactions.

To assess the phytophthora blight reactions, 30-day-old plants were inoculated by pipetting 5 ml of a zoospore (5×10^4/ml) suspension from *P. capsici* cultures into the potting medium at the base of each plant. Disease severity ratings were made at 7, 14, and 21 DAI, and the percentage of surviving plants recorded at 21 DAI.

Twenty pepper entries in ICPN 6 were evaluated in the greenhouse for their phytophthora blight reactions by inoculation with the highly virulent isolate, Pc-17E. One entry, PBC 714, a selection from PI 201234, a known resistance source, was completely resistant (table 6). Three other entries, PBC 404, 142A, and 739, showed low levels of resistance with 32, 21, and 13% survival, respectively. The survival rate among other entries ranged from 0 to 8%.

Pepper accessions Blue Star and PBC 137 were shown previously to serve as differential hosts for some *P. capsici* isolates. More recently single zoospore subcultures of isolates Pc-17 and Pc-33 designated as Pc-17E and Pc-33E, respectively, were found to be highly virulent to Blue Star and PBC 137. Furthermore, isolate Pc-17E was also highly

Table 6. Phytophthora blight reactions[a] of entries in the ICPN 6 to isolate Pc-17E of *Phytophthora capsici*

Entry	Name	Origin	Survival (%)[b]	DSR[c]
PBC 714	PI 201234 Selection	Mexico	100	0.0a[d]
PBC 404	Var. PL-38475	Nigeria	32	2.6b
PBC 142A	Pant C-1	India	21	3.0b
PBC 739	Luang 8	Thailand	13	3.6c
PBC 367	PBC 367	Sri Lanka	8	3.7c
PBC 586	PBC 586	Thailand	8	3.7c
PBC 585	PBC 585	Thailand	4	3.8c
PBC 634	Wanni Miris 01013	Sri Lanka	4	3.8c
PBC 206C	PI 152225	Peru	0	4.0c
PBC 316	PI 163201	India	0	4.0c
PBC 364	PBC 364	Italy	0	4.0c
PBC 368	PBC 368	Indonesia	0	4.0c
PBC 479	Serrano 1534	Mexico	0	4.0c
PBC 556B	MC-003	USA	0	4.0c
PBC 559	Tabasco L-167	USA	0	4.0c
PBC 601	PBC 601	Taiwan	0	4.0c
PBC 972	Kulai	Malaysia	0	4.0c
PBC 973	Chilli Cabai	China	0	4.0c
PP 921206	Szechwan 1 Selection	Taiwan/AVRDC	0	4.0c
PBC 137	CNPH 703	Brazil	0	4.0c
PBC 178	PI 201234 (R ck)	Mexico	100	0.0a
Commercial F_1	Blue Star (S ck)	Taiwan	0	4.0c

[a] Inoculated 35 days after sowing with 5 ml/plant of a 5×10^4 zoospores/ml suspension. Results based on 24 plants, 4 replications of 6 plants for each line.

[b] Survival was based on the percentage of plants with no symptoms 21 days after inoculation.

[c] Disease severity rating: 0 = no symptoms and 4 = dead plant.

[d] Mean separation by the DMRT; numbers followed by the same letter are not significantly different at $P < 0.05$.

virulent to PBC 602, but isolate Pc-33E was weakly virulent to this accession, suggesting that PBC 602 may serve as a differential host for these two isolates. Studies to date suggest that field isolates of *P. capsici* may be mixtures of pathotypes and that partially resistant pepper lines may be heterogenous for the resistance trait. Single zoospore isolates are being made to obtain isolates that represent a single pathotype. Resistant plants from partially resistant lines are being selected to develop lines that are homogenous in their response to the pathotypes.

Studies were conducted using isolates Pc-1E and Pc-17E, which appear to represent two distinct pathotypes, to reevaluate previously reported sources of phytophthora blight resistance. Most of the sources were highly resistant to Pc-1E, but only two, PI 201234 and Criollo de Morelos 331, were highly resistant to Pc-17E. Seven lines showed various levels of intermediate resistance to Pc-17E. Surviving plants from some of the more resistant lines in the intermediate category were saved for seed increase to determine if the resistance level can be increased through selection.

Phytophthora blight reactions were determined for 22 F_6 hot pepper lines that were developed by using four different resistant parents. All of the F_6 lines showed some resistance, ranging from 17 to 100% survival, following inoculation with isolate Pc-17. A single line, CCA 285R, which was not derived from a resistant parent, had only 4% survival in the test. These results show definite progress in introgressing phytophthora blight resistance into advanced AVRDC lines.

Host resistance to anthracnose of pepper

Anthracnose, caused by *Colletotrichum gloeosporioides* and *C. capsici*, occurs worldwide wherever pepper is grown under overhead or rainfed conditions. It occurs as a pre- or postharvest fruit rot causing extensive losses in pepper grown during the warm, wet season in tropical and subtropical climates. No resistant varieties are known, and identifying resistant sources has proven to be a difficult task. The objectives of this study were (1) to assess the anthracnose reactions of entries in ICPN 6 based on incidence of diseased fruit in the field and (2) to reevaluate the field reactions of previously reported anthracnose-resistant pepper lines.

Field evaluation of ICPN 6 entries. Twenty entries in ICPN 6 were evaluated for their anthracnose reactions based on mean incidence of affected fruit over three harvests. The percentage of fruit showing anthracnose symptoms at harvest ranged from 0.2 to 96% among entries (table 7). Tabasco L-167, MC-003 (a Tabasco selection), Kulai, and PBC 367 with 0.2, 2.5, 8.0, and 11.6% diseased fruit, respectively, had a significantly ($P < 0.05$) lower percentage of fruit affected than all other entries. PBC 404 which ranked next with 25% had a significantly lower percentage of diseased fruit than the remaining entries.

Field evaluation of reported resistant pepper lines. Nineteen pepper lines previously rated resistant, three lines rated intermediate, and four lines rated susceptible were evaluated for their anthracnose reactions based on mean incidence of affected fruit over four harvests. The percentage of fruit showing anthracnose symptoms at the time of harvest ranged from 1 to 92% among all entries (table 8). Tabasco L-167 (PBC 559) and *C. baccatum* pen. 3-4 (PBC 1351) with 1 and 8% diseased fruit, respectively, had a significantly ($P < 0.05$) lower percentage of fruit affected than all other entries. The next four entries in rank order were Chinda 2 (PBC 743) with 30%, Prapadaeng (PBC 613) with 37%, PBC 582 with 37%, and Banglen (PBC 612) with 41% affected fruit at the time of harvest. Entries previously rated as susceptible or with intermediate resistance had ratings ranging from 70 to 92% affected fruit in this study, placing them among the lines with the highest incidence of affected fruit.

Table 7. Incidence of anthracnose-affected pepper fruit among ICPN 6 entries in a field trial at AVRDC, summer 1996[a]

Entry	Name/Origin	Fruit with anthracnose symptoms[b] (%)			Mean[c]
		18 Sept.	9 Oct.	29 Oct.	
PBC 559	Tabasco L-167/Mexico/USA	0.6	0.1	0.0	0.2a
PBC 556B	MC-003 (Tab.)/Mexico/USA	4.3	1.1	2.2	2.5a
PBC 972	Kulai/Malaysia	12.5	5.9	5.5	8.0a
PBC 367	PBC 367/Sri Lanka	22.3	5.9	6.5	11.6a
PBC 404	Var. PL-38475/Nigeria	42.2	9.1	24.3	25.2b
PBC 368	PBC 368/Indonesia	83.6	23.2	24.3	43.7c
PBC 973	Chilli Cabai/China	90.7	25.3	32.9	49.6c
PBC 739	Luang 8/Thailand	66.8	47.6	37.0	50.5c
PBC 585	PBC 585/Thailand	90.3	20.5	72.4	61.1d
PBC 137	CNPH 703/India/Brazil	96.1	59.1	49.9	68.4d
PBC 634	Wanni Miris 01013/Sri Lanka	86.0	34.3	85.8	68.7d
PBC 586	PBC 586/Thailand	95.8	39.0	75.2	70.0de
PBC 364	PBC 364/Italy	86.4	64.4	95.6	82.1ef
PBC 142A	Pant C-1/India	85.1	70.0	98.0	84.4f
PP 921206	Szechwan 1 sel./Taiwan	97.1	73.2	89.9	86.7f
PBC 316	PI 163201/India	98.3	62.9	99.4	86.9f
PBC 601	PBC 601/Taiwan	96.6	91.9	91.6	93.4f
PBC 714	PI 201234 sel./Mexico	96.9	91.2	100.0	96.0f
PBC 206C	PI 152225/Peru	-	27.3	100.0	63.7[d]
PBC 497	Serrano 1534/Mexico	89.4	13.8	98.1	67.1[d]

[a] Transplanted to the field 20 May; 20 plants per replication with 4 replications; Inoculated with *C. gloeosporioides*, isolate Cg-153 on 27 August.

[b] Harvests made on 18 September, 9 and 29 October were the 4th, 7th, and 10th harvests, respectively.

[c] Mean separation by DMRT, $P < 0.05$.

[d] Insufficient number of fruit for a valid statistical comparison with other lines.

Table 8. Incidence of anthracnose-affected pepper fruit among suspected resistant lines in a field trial, AVRDC, summer 1996[a]

Entry	Name/Origin	Previous disease reactions	Fruit with anthracnose symptoms[b] (%)				Means[c]
			19 Sept.	25 Sept.	23 Oct.	13 Nov.	
PBC 559	Tabasco L-167	R	0	1.9	0.4	1.5	1.0a
PBC 1351	C. bacc. p. 3-4	R	20.9	7.8	1.5	3.9	8.5a
PBC 743	Chinda 2	R	39.1	40.0	5.7	34.1	29.7b
PBC 613	Prapadaeng = C4	R	60.6	34.8	3.9	50.2	37.0bc
PBC 582	(Malaysia)	R	53.0	30.4	15.5	25.4	37.1bc
PBC 612	Banglen = C7	R	61.7	41.4	21.4	40.0	41.4bc
PBC 370	(Thailand)	R	64.7	61.4	24.8	51.6	50.6cd
PBC 495	Perennial HDV	R	52.3	68.2	22.0	60.7	50.8cd
PBC 151	IAC Ubatuba Cam.	R	96.8	41.3	53.2	67.1	57.1de
PBC 157	Huey Sithon	R	79.2	66.9	47.3	70.5	66.0def
PBC 371	(Thailand)	R	72.5	73.0	53.4	73.6	68.1efg
PBC 643	Athi Slim	R	81.5	56.0	54.6	81.3	68.4efg
PBC 636	Galkunda Miris	S	64.6	52.1	85.1	75.0	69.5efg
PBC 155	Huaruar	R	88.4	72.4	41.5	87.8	72.5efgh
PBC 148	Punjab Lal	R	77.3	68.0	63.0	83.1	72.8efgh
PBC 137	CNPH 703	I	96.3	91.6	54.1	78.3	77.8fghi
PBC 365	PBC 365	S	91.3	91.6	45.9	86.0	78.7fghi
PBC 417	Ca 87067	R	82.5	76.2	83.9	72.2	79.5fghi
PBC 142	Pant C-1	I	87.9	73.2	83.5	94.2	84.0ghi
PBC 156	KKU Cluster	R	91.8	86.0	68.8	91.4	84.5ghi
PBC 067	MC 5	R	87.9	76.5	83.5	92.9	85.2ghi
PBC 074	Szechwan 8	I	96.7	87.2	75.0	94.4	88.3hi
PBC 651	Chili Hybrid - 1	R	97.0	74.0	89.9	92.5	88.3hi
PBC 717	Sheetal-51	S	98.9	94.1	49.8	95.6	89.6hi
PBC 679-1	Caliente	R	95.9	82.5	92.4	98.3	92.1i
PBC 602	Szechwan type	S	91.6	84.8	94.9	96.0	92.4i

[a] Transplanted to the field 13 June; 20 plants per replication with 4 replications; inoculated with *C. gloeosporioides*, isolate Cg-153, on 27 August.

[b] Harvests shown were the 2nd, 3rd, 7th, and 10th, respectively.

[c] Mean separation by DMRT, $P < 0.05$.

Strategic and/or supporting studies

Genetics of resistance to major pepper diseases

In the CVMV backcrossing activity, segregation ratios of R x S varied widely, indicating that more than a single dominant gene was involved and/or that some of the recurrent parents were already resistant to CVMV. Therefore, to confirm the single dominant gene hypothesis, two sets of 100 F_3 families (14 plants/family) from Perennial/Cheongryong (CCA 369) and Cheongryong/PSP 11 (CCA 372) and 100 F_2 plants from a third R x S cross [PI 201234/Perennial (CCA 298)] were grown in the greenhouse and inoculated twice with CVMV, followed by two ELISA tests.

In the F_2 population segregating for CVMV resistance, the ratio was 79 R:26 S, which fits the single dominant gene hypothesis, but the results for the F_3 families showed that resistance to CVMV is more complicated than previously thought. Previous results from F_2 plants from these populations indicated that in CCA 369 one dominant gene and in CCA 372 one dominant and one recessive gene were involved (AVRDC 1995 Report). In the F_3 families from CCA 369, 74% of the plants were susceptible, and only 26% were resistant, exactly the opposite of what was expected (75% resistant: 25% susceptible, if one dominant gene is involved).

In the F_3 families from CCA 372, 95% of the plants were susceptible, and only 5% were resistant, again opposite to what was expected (81% resistant: 19% susceptible, if one dominant and one recessive gene are involved). In many cases F_2 plants rated as resistant gave all susceptible F_3 plants. This indicated that something else was involved, perhaps temperature-sensitive resistance. A growth chamber study was carried out to test this hypothesis.

Sixteen F_3 families (eight each from CCA 369 and CCA 372) were grown in a growth chamber at 24 and 32°C to test for temperature-sensitive inheritance. In the F_3 families from CCA 369 and CCA 372, 74 and 95% of the plants were susceptible, respectively, while 26 and 5%, respectively, were resistant. The test revealed that two F_3 families from CCA 372 appear to have temperature-sensitive resistance; they are susceptible at 24°C and resistant at 32°C. This type of temperature-sensitive resistance has never been reported in pepper and needs to be confirmed. More families from CCA 369 and CCA 372 will be tested.

For the bacterial spot (BS) genetic study utilizing Nacional AG-506/CNPH 703 recombinant inbred lines (CCA 250), three replications of each recombinant inbred line (RIL) plus parents and checks were screened under controlled temperature and humidity conditions. However, one replication suffered severe thrips damage and had to be repeated in the fall season. A set of 46 RILs was chosen to develop a rough genetic map and identify RAPD primers with roughly even distribution along the 12 pepper chromosomes. RAPD genotyping of these 46 RILs was begun by cooperators in the National Taiwan University in Taipei and University of Wisconsin in Madison. Once the final map is made, it will be compared to the BS reactions of the RILs and the number and location of genes responsible for BS resistance in this cross will be determined.

AVNET support

Virus strain detection, characterization, and antiserum production

Eleven new CVMV isolates collected from peppers throughout Taiwan were tested on 12 pepper lines resistant to the CVMV common isolate P-1037: VC 16a, 33a, 34a, 35a, 36a, 37a, 41a, 160a, 206a, 208a, 221a, and C 00265. All 12 pepper lines showed the same resistant reaction, indicating that the 11 new CVMV isolates from Taiwan may all belong to the same strain.

Thirty isolates of PVY previously collected from peppers in different areas of Taiwan were pathotyped on eight differential *Capsicum* sp. hosts (*C. annuum* Yolo Wonder, Bastidon, Perennial, Serrano Vera Cruz, Delray Belle, Yolo Y, Florida VR-2, and *C. chinense* Miscucho). All produced the same phenotypic reactions typical of pathotype 0. Thus, there appears to be only one pathotype in Taiwan.

A set of nine lines with confirmed resistance to CMV at AVRDC was prepared for international testing. One set was sent to Thailand for testing with five local CMV isolates. One line, PBC 569, was immune to three CMV isolates (CMV5011B, CMV1, CMV8) and heterogeneous to the three others (table 9). Three lines (VC 41a, PBC 370, PBC 521) were immune to isolate CMV 1. Another line (VC 40a) was immune to isolate CMV30RS. Although none of the lines was immune to all five Thai CMV isolates, six (VC 16a, VC 41a, PBC 370, PBC 521, PBC 549, and I-13-1) had a high percentage of resistant individuals upon inoculation with each of the individual strains (from 50 to 96%, 84 to 100%, 56 to 100%, 64 to 100%, 80 to 92%, 64 to 92%, respectively). It should, thus, be possible to purify the CMV resistance in these lines by several cycles of CMV inoculation, preferably with mixed strains followed by collection of seed of resistant plants. Similarly, a set of 11 confirmed CVMV-resistant lines has been developed for international testing.

Temperature did not seem to have any effect on CMV infection,but CVMV was affected by temperature (table 10). CVMV infection was higher at 26°C than at 32°C. To obtain consistent and reproducible results, CVMV resistance screening or genetic studies should not be conducted at temperatures above 26°C.

Table 9. Reaction (% infection) of Thai CMV isolates on a set of CMV-resistant pepper lines[a]

Line	30 RS	5011 B	15 PJ	1 CM	8 KB	Average
VC 16a	4	52	8	16	16	19
VC 40a	0	40	84	4	24	30
VC 41a	4	16	8	**0**	8	7
PBC 370	4	16	44	**0**	4	14
PBC 521	12	8	40	**0**	16	15
PBC 549	8	20	12	12	8	12
PBC 569	64	**0**	52	**0**	**0**	23
I-13-1	8	32	8	28	36	32
P-3-1	76	52	12	16	4	32
Hybrid Huareua[b]	92	28	28	4	56	42

[a] 25 plants were mechanically inoculated at seedling stage with the respective isolates and kept in an insect-proof screenhouse. Testing was by ELISA.
[b] Best virus-resistant local check.

Table 10. Effect of temperature on CMV and CVMV[a]

Plant stage	26°C			32°C		
at inoculation	E_1	E_2	E_3	E_1	E_2	E_3
CMV						
cotyledon	76	88	94	62	81	79
2nd leaf	38	97	100	100	100	100
3rd leaf	49	100	100	100	100	100
5th leaf	100	100	100	100	100	100
CVMV						
cotyledon	27	76	100	0	9	11
2nd leaf	83	88	100	31	47	53
3rd leaf	91	100	100	34	66	75
5th leaf	97	100	100	56	72	81

[a] Plant age at inoculation: cotyledon, 2nd, 3rd and 5th leaf inoculations were done at the same time; 36 plants were inoculated for each treatment. Plant variety: New Comer: susceptible to CMV and CVMV. Temperature: 26°C, 32°C, growth room. ELISA: 31 July, 1 week after inoculation (E_1); 5 August, 2 weeks after inoculation (E_2); 21 August, 4 weeks after inoculation (E_3).

Development of molecular markers for CVMV resistance

A DNA fragment previously identified as linked to CVMV resistance by RAPD technology was cloned. Linkage was verified by hybridization of the cloned fragment to Southern blots of F_2 individuals that segregated for the RAPD marker. Double-strand sequencing (Sequenase kit USB) was done by the dideoxy-chain termination method using the T3 and T7 primers.

Two sets of oligonucleotide sequences were designed (table 11) and a reciprocal test was conducted to choose the best combination for SCAR analysis. PCR amplification was done at 40 cycles for 1 min at 94°C, 1 min at 60°C, and 2 min at 72°C. Amplification products were resolved electrophoretically in a 2% agarose gel. Two hundred and forty F_2 individuals each from crosses of VC 16a x PBC 186 and VC 160 x PBC 186 were analyzed. Inheritance of the SCAR matched the expected ratio of 3 to 1 in both crosses (table 12).

The results of the SCAR analysis for 240 F_2 plants were compared with those of ELISA (table 13). The recombination in the F_2 generation of VC 160 x PBC 186 and VC 16a x PBC 186 was 22 and 26%. A previous study indicated that two genes may be involved in VC 160. The higher recombination ratio in VC 16a might be due to the interaction between the two genes involved. Although linkage of the SCAR with ELISA data is only 74%, a clear linkage of the SCAR defined by primers A72/A32 with the RFLP probe TG232 and some AFLP markers in linkage group 6 was demonstrated by collaborators at Cornell University.

The cloned RAPD fragment (2.0 kb) was sequenced for at least 200 bp from each end. To exclude dimer formation and nonspecific binding, two sequences were designed from each end containing the RAPD primer (UBC813) sequence and 30 to 40 bp downstream of RAPD primer sequence (table 11). Reciprocal tests suggested that the two best primer combinations were A7/A32, which generated a single band at 1.9 kb, and A72/A32, which produced a specific 1.9 kb band and an extra band at 0.38 kb (fig. 1).

Table 11. Primer sequence designed for detection of SCAR

Primer	Sequence	Start of sequence
A7[a]	TCTCTTTATATATGTGTGTATGTG	3' end of UBC813
A72[a]	TATTGCTGGAACCCTTGGA	14 bp downstream of A7
A3[b]	TTCATGATTAAAAAACTTTTC	3' end of UBC813
A32[b]	GGACCCTGCCAACTCAACT	44 bp downstream of A3

[a] Sequencing with the T7 primer.
[b] Sequencing with the T3 primer.

Table 12. Segregation of SCAR in the F_2 generation

	Observed	Expected	Chi-square	P value	Expected ratio
VC 16a x PBC 186					
SCAR	175	180			
No SCAR	65	60	0.56	0.45	3:1
Total	240	240			
VC 160 x PBC 186					
SCAR	171	175.5			
No SCAR	63	58.5	0.46	0.5	3:1
Total	234	234			

Table 13. Correlation of SCAR with ELISA data

ELISA	SCAR	VC 16a x PBC 186		VC 160 x PBC 186	
		obs no.	obs %	obs no.	obs %
-	+	149	62.1	145	62.0
+	+	26	10.8	26	11.1
-	-	37	15.4	26	11.1
+	-	28	11.7	37	15.8
Total		240		234	

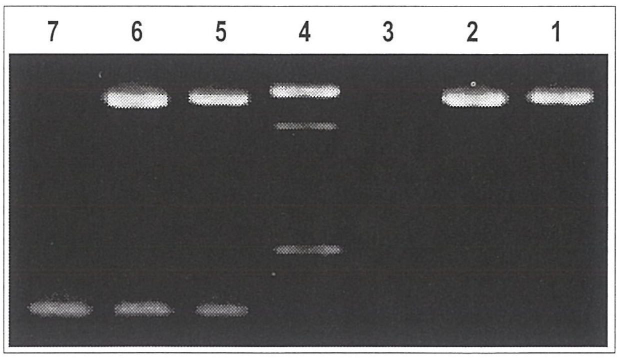

Fig. 1. Amplification of genomic DNA of 3 pepper parents with 2 sets of SCAR primers
Lanes 1 to 3: VC 16a, VC 160, and PBC 186 amplified with the A7/A32 primer set; lane 4: 100 bp ladder; lanes 5-7: VC 16a, VC 160, and PBC 186 amplified with the A72/A32 primer set

Tomato Improvement

The general objective of the tomato improvement project is to increase year-round tomato supply in tropical countries, focusing on development of tomato lines adapted to high temperatures and humidities. Consequently, high temperature fruit-set, bacterial wilt, fusarium wilt, and geminivirus resistances, as well as good fruit qualities are the major specific objectives.

In 1994–95, eight preliminary yield trials were conducted for fresh market, cherry, and processing tomato. Promising entries for each tomato type were selected for further evaluation of yield and other horticultural characteristics, including resistance to bacterial wilt.

A study to determine seasonal variation in marketable yield in the Philippines and Thailand was conducted using 22 determinate tomato inbreds. Results showed that mean dry season marketable yield over locations was about three times greater than the mean summer marketable yield over locations. Hence, development of varieties suitable for the dry season and summer tomato production is possible. Several small-fruited entries performed relatively well in both seasons.

L 123 was confirmed tolerant to flooding in a greenhouse experiment. Molecular markers are being developed to assist breeding for resistance to tomato leaf curl virus (TLCV), CMV, and PVY. Resistance to these three viruses has been identified in wild tomatoes. The chitinase gene from fungi inhibitory bacteria was successfully cloned.

AVRDC continued to provide support to its networks through a survey on the occurrence of geminiviruses on tomato and pepper. The presence of a geminivirus was confirmed on tomato in Tanzania and India, and tomato and pepper in Nepal, Pakistan, and Thailand. In screening for TLCV resistance, TyKing, a commercial F_1 hybrid previously found resistant showed a high level of resistance after exposure to viruliferous whiteflies.

Tomato accessions were scored for their reactions to black leaf mold (BLM), late blight, and fusarium wilt. Two accessions were identified as BLM-resistant and four as moderately resistant; 36 were resistant to fusarium wilt race 1 and 27 to races 1 and 2; *L. hirsutum* accessions L 3683, L 3684 and *L. pimpinellifolium* accessions L 3707 and 3708 remain resistant to late blight.

This year considerable progress was made towards development of medium-large fruited fresh market tomato lines with high bacterial wilt resistance levels. The association of small fruit size and bacterial wilt resistance has been a difficult problem in the past. The release of CHT 154 in Taiwan this year as ASVEG #6 was significant in that this variety was the first AVRDC cherry tomato released by a national program. Major progress was achieved towards introgression of late blight resistance into tomato and determining the inheritance of resistance. Progress was also made towards evaluation of the effectiveness of gene constructs conditioning resistances to cucumber mosaic virus, tospovirus, or fusarium wilt. Gene constructs offer the potential to overcome intractable problems and enrich tomato genetic diversity.

Genetic resources enhancement and varietal improvement

Genetic resources activities

A total of 38 accessions were acquired in 1996 bringing the total in the tomato collection to 6944 (table 1).

Table 1. AVRDC tomato germplasm collection, 1996

Species	No. of accessions
L. esculentum	5,070
L. pimpinellifolium	312
L. peruvianum	126
L. hirsutum	65
L. pennellii	60
L. chilense	30
L. cheesmanii	26
L. parviflorum	12
L. glandulosum	11
L. chmielewskii	11
L. sp.	1,221
Total	6,944

Seventeen accessions of *L. esculentum*, two each of *L. esculentum* var. *cerasiforme* and *L. peruvianum*, one each of *L. chilense*, *L. hirsutum* f. *glabratum*, *L. parviflorum*, *L. pennellii*, and *L. pimpinellifolium*, were planted for regeneration in 1995–96. The majority carried resistances to fusarium wilt and late blight. One accession of *L. peruvianum* (TL 1172) did not produce seed. To date, excluding duplicates, 3596 accessions (52%) have been regenerated.

The materials obtained were characterized based on a standard set of descriptors. Eight accessions suspected to be misidentified as to species or name were planted for verification. Seeds from different sources were obtained and putatively similar accessions were planted side by side for comparison. To date excluding duplicates, 3425 accessions (49%) have been fully characterized.

About 3259 accessions (47%) are in the base collection maintained in the long-term store.

The Center sent out 2717 samples to 67 countries and territories. Center scientists used tomato germplasm for studies on grafting compatibility and as rootstocks for bacterial wilt resistance, tomato late blight and black leaf mold resistance evaluation, screening for bacterial wilt and tomato yellow leaf curl virus (TYLCV).

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

Genetic improvement of fresh market tomato

Fresh market tomato (FM) tomato is the most important market type in tropical countries. AVRDC seeks to improve year-round FM production in the tropics by developing heat-tolerant, bacterial-wilt (BW) resistant lines and hybrids with excellent fruit qualities. In 1995–96, two advanced yield trials (AYT) and two preliminary yield trials (PYT) of FM tomato inbreds and hybrids were conducted. Entry types, and dates of sowing, transplanting, and harvest of FM trials are given in table 2.

Advanced yield trials were arranged in RCBD with three replications. Plots consisted of four 4.8-m-long rows on two raised beds (2 rows/bed); between and within-row spacing 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.

PYT I plots were identical to those of the AYT except that one bed with two rows was used and the replication number was two. Plants in AYT I and II and PYT I were pruned. Plots of PYT II consisted of two 4.8-m-long beds with one row/bed. Fruit were harvested from the inner 4 m of each row and yield per plot was determined from a 12-m^2 area in AYTs and 6 m^2 in PYT.

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 all trials were side-dressed at 10 days (20-0-30 N-P_2O_5-K_2O), 21 days (60-20-60 N-P_2O_5-K_2O), 42 days (60-20-30 N-P-K), and 63 days (60-20-30 N-P_2O_5-K_2O) after transplanting.

Table 2. Entry types and dates of sowing, transplanting, and harvest of AVRDC tomato trials, 1995–96

Type	Trial dates	Entry type	Entry no.	Sowing	Transplanting	Harvest
FM	AYT I	Indet. hybrids	6	16 Aug. 95	14 Sept. 95	23 Nov. 95–3 Jan. 96
	AYT II	Indet. lines	12	25 June 96	23 July 96	1–29 Oct. 96
	PYT I	Det./Indet. lines	38	20 July 95	16 Aug. 95	9 Nov.–18 Dec. 95
	PYT II	Det. lines	32	3 July 96	8 Aug. 95	15 Oct. 95–6 Nov. 96
CH	AYT I	Indet. lines	10	16 Aug. 95	14 Sept. 95	23 Nov. 95–3 Jan. 96
	AYT II	Indet. lines	10	26 Nov. 95	14 Dec. 95	18 Mar.–28 Apr. 96
	PYT I	Indet. lines	22	20 July 95	16 Aug. 95	5 Oct.–7 Nov. 95
	PYT II	Semidet./Indet. hybrids	23	20 July 95	16 Aug. 95	3 Oct.–7 Nov. 95
PT	PYT I	Det. lines	15	26 Sept. 95	24 Oct. 95	12 Mar.–11 Apr. 96
	PYT II	Det. lines	12	26 Sept. 95	24 Oct. 95	12 Mar.–11 Apr. 96
	PYT III	Det. lines	18	26 Sept. 95	24 Oct. 95	12 Mar.–11 Apr. 96

AYT I. Entries were indeterminate hybrids with large, dark-green shouldered fruit desirable for the Taiwan fresh market. The intention is to identify candidates to replace AVRDC hybrid FMTT 22, which has been grown extensively in Taiwan since 1989. Yields of the experimental hybrids were similar to FMTT 22, but fruit sizes of FMTT 556 and FMTT 553 were larger and fruit shoulders were a more intense green compared to FMTT 22 (table 3). Bacterial wilt survival of hybrids in greenhouse tests ranged from 6 to 38%. The four experimental hybrids are undergoing regional testing in Taiwan.

AYT II. Trial entries were selections from crosses of AVRDC tropical tomato lines to large-fruited bacterial wilt-resistant lines from Guadeloupe. The goal is to identify heat-tolerant, bacterial wilt-resistant lines with moderately large fruit sizes. Three lines, CLN 1462A, CLN 1462B, and CLN 1463B, achieved yields and fruit sizes comparable to hybrid check FMTT 22, as well as moderately high bacterial wilt resistance levels. Seed of these lines are available for distribution.

PYT I. Objectives and crosses from which entries were derived are the same as described for AYT I. Two entries, CLN 1466M and CLN 1466K, yielded significantly more than the hybrid checks with fruit sizes similar to the checks. Seed of selected lines will be increased for international distribution in 1997.

PYT II. Trial entries were derived from crosses designed to improve heat tolerance and bacterial wilt resistance in tropical tomato types for lowland summer production.

Marketable yields of entries did not differ significantly from heat-tolerant check CL 5915-93D4-1-0-3 and fruit sizes ranged from small to medium. Most entries showed outstanding bacterial wilt resistance and will be targeted for areas with severe bacterial wilt problems.

Genetic improvement of cherry tomato

Although cherry tomato is not an important tomato market class in most tropical countries, it does have potential to become popular quickly, as has been the case in Japan, Korea, and Taiwan. Desirable characteristics of cherry varieties include small fruit size (< 30 g), high solids content, and good taste. During 1995–1996, four yield trials were conducted to identify promising cherry lines and hybrids for international distribution. Entry types and sowing, transplanting, and harvest dates of cherry trials are listed in table 2.

Two AYTs and two PYTs of cherry tomato entries were conducted at AVRDC during 1995–1996 to identify high-yielding inbreds with good fruit quality. Except for PYT II which included F_1 hybrids, trial entries were indeterminate inbreds. AVRDC cherry inbreds carry the prefix "CH" or "CLN" and hybrids are coded beginning with "CHT."

Table 3. **Horticultural and quality characteristics of selected fresh market tomato entries from AYT I-II and PYT I-II, AVRDC, 1995**

Trial	Entry	Mean yield (t/ha)	Fruit-set (%)	Fruit size (g)	Brix (%)	Acid (%)	Color (a/b)	pH	BW survival (%)
AYT I	FMTT 593	65	51	115	5.0	0.45	1.93	4.3	38
	FMTT 591	64	44	141	4.7	0.41	1.79	4.3	13
	FMTT 556	63	43	145	4.7	0.41	1.85	4.2	11
	FMTT 553	62	48	129	4.8	0.41	1.84	4.3	17
	FMTT 22 (ck)	60	49	103	5.0	0.39	1.83	4.2	15
	Ky 301 (ck)	26	36	141	5.2	0.44	1.79	4.4	6
	Mean of all entries	56	45	129	4.9	0.42	1.83	4.3	21
	CV %	10	15	11	4.0	10.27	7.30	1.7	-
	LSD (P = 0.05)	10	12	26	0.4	0.07	0.24	0.1	-
AYT II[a]	CLN 1462A	43	25	82	4.9	0.28	1.59	4.3	83
	CLN 1462B	42	32	80	4.8	0.27	1.52	4.3	71
	CLN 1463B	36	29	80	4.8	0.24	1.52	4.3	52
	FMTT 22 (ck)	43	30	79	4.8	0.30	1.61	4.3	52
	CL 5915-93D4-1-0-3 (ck)	58	29	27	5.6	0.46	1.51	4.2	29
	Mean of all entries	34	22	75	4.8	0.31	1.70	4.3	70
	CV %	18	29	6	12.0	9.93	7.91	1.4	14
	LSD (P = 0.05)	10	11	8	1.0	0.05	0.23	0.1	23
PYT I	CLN 1466M (Det)[b]	72	30	88	4.9	0.37	2.41	4.4	85
	CLN 1466K (Det)	71	36	117	4.7	0.37	2.31	4.3	88
	FMTT 574 (ID ck)	43	33	114	5.0	0.37	2.23	4.3	58
	FMTT 22 (ID ck)	50	28	100	4.6	0.38	2.02	4.2	52
	Mean of all entries	46	30	107	4.5	0.35	2.06	4.2	76
	CV %	17	19	6	4.7	8.64	7.43	1.3	14
	LSD (P = 0.05)	21	15	17	0.6	0.08	0.42	0.1	22
PYT II	CLN 1621-146-4-0	54	37	28	5.0	0.34	1.23	4.3	90
	CLN 1621-235-2-0	53	36	54	5.0	0.45	1.73	4.1	86
	CLN 1621-360-7-0	51	28	36	5.3	0.45	1.66	4.1	100
	CLN 1617-164-7-0	51	43	44	5.3	0.51	1.60	4.2	83
	CL 5915-93D4-1-0-3 (ck)	44	33	28	5.0	0.43	1.69	4.3	29
	Mean of all entries	44	32	32	5.0	0.41	1.65	4.2	76
	CV %	13	13	10	3.6	10.12	14.62	1.2	-
	LSD (P = 0.05)	12	9	7	0.4	0.09	0.49	0.1	-

[a] Fruit samples for color analysis in AYT II were harvested at pink stage to avoid bird damage.
[b] Det = determinate type; ID = indeterminate type.

Plot sizes and cultural practices for cherry AYT and PYT are identical to those for fresh market AYT and PYT I, respectively.

AYT I. The mean marketable yield of the trial was 25 t/ha and mean yields ranged from 17 to 31 t/ha (table 4). CH 164 significantly outyielded inbred line check CH 154 and commercial hybrid check Santa. Average fruit size of CH 164 was 6.5 g, similar to the checks, but fruit Brix value significantly exceeded that of CH 154. Bacterial wilt resistance of entries was low and consequently they should not be grown in areas where this disease is a problem.

AYT II. Entries CH 162, CH 159, CH 164, CH 166, and CH 160 produced yields ranging from 41 to 44 t/ha which were significantly greater than Santa but significantly less than CH 154. Entry fruit sizes were similar (9–10 g) but Brix values of most experimental lines (ranging from 6.1 to 7.2%) equaled or surpassed that of CH 154 (6.1).

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

Trial	Entry	Mean yield (t/ha)	Fruit-set (%)	Fruit size (g)	Brix (%)	Acid (%)	Color (a/b)	pH	BW survival (%)
AYT I	CH 164	31	44	7	7.5	0.72	1.46	4.1	21
	CH 174	29	41	10	5.5	0.49	2.17	4.2	27
	CH 173	26	44	8	5.9	0.54	2.21	4.3	25
	CH 154 (ck)	36	42	6	6.3	0.70	1.58	4.4	9
	Santa (ck)	21	4	7	7.1	0.67	1.58	4.5	15
	Mean of all entries	25	48	9	6.2	0.54	1.95	4.3	18
	CV %	11	12	8	3.8	4.35	4.81	5.0	-
	LSD (P = 0.05)	5	10	3	0.4	0.04	0.17	0.4	-
AYT II	CH 152	44	78	10	6.8	0.45	1.26	4.2	-
	CH 159	44	69	9	6.1	0.51	1.45	4.2	-
	CH 164	43	74	10	7.1	0.55	1.35	4.1	-
	CH 166	42	67	10	7.1	0.51	1.28	4.2	-
	CH 160	41	81	10	7.0	0.49	1.29	4.2	-
	CH 154 (ck)	61	80	9	6.1	0.41	1.45	4.2	-
	Santa (ck)	36	85	10	6.6	0.41	1.51	4.3	-
	Mean of all entries	42	76	9	6.8	0.48	1.33	4.2	-
	CV %	5	7	6	5.9	7.84	5.73	1.0	-
	LSD (P = 0.05)	4	10	1	0.7	0.06	0.13	0.1	
PYT I	CLN 1561-128-37-6-1-1-36	30	14	12	5.0	0.40	1.86	4.2	-
	CLN 1561-128-37-6-1-1-24	23	9	12	4.7	0.41	2.16	4.2	-
	Santa (ck)	8	11	6	6.6	0.46	1.89	4.4	-
	CH 154 (ck)	20	35	9	5.7	0.41	1.68	4.2	-
	CH 168 (ck)	10	15	11	5.1	0.27	2.05	4.3	-
	Mean of all entries	13	13	11	5.2	0.39	2.09	4.3	-
	CV %	36	27	13	5.1	6.77	4.41	0.8	-
	LSD (P = 0.05)	9	7	3	0.6	0.05	0.19	0.1	-
PYT II	CHT 976	51	23	13	5.8	0.50	2.02	4.1	-
	CHT 961	49	17	13	6.2	0.55	2.17	4.3	-
	CHT 1005	49	49	13	5.7	0.45	2.15	4.3	-
	CHT 972	49	34	13	5.5	0.44	2.20	4.3	-
	CHT 983	49	31	16	5.6	0.43	2.06	4.3	-
	CHT 264 (ck)	39	17	13	5.9	0.45	2.19	4.2	-
	CH 154 (ck)	18	38	10	6.1	0.44	1.72	4.3	-
	CH 168 (ck)	10	10	11	5.9	0.36	1.68	4.2	-
	Santa (ck)	6	17	7	7.5	0.42	1.94	4.5	-
	Mean of all entries	18	24	12	5.9	0.46	4.31	2.0	-
	CV %	14	24	8	8.3	7.51	3.03	3.0	-
	LSD (P = 0.05)	5	12	2	1.0	0.07	0.06	0.1	-

PYT I. Entry mean yields ranged from 8 to 30 t/ha and the trial mean yield was 12 t/ha. High temperatures and humidities during the initial 3 months of the trial reduced fruit-set and yield. CLN 1561-128-37-6-1-1-36 (30 t/ha) and CLN 1561-128-37-6-1-1-24 (23 t/ha) significantly outyielded checks Santa (8 t/ha) and CH 168 (10 t/ha), but not CH 154 (20 t/ha). The Brix content of Santa (6.6%) was greater than all other entries and was likely a consequence of its low yield (8 t/ha).

PYT II. Mean yields ranged from 6 to 51 t/ha and the trial mean yield was 18 t/ha. Five experimental hybrids, CHT 976, CHT 961, CHT 1005, CHT 972, and CHT 997, yielded 2.5–3 times more than the highest yielding check, CHT 264. Brix values of the experimental hybrids (ranging from 5.5 to 6.5) were not significantly different from CH 154, CHT 264, and CH 168, but were significantly less than Santa (7.5).

A set of cherry tomato lines will be selected for distribution in 1997, based on yield, fruit quality, and reactions to TMV, fusarium wilt (races 1 and 2), bacterial wilt, and gray leaf spot.

Genetic improvement of processing tomato

Processed tomato products such as catsup, paste, or sauces are becoming increasingly popular in many parts of the world and processing industries generate additional employment. In the development of processing tomato (PT) varieties, AVRDC selects for lines with deep-red color, high solids and acid contents, high yield, and a high percentage (> 70%) of total yield in the first harvest. Entry types and dates of sowing, transplanting, and harvest of PT trials are shown in table 2.

Three processing tomato PYTs were conducted at AVRDC during 1995–1996. Trial objectives were to identify high-yielding lines with a high proportion of ripe fruit at the first harvest (important for mechanical harvest) and high fruit solids contents. Except for hybrid check PT 4225, all entries were determinate inbreds.

Trials were planted in RCBD with two replications. Plots consisted of two 4-m-long beds spaced 1.5 m apart with one row per bed; within-row spacing was 40 cm. Fertilizer was broadcast into the field prior to bed formation at 40-100-120 kg/ha N-P_2O_5-K_2O. Organic compost (2 t/ha) and borax (5 kg/ha) were also broadcast prior to bed formation.

PYT I. Yields of PT 4678B, PT 4719A, and PT 4675A (all jointless pedicel types) significantly surpassed that of PT 4225, and the first-time harvest proportion of these lines ranged from 77 to 86% (table 5). Entries in this trial were selected for cool-dry season production and lack sufficient heat tolerance for summer production. Seed of PYT I entries are available upon request.

Table 5. Horticultural and quality characteristics of selected processing tomato entries from PYT I-III, AVRDC, October 1995–April 1996

Trial	Entry	Mean yield (t/ha)	MY1[a] (%)	Fruit size (g)	Brix (%)	Acid (%)	Color (a/b)	pH
PYT I	PT 4678B	124	86	126	5.2	0.27	2.23	4.6
	PT 4719A	116	77	63	4.5	0.26	2.18	4.5
	PT 4675A	110	81	81	4.8	0.22	2.09	4.6
	PT 4225 (ck)	99	65	52	4.5	0.25	1.89	4.5
	UC 204A (ck)	72	57	67	4.8	0.29	2.15	4.5
	Mean of all entries	86	72	69	4.7	0.26	2.13	4.5
	CV %	17	6	30	6.0	12.94	6.03	1.5
	LSD (P = 0.05)	8	10	10	0.6	0.07	0.27	0.2
PYT II	PT 4678A	145	76	97	4.8	0.25	2.14	4.3
	PT 4675B	122	80	86	4.5	0.23	2.15	4.6
	PT 4664B	114	82	87	4.0	0.23	2.06	4.6
	PT 4225 (ck)	122	69	63	4.1	0.23	1.98	4.6
	UC 204A (ck)	77	62	81	4.9	0.28	2.28	4.5
	Mean of all entries	102	74	84	4.6	0.24	2.13	4.6
	CV %	23	6	6	7.5	8.37	4.59	1.6
	LSD (P = 0.05)	11	10	12	0.6	0.07	0.31	0.2
PYT III	PT 4674D	123	81	79	5.0	0.24	2.34	4.5
	PT 4675A	118	84	76	4.9	0.27	2.28	4.4
	PT 4660B	102	71	74	4.7	0.21	2.28	4.6
	PT 4674B	99	73	85	4.5	0.28	2.18	4.5
	UC 204A (ck)	75	64	72	4.7	0.30	2.12	4.5
	PT 4225 (ck)	79	57	56	4.5	0.24	1.95	4.5
	Mean of all entries	85	74	75	4.7	0.24	2.16	4.5
	CV %	29	9	8	6.6	10.20	4.98	1.3
	LSD (P = 0.05)	10	14	13	0.7	0.05	0.23	0.1

[a] MY1 = percentage of total yield in the first harvest.

PYT II. PT 4678A significantly outyielded hybrid check PT 4225. Proportions of total yield in the first harvest ranged from 62 to 82%. Internal red color of entries was good, ranging from 1.97 to 2.20, but Brix values of most entries was <5.0. PYT II entries possessed fair heat tolerance; seed of these entries are available for international distribution.

PYT III. Yields of PT 4674D, PT 4675A, PT 4660B, and PT 4674B ranged from 90 to 123 t/ha, significantly greater than checks UC 204A (75 t/ha) and PT 4225 (79 t/ha); Brix values of the best four entries ranged from 4.5 to 5.0, which were not significantly different from the checks (4.7 and 4.5 for UC 204A and PT 4225, respectively). Proportion of total yield in the first harvest ranged from 71 to 81% and mean fruit sizes ranged from 49 to 85 g.

Genetic improvement of tomato for tropical home gardens

One observational trial of high beta-carotene lines was carried out at AVRDC from October 1995 to March 1996. The trial objective was to identify horticulturally acceptable lines high in fruit beta-carotene content. Lines carrying either *dgdg* or *B* genes were evaluated in the trial. Beta-carotene contents of *B* and *dg* lines ranged from 3.00 to 7.44 mg/100 g, and 0.75 to 1.33 mg/100 g, respectively. Entry mean fruit sizes ranged from 131 to 183 g and yields ranged from 83 to 119 t/ha. Most entries possessed good bacterial wilt resistance with percent survival means in greenhouse tests ranging from 46 to 91%. Two PYTs of high beta-carotene entries are in progress at AVRDC. Superior lines will be selected for testing in Bangladesh and used as parents in crosses to develop heat-tolerant high beta-carotene lines.

Management of diseases

Identification and characterization of bacterial wilt and bacterial spot resistance in tomato

Bacterial wilt diallel analysis

Diallel analysis of bacterial wilt resistance in tomato was conducted to determine if combining different BWR sources can achieve higher resistance levels. Five tomato lines (CL 5915, L 285, CRA 84, Hawaii 7997, and GA 219) each derived from different BWR sources and a susceptible processing tomato line (UC 204A) were crossed in all combinations without reciprocals. Parents, F_1, and F_2 progenies were evaluated in the greenhouse at three locations for percent survival 6 weeks after drenching inoculation with local virulent strains.

Percent survival means over locations of parents and crosses ranged from 17 to 83 in the F_1 and 16 to 75 in the F_2 (table 6). The percent survival mean over locations of L 285 x Hawaii 7997 was highest among entries in the F_1 (83) and F_2 (75), but it was not significantly greater than Hawaii 7997. Highly significant mean squares were found in the F_1 and F_2 for general combining ability (GCA), and GCA x locations (table 7). Positive GCA effects over locations were detected for Hawaii 7997, CRA 84, and L 285 although only Hawaii 7997 showed positive GCA effects at each location and generation. Significant increase in BWR was not observed by combining different resistance sources. However, the presence of larger GCA variances suggested that higher BWR may be achieved by recurrent selection.

Table 6. Percent survival means[a] over locations of selected parents, F_1 and F_2 crosses evaluated for bacterial wilt resistance

Parent/cross	Parents and F_1	Parents and F_2
CRA 84	64.8c-e	75.0a
H 7997	76.4ab	63.1a-c
L 285	62.3c-e	45.5a-f
UC 204	17.4j	16.2f
L 285 x CRA84	76.9ab	68.1a-c
L 285 x H 7997	83.0a	75.0a
CRA 84 x H 7997	68.1b-d	70.6a

[a] Mean separation by DMRT (K ratio = 100). Data were transformed by the arcsin of the square root for analysis. Nontransformed means are shown.

Table 7. GCA effects of F_1 and F_2 crosses evaluated for bacterial wilt reactions at greenhouses in Taiwan, the Philippines, and Indonesia

	F_1				F_2			
	Taiwan	Phil.	Indo.	Combined	Taiwan	Phil.	Indo.	Combined
CL 5915	-3.97	-1.97	1.45	-1.50	-2.52	-2.53	2.69	-0.79
L 285	10.99	14.50	-3.22	7.42	4.81	11.86	-1.53	5.05
CRA 84	6.59	-7.26	13.85	4.39	4.81	-7.66	11.15	2.76
H 7997	11.44	3.62	18.20	11.09	11.29	7.29	14.56	11.05
GA 219	-3.79	1.06	-12.80	-5.17	-0.52	-3.48	-11.40	-5.13
UC 204A	-21.26	-9.95	-17.48	-16.23	-17.87	-5.48	15.47	-12.94
SE of GCA effect	1.65	2.40	1.98	1.15	1.62	3.38	1.98	1.41

QTL mapping of bacterial wilt resistance in Hawaii 7996

A total of 191 F_3 lines derived from a cross between Hawaii 7996 (resistant parent) and Wva 700 (susceptible parent) were evaluated in the greenhouse by drench inoculation with strain Pss4. Severity ratings were used to identify loci associated with BWR by a cooperator at the Institut National de la Recherche Agronomique (INRA) in France. A total of 20 QTLs were mapped on chromosome 2, 3, 6, 8, and an unknown region. Among these, an unmapped QTL accounted for about 40% of the total variation at 10 and 14 days after inoculation. Efforts are being made to locate this QTL.

Bacterial spot

Race identification was conducted for a total of 152 strains of *Xanthomonas campestris* pv. *vesicatoria* isolated from tomato in Taiwan from 1989 to 1996. Race identification of 116 strains was completed and reactions of 36 strains still require confirmation. The predominant race was T1P3 (table 8). Strains were isolated in the highlands. However, among the T2P3 strains, only one was isolated in the highlands. Streaking Xcv on nutrient agar with 1% starch indicated that only the four T2 strains can hydrolyze starch. The reported new race, T3, was not found in this collection. Resistance sources to race T1 and T3, but not to race T2, have been identified in tomato.

Ecotyping of *Ralstonia (Pseudomonas) solanacearum* isolated from tomato

In 1996 a collaborative effort among researchers at AVRDC, Australia, Indonesia, Malaysia, Philippines, Thailand, and Vietnam was established to study and characterize genetic variation of *R. solanacearum* strains from Southeast Asia. *R. solanacearum* (Ps) strains are being collected by collaborators and development of national catalogs of Ps strains was initiated in Vietnam, Thailand, and finalized in Indonesia, Malaysia, and the Philippines. Common protocols for strain

Table 8. Race identification of strains of *Xanthomonas campestris* pv. *vesicatoria* isolated from tomato in Taiwan from 1989 to 1996

		Pepper[a]				Tomato		
Race	No. of strain	ECW	ECW -10R	ECW -20R	ECW -30R	Bonny Best	Hawaii 7998	Hawaii 7981[b]
T2	4	+[c]	+	+	+	-	-	-
T1P1	26	-	-	+	+	-	+	-
T1P2	15	-	+	+	-	-	+	-
T1P3	65	-	-	+	-	-	+	-
T2P3	6	-	-	+	-	-	-	-

[a] ECW : Early Calwonder; ECW-10R, ECW-20R, and ECW-30R are near-isogenic lines of ECW which carry *Bs1*, *Bs2*, and *Bs3* genes respectively.
[b] Reactions on PI 126932 and PI 128216 were identical as on Hawaii 7981.
[c] + : incompatible reaction; - : compatible reaction.

pathogenicity testing, and strain characterization have been developed at AVRDC and the University of Adelaide, Australia. Fingerprinting of Ps strains by PCR is ongoing.

Standard procedures of pathogenicity testing developed for *R. solanacearum* have been distributed to collaborators in Australia, Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Leaf clipping inoculation was identified as the best method for pathogenicity testing. The procedure includes dipping scissors in a bacterial suspension, clipping three sites on each tomato seedling with three fully expanded true leaves (L 390), and keeping the inoculated plants in a warm greenhouse. Four plants were inoculated per strain.

A scale of 0 to 5 (0 = no symptoms, 5 = wilted) was used to rate severity of bacterial wilt in test plants. Based on the severity scores of four plants, strains could be grouped into virulent (all plants had scores ≥ 3), weakly virulent (all the four plants had scores < 3), and avirulent (all the scores are 0).

A total of 176 strains in the AVRDC collection were tested by leaf clipping method. Based on the results, 141 of the strains were virulent; 13 strains were weakly virulent; and 3 strains were avirulent; reactions of 19 strains need confirmation.

Host resistance to black leaf mold of tomato

Black leaf mold (BLM) of tomato, caused by *Pseudocercospora fuligena*, is widespread in the tropics and subtropics where it can cause extensive defoliation. BLM is controlled by application of fungicides because resistant varieties are not available. Over the past 10 years several BLM-resistant accessions have been identified in laboratory studies at AVRDC. The objective of this study was to compare and rank the resistance sources that were previously identified.

Twenty-four 35-day-old plants of each entry were spray-inoculated to the point of run-off with a conidial suspension (1 x 10^4/ml) from *P. fuligena*, isolate Pf-2. The inoculated plants were maintained continuously at 28±1°C. For the first 36 h after inoculation they were kept in the dark at 100% RH to maintain leaf wetness. Thereafter, the humidity was reduced to 95±2% RH and the plants provided a 14 h/day photoperiod. Disease severity evaluations were made by visual estimation of the percentage of leaf area affected by BLM at 18 days after inoculation. Disease reaction categories were established based on the percentage leaf area affected. FMTT 22 and TK 70 were included as susceptible controls.

Fifty-four of the most resistant accessions previously identified were chosen for reevaluation and comparison in a single laboratory inoculation experiment. Twenty-six entries including nine *L. hirsutum* (L 643, L 645, L 733, L 5996, LA 1033-1, LA 1033-2, LA 1353, LA 1777, and LA 1928), three *L. cheesmanii* (TL 1044, TL 1078, and TL 1082) and *L. glandulosum* (L 634, L 639, and L 641), two *L. chmielewskii* (L 1028 and L 2633), *L. parviflorum* (LA 1326 and LA 2133), *L. peruvianum* (L 638 and LA 385), and one *L. chilense* (LA 2284), *L. hirsutum* f. *glabrasum* (LA 1223), *L. peruvianum* f. *glandulosum* (LA 1292), *L. esculentum* (L 1777), and L 5637 were rated resistant. Twelve entries were rated moderately resistant, and all other entries were classified as moderately susceptible and susceptible (table 9). Four of the accessions previously rated resistant fell into the susceptible category. These results should be useful in choosing BLM-resistant parents in the future for developing BLM-resistant tomato varieties.

Table 9. **Confirmatory screening and ranking of previously identified black leaf mold-resistant tomato accessions**[a]

Entry	Species	Foliage affected (%)	Disease[b] reaction	Entry	Species	Foliage affected (%)	Disease[b] reaction
FMTT 22 (ck)	*L. escu.*	66.7 a	S	TL 1052	*L. chees.*	11.3 n-r	MR
LA 2184	*L. pimp.*	61.7 ab	S	LA 1402	*L. chees.*	10.8 n-s	MR
LA 473		59.2 bc	S	L 639	*L. glan.*	10.0 n-t	R
L 5951		55.8 bcd	S	TL 1044	*L. chees.*	10.0 n-u	R
LA 317	*L. chees.*	54.2 cde	S	L 5637		9.2 n-u	R
TK-70 (ck)	*L. escu.*	50.8 def	S	LA 1028	*L. chmiel.*	9.2 n-u	R
L 5774	*L. penne.*	49.2 efg	MS	L 733	*L. hirsu.*	8.3 op-u	R
L 486	*L. escu.* x *L. pimp.*	46.7 fgh	MS	LA 1928	*L. hirsu.*	8.1 p-u	R
LA 1908	*L. hirsu.*	45.0 fgh	MS	LA 1223	*L. hirsu.* f. *glabra*	6.7 p-v	R
L 5281	*L. escu.*	44.2 gh	MS	L 634	*L. glan.*	5.8 q-v	R
LA 722	*L. pimp.*	42.5 hi	MS	L 5996	*L. hirsu.*	5.0 r-v	R
LA 1546	*L. escu.* v. *cerasiforme*	40.8 hi	MS	L 1777	*L. escu.*	4.2 s-v	R
L 5879		36.7 ij	MS	TL 1078	*L. cheesma.*	3.8 uvt	R
L 2110	*L. pimp.*	36.7 ij	MS	LA 2284	*L. chilense*	3.8 uvt	R
LA 111	*L. peru.*	33.3 jk	MS	LA 1326	*L. parvi.*	3.3 uvt	R
L 2106	*L. escu.* x *L. pimp.*	32.5 jk	MS	LA 2133	*L. parvi.*	2.5 uv	R
L 1533	*L. pimp.*	31.7 jk	MS	L 641	*L. glan.*	2.5 uv	R
L 141	*L. pimp.*	31.7 jk	MS	LA 1777	*L. hirsu.*	0.8 v	R
L 1959	*L. escu.* x *L. pimp.*	30.0 k	MR	LA 1033-1	*L. hirsu.*	0.8 v	R
LA 1306	*L. chmiel.*	30.0 k	MR	LA 1033-2	*L. hirsu.*	0.8 v	R
LA 1963	*L. chilense*	30.0 k	MR	L 643	*L. hirsu.*	0.8 v	R
L 4862	*L. pimp.*	29.2 k	MR	L 638	*L. peru.*	0.0 v	R
LA 1673	*L. escu.* v. *cerasiforme*	23.3 l	MR	L 645	*L. hirsu.*	0.0 v	R
L 4863	*L. pimp.*	19.2 lm	MR	LA 2663	*L. chmiel.*	0.0 v	R
L 5836		15.8 mn	MR	TL 1082	*L. cheesma.*	0.0 v	R
L 1064 (P_2)	*L. hirsu.*	15.0 mno	MR	LA 1292	*L. peru.* f. *glan.*	0.0 v	R
LA 2584	*L. pimp.*	13.3 m-p	MR	LA 1353	*L. hirsu.*	0.0 v	R
LA 1932	*L. chilense*	12.5 n-q	MR	LA 385	*L. peru.*	0.0 v	R

[a] Date planted: 6 September; date inoculated: 11 October (Pf-2, 1 x10^4 conidia/ml); date evaluated: 29 October.
[b] R = ≤10% foliage affected; MR = 10.1–30% foliage affected; MS = 30.1–50% foliage affected; S = >50%.
[c] Mean separation by DMRT, P < 0.05.

Host resistance to late blight of tomato

Late blight, caused by *Phytophthora infestans*, is one of the most devastating diseases of tomato in most of the Asian, African, and Central American countries where AVRDC is engaged in research to improve vegetable productivity. Presently, there are no tomato varieties that are resistant to the *P. infestans* races that occur in these areas, but four wild tomato lines were identified in laboratory studies at AVRDC during 1993–94 that were resistant to Taiwan isolates of *P. infestans*. The study objectives were (1) to field test the resistant lines for their reactions to late blight in different geographic areas, (2) to determine the inheritance of resistance, and (3) to introgress late blight resistance into desirable tomato types.

Geographic testing of resistance. Results have been received from Indonesia, Nepal, Philippines, Taiwan, Tanzania, Thailand, and USA. In each of these locations the four AVRDC lines were the most resistant among the lines tested. Under severe late blight pressure, L 3707 and L 3708 were very resistant and L 3683 and L 3684 expressed an intermediate level of resistance, while all other accessions tested were severely damaged or killed. Representative data from Taiwan and Nepal field experiments are shown in fig. 1 and 2.

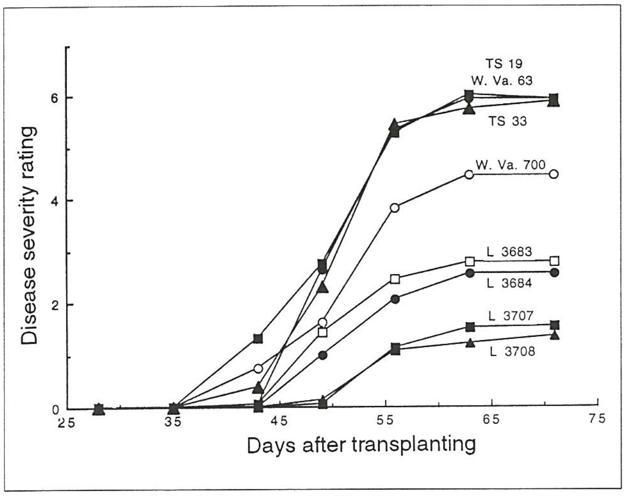

Fig. 1. Late blight development from natural inoculum in tomato accessions in a field at Puli, Taiwan, spring 1996

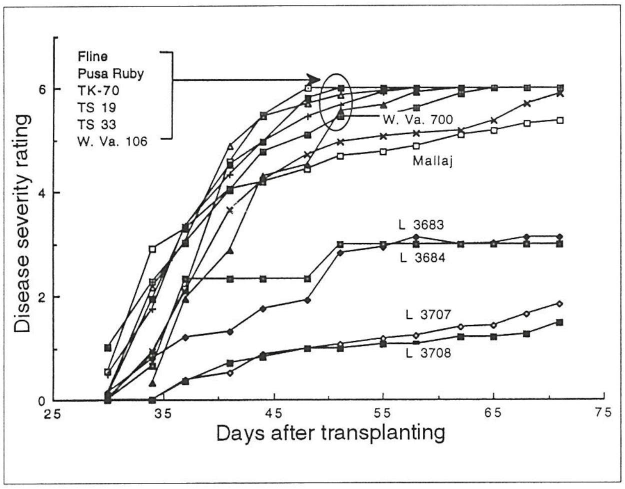

Fig. 2. Late blight development from natural inoculum in tomato accessions in a field at Pokhara, Nepal, winter, 1995–96

Inheritance of resistance. Analyses of data based on the late blight reactions of F_1, F_2, B_1F_2, and B_1F_1 populations derived from '*L. esc.* x L 3708' and '*L. esc.* x L 3684' crosses showed that the resistance in both accessions is inherited as a single partially dominant gene (tables 10 and 11). F_1 plants derived from susceptible x resistant crosses involving either L 3708 or L 3683 expressed resistance levels intermediate to the two parents, but skewed toward the resistant parent. Resistant homozygotes in the F_2, B_1F_2, and subsequent populations appeared to have resistance levels similar to the resistant parent (fig. 3).

Table 10. Late blight reactions of L 3708, CLN 657, and progenies

	No. plants				Expected	
Population	n	R	I	S	ratio	X^2
L 3707 (R)	48	48	0	0		
CLN 657 (S)	48	0	0	48		
F_1	78	25	50	3		
F_2	478	123	255	100	1R : 2I : 1S	4.36ns
		No. families			Expected	
Population	n	Seg.	S		ratio	X^2
B_1F_2	38	19	18		1 Seg : 1 S	0.03ns

Table 11. Late blight reactions of L 3684, Moneymaker, and progenies

	No. plants				Expected	
Population	n	R	I	S	ratio	X^2
L 3707 (R)	48	48	0	0		
L 3684 (R)	48	41	7	0		
MM (S)	36	0	0	36		
F_1	12	5	5	2		
F_2	211	55	96	60	1R : 2I : 1S	1.95ns
		No. families			Expected	
Population	n	Seg.	S		ratio	X^2
B_1F_2	27	12	15		1 Seg : 1 S	0.33ns

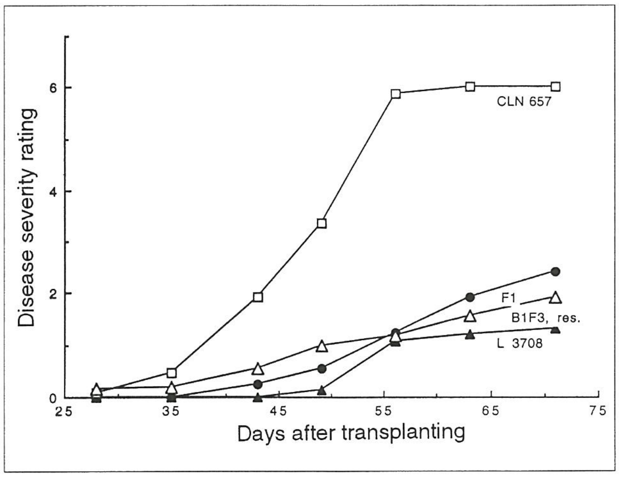

Fig. 3. Late blight development in populations derived from tomato accession L 3708 in a field at Puli, Taiwan, spring 1996

Host resistance to fusarium wilt of tomato

Fusarium wilt of tomatoes, caused by *Fusarium oxysporum* f.sp. *lycopersici* (Fol), is a threat to tomato production worldwide. This disease is managed primarily by resistant varieties. Three races of *Fol* are known to occur, but at present only races 1 and 2 appear to be important in Asia. The objectives of this study were (1) to assess the occurrence and prevalence of Fol races in Taiwan and (2) to determine the Fol race 1 and 2 reactions of tomato varieties, lines, and breeding populations. The overall objective is to ensure that advanced AVRDC tomato lines possess resistance to Fol races 1 and 2.

A total of 22 *F. oxysporum* isolates were obtained from tomato plants showing fusarium wilt symptoms that were collected from six locations in Taiwan. Assays of the isolates on tomato host differentials showed that 7 were avirulent and 15 were Fol of which 14 belong to race 2 and 1 to race 1 (table 12).

Tomato accessions and lines distributed by AVRDC for bacterial wilt nurseries (table 13) and the international bacterial wilt-resistant tomato set (table 14) distributed from Australia were assayed for their reactions to races 1 and 2 of Fol. Most of the entries in these two sets were resistant to race 1, but only a few were resistant to race 2. This

Table 12. Virulence and race determination of *Fusarium oxysporum* isolates from tomato in Taiwan, 1995-96 survey

Location	Date isolated	Avirulent	Race 1	Race 2	Total
Likang, Pingtung	Oct. 1995	2	0	4	6
Taipao, Chiayi	Oct.	2	0	0	2
AVRDC, Tainan	May 1996	0	1	3	4
Luchu, Kaohsiung	May	3	0	2	5
Chufu, Kaohsiung	May	0	0	2	2
Wangmei, Nantou	June	0	0	3	3
Totals		7	1	14	22

Table 13. Fusarium wilt reactions of tomato lines[a] in the AVNET bacterial wilt nursery

	Race 1, Fol-11A		Race 2, Fol-14	
Entry	DSR[b]	Reaction[c]	DSR[b]	Reaction[c]
L 390	8.7	S	6.8	S
BL 350	0.0	R	5.0	S
BL 342	0.0	R	2.3	seg
BL 323	1.2	R (seg?)	6.8	S
BL 341	0.0	R	6.4	S
BL 355	0.0	R	6.2	S
BL 312	0.0	R	1.7	seg
BL 410	0.0	R	3.9	seg
BL 333	0.0	R	3.7	seg
L 285	0.0	R	0.0	R
CL 1131-0-0-13-0-6	0.0	R	5.2	S
CL 143-0-10-3-0-1-10	0.0	R	6.8	S
CL 8d-0-7-1	0.0	R	7.5	S
CL 9-0-0-1-3	7.4	S	7.4	S
CL 11d-0-2-1	0.0	R	6.2	S
CL 5915-93D4-1-0	1.3	R (seg?)	7.3	S
CL 5915-206D4-2-2-0	9.0	S	9.7	S
CL 6047-1-1-2-3-2-7-0	0.0	R	7.4	S
CLN 475-BC_1F_2-265-4-19	7.1	S	6.3	S
CLN 675-BC_1F_2-285-0-21-0	6.9	S	2.8	(seg?)
CLN 65-349D5-2-0	7.4	S	8.8	S
Fantastic, S ck	7.2	S	8.0	S
UC82-L, F-1 R ck	0.0	R	8.1	S
Fla MH-1, F-1&2 R ck	0.0	R	0.0	R

[a] Plants evaluated at AVRDC 8 April.
[b] Disease severity rating scale of 0-10; 0 = no symptoms and 10 = permanently wilted or dead; values shown are based on means of 24 plants (4 rep. x 6 plants).
[c] Reactions: R = resistant; S = susceptible; and seg = segregating, i.e., both resistant and susceptible plants.

Table 14. Fusarium wilt[a] and gray leaf spot[b] reactions of the international tomato set of bacterial wilt-resistant lines

	Race 1, Fol-11A		Race 2, Fol-14		Gray leaf spot	
Variety/Line	DSR[c]	Reaction[d]	DSR[c]	Reaction[d]	Mean[e]	Reaction[f]
Hawaii 7998	0.0	R	0.0	R	1.2	R
Hawaii 7997	0.0	R	4.8	S	4.0	S
Hawaii 7996	0.0	R	0.0	R	1.2	R
GA 219 (PI 126408)	8.1	S	5.5	S	3.4	S
CRA 66	0.0	R	2.8	seg	0.7	R
GA 1565 (PI 263722)	0.0	R	4.9	S	0.8	R
GA 1405 (PI 251323)	5.0	S	5.0	S	3.5	S
BRS-1	0.0	R	0.0	R	0.5	R
Fla 7421	0.0	R	4.7	S	1.0	R
Hawaii 7998	0.0	R	4.1	seg	1.6	R
BF-Okitsu 101	0.0	R	0.8	R	1.5	R
TBL - 1	0.0	R	7.4	S	1.0	R
TBL - 2	0.0	R	6.1	S	0.2	R
TBL - 3	0.0	R	8.2	S	0.3	R
TBL - 4	0.0	R	7.1	S	0.2	R
MT - 1	0.0	R	6.0	S	0.7	R
MT - 11	8.0	S	7.6	S	1.0	R
Kemir	8.7	S	6.7	S	2.9	S
Intan Putih	0.0	R	5.4	S	1.0	R
Ranti	6.1	S	6.5	S	3.8	S
R-3034-3-10-N-UG	0.0	R	5.1	S	0.9	R
TML-114-48-5-N spreading	0.0	R	5.5	S	1.0	R
TML-46-N-12-N-early N.T.	0.0	R	6.3	S	1.0	R
F7-80-465-10-Pink	0.0	R	6.3	S	1.3	R
Hawaii 7997	0.0	R	5.6	S	4.0	S
CRA 66	0.0	R	0.8	R	1.2	R
Caraibo	0.0	R	5.3	S	0.8	R
Caravel (CRA 90-30)	0.0	R	5.5	S	0.8	R
L285	0.0	R	1.0	R	1.0	R
CL 5915-93-D4-1-0	0.5	R	7.5	S	3.2	S
CLN 65-349-D5-2-0	7.9	S	8.5	S	3.4	S
CLN 1463-160-40-60	8.1	S	7.3	S	0.7	R
CLN 1464-111-30-45	0.0	R	7.2	S	0.8	R
Rodade	0.0	R	0.6	R	0.5	R
Redlander	0.0	R	0.0	R	0.7	R
L 390	8.9	S	8.2	S	4.0	S
Fantastic, S ck	9.1	S	7.2	S	4.0	S
Bonny Best, S ck					3.8	S
UC 82-L, F-1 R ck	0.0	R	8.6	S	3.8	S
Fla MH-1, F-1&2 R ck	0.0	R	0.8	R	0.9	R
Homestead 24; F-1					4.0	S
L 3684					2.1	I (seg)
L 3708					2.7	I
LA 1777					1.8	I (seg)
L 733					2.0	I (seg)

[a] Plants evaluated at AVRDC 8 April.
[b] Conditions: 100% RH (2 min on, 4 min off) at 25°C without light for the first 36 h after inoculation; then 98±2% RH (2 min on, 8 min off), 25°C and 14-h photoperiod until evaluation.
[c] Disease severity rating scale of 0-10; 0 = no symptoms and 10 = permanently wilted or dead; values shown are means of 24 plants (4 rep. x 6 plants).
[d] Reactions: R = resistant; S = susceptible; and seg = segregating, i.e., both resistant and susceptible plants.
[e] Disease severity rating scale: 0 = no symptoms; 1 = occasional necrotic fleck; 2 = numerous necrotic flecks; 3 = numerous necrotic spots; and 4 = coalescing necrotic spots and leaf collapse. Values based on reactions of 6 plants in each replication.
[f] Disease reactions were categorized as follows: DSR: 0-1.6 = R; 1.7-2.8 = I; and 2.9-4.0 = S.

information may be of value when these lines are tested in locations where the cause of tomato wilting cannot be confirmed.

Host resistance to gray leaf spot of tomato

Gray leaf spot of tomato, caused by *Stemphylium solani* and *S. lycopersici* is worldwide in distribution and frequently causes extensive defoliation. It is controlled primarily by use of resistant varieties. This study aimed to (1) confirm the utility of AVRDC's laboratory protocol for evaluating gray leaf spot reactions of tomatoes and (2) evaluate tomato lines important to the AVRDC tomato improvement project for their gray leaf spot reactions.

Artificial inoculation was made by atomizing the conidial suspension (1×10^4/ml) from *S. solani* (isolate *Ssol*-1) to the plants to the point of runoff. The inoculated plants were incubated at 25±2°C continuously; they were held in the dark at 100% RH for the first 36 h after inoculation, and thereafter with a 14 h/day light period at 95±2% RH. Disease evaluation was made 7 days after inoculation.

Among the 36 entries in the set of international bacterial wilt-resistant lines, 27 were rated resistant and 9 susceptible to gray leaf spot (table 14). Among the other eight cultivars and lines that were included in the test only one was resistant, four gave intermediate reactions, and three were susceptible. Knowledge of the gray leaf spot reactions of these lines may help explain their performance in some locations and also be useful to breeders wishing to use them in breeding activities.

Development of multivirus-resistant tomato

The development of a tomato variety resistant to viruses such as CMV, TYLCV, PVY, and TSWV, has been a goal of the tomato project for many years. To realize this goal a cooperative activity was launched in 1993.

In 1996, B_3F_2 and B_4F_1 plants of crosses developed for leaf curl virus resistance derived from LA 1932 and LA 2737 were exposed to viruliferous whiteflies from the seedling stage up to maturity. Immune or resistant plants were selected by absence of symptoms and negative nucleic acid hybridization tests. Selfed seed were harvested from resistant plants and B_3F_3 and B_4F_2 progenies evaluated for TYLCV reaction.

Crosses for CMV resistance involving two *L. chilense* selections, LA 1969-9 and LA 1969-11, were advanced to B_1F_2. Screening by mechanical inoculation followed by two ELISA tests showed resistances ranging from 100 to 38% in populations of LA 1969-11 selections and from 67 to 24% in LA 1969-9 selections.

Table 15 shows the RFLP markers associated with PVY resistance in CLN 808 selections fom crosses involving *L. hirsutum* PI 247087. Marker analysis of advanced inbred PVY-resistant tomato lines with *L. hirsutum* PI 247087 as the resistance donor has shown *L. hirsutum* introgressions on top of chromosome 7, 9, and 10 and on chromosome 4. A new source of resistance to PVY was identified in *L. hirsutum* L 3683. The resistance was confirmed with isolates from Australia, Hawaii, California, Thailand, and Germany.

Table 15. RFLP markers associated with PVY resistance in CLN 808 BC_4F_6 selections of crosses involving *L. hirsutum* PI 247084

Marker	Chromosome	CLN line[a]	Type of allelism[b]
TG499	7	AB	H/H H/H
TG254	9	A	H/H
CT143	9	A	Seg
CT283	9	B	Seg
CT16	10	B	H/H
CT234	10	AB	Seg H/H
CT11	10	A	H/H
TG574	4	B	Seg

[a] A = CLN808BC_4-5-16-1-12, B = CLN808BC_4-2-22-1-32.
[b] H/H = for the specific marker, the samples have only *L. hirsutum* alleles, no susceptible *L. esculentum* alleles; Seg = the line carries some *L. esculentum* in addition to *L. hirsutum* alleles.

Five tomato clones transformed with the N protein gene were tested for tospovirus resistance by mechanical inoculation. One of the clones (657-12-2 R_0) was found resistant; the other one (4783-12-11 R_1) was segregating for resistance to watermelon silver mottle virus (WSMV).

Studies on leaf curl virus

Routine screening for leaf curl virus resistance

Routine screening for leaf curl virus resistance were continued to identify additional sources of TYLCV resistance. A total of 119 lines were screened, including accessions of *L. pimpinellifolium*, *L. peruvianum*, *L. hirsutum*, *L. chilense*, and *L. esculentum*. Screening was done by subjecting 48 seedlings of each accession/line to viruliferous whiteflies followed by visual symptom observation and nucleic acid hybridization tests after the susceptible check developed symptoms. This method was found to be highly effective. One *L. hirsutum* accession, three *L. peruvianum*, and five additional *L. chilense* were identified with high resistance levels.

Thirty-seven lines were screened for the first time, whereas all others were selections of lines that were previously found to be segregating for leaf curl virus resistance. Three additional lines [L 736 *(L. peruvianum*), L 737 *(L. peruvianum*), and LA 1777 *(L. hirsutum*)] were identified with high levels of resistance (50, 60, and 89%, respectively). The resistance was confirmed in selections of *L. peruvianum* VL 215 and *L. chilense* accessions LA 1930, LA 2737, 2746, 2747, and 2980.

Identification and characterization of a new tomato-infecting geminivirus in Tanzania

It was previously established that a geminivirus (gv) closely related to TYLCV-Isr infects tomato in Tanzania. However, some leaf samples from Tanzania failed to hybridize with DNA-A probes against TYLCV-Isr. These were subjected to PCR with a primer pair which amplifies part of the replicase, the intergenic and the coat protein region of whitefly-transmitted gv, and yielded a 1.5-kb fragment. This fragment was cloned and sequenced. The C_1 sequence was compared to known sequences of TYLCV-Isr, TYLCV-Sar, TYLCV-Thai, TLCV-Aus, TLCV-Ind (Bangalore 1), TLCV-Tai ToMoV, cassava mosaic virus-Ind (ICMV), cassava mosaic virus Africa (ACMV), and mungbean yellow mosaic virus (MYMV). Nucleotide homologies are shown in table 16. Common region comparisons were 62–65% for TTLCV-Isr, TYLCV-Sar, TYLCV-Thai, TLCV-Aus, and TLCV-Tai. Since isolates of the same geminivirus usually have nucleotide identities >90, this virus is considered different from all previously characterized geminiviruses, and is, thus, considered a new geminivirus, which has been named TLCV-Tan.

Table 16. Comparisons of the AC1 region of TLCV-Tanzania with other tomato infecting geminiviruses, ACMV, ICMV, and MYMV

Virus	% nucleotide homology
TYLCV-Isr	74
TYLCV-Sar	75
TYLCV-Thai	75
TLCV-Aus	77
TLCV-Ind (B'lore 1)	72
TLCV-Tai	78
ToMoV-Fla	73
ICMV	70
ACMV	65
MYMV	66

Host range studies on Taiwan tomato leaf curl virus

Twenty-eight plants each of 11 *C. annuum* and 1 *C. frutescens* (VC 6, VC 10, VC 16, VC 17, VC 35, VC 37, VC 40, VC 58, Passion, and VC 170) varieties were subjected to seedling screening by viruliferous whiteflies. The screening was repeated twice, in May and in August. None showed symptoms nor was a gv detected by NASH. Similarly, samples of 39 pepper plants collected in AVRDC fields that showed symptoms typical of geminivirus infection (yellowing, small leaves, and curling), which were tested by NASH using the TLCV-Tai probe, were negative. This indicated that the Taiwan tomato leaf curl virus does not infect *Capsicum* sp.

Network support

Some of AVRDC's network cooperators from South and Southeast Asia lack the facilities to conduct routine gv detection. To assist them, AVRDC asked them to select samples with typical gv infection (yellowing, leaf curling), squash them on Hybond membranes provided by the Center, and return these membranes to AVRDC for NASH testing using the TLCV-India and the TYLCV-Thai probe, a general probe which detects many geminiviruses. A total of 112 tomato samples suspected to be infected with a leaf curl virus were received from Nepal, India, the Philippines, and Mauritius. The presence of a geminivirus was confirmed in only 13 samples originating from Nepal and India (table 17). All other samples from the Philippines and Mauritius either did not contain a geminivirus or were infected with a geminivirus that could not be detected with AVRDC probes. This will be followed up. A 1.5 kb part of the genome of the Philippine virus has been cloned.

Identification of molecular markers linked to heat tolerance in CLN 1639F_6 recombinant inbred lines

A previous study to identify RAPD markers linked to heat tolerance in an F_2 segregating population derived from a single cross of CL 5915-206 (heat-tolerant inbred line) and L 4422 (heat-sensitive accession) was implemented in summer 1994. F_2 plants were screened for heat tolerance and classified as heat-tolerant or heat-sensitive according to fruit-set. A DNA bulk was created from each group and a total of 849 primers were screened for the ability to detect polymorphism between the two groups. However, no primer associated with heat tolerance was detected. The failure to obtain markers cosegregating with the heat tolerance trait in that study might be attributed to heterozygosity in the mapping population and the choice of fruit setting rate as the only distinction between heat-tolerant and sensitive lines.

In a second study, 151 CLN 1639F_6 recombinant inbred lines derived from the cross between CL 5915-93 and L 4422 were used as a mapping population. Three F_6 plants from each RIL were grown in a greenhouse in June 1996 and scored for fruit setting, fruit weight, seed number, and fruit yield from August to October. Five clusters, from the second to the sixth, of each plant were scored.

Table 17. Survey for geminiviruses of tomato, pepper, and mungbean

Country	Crop	No. samples tested	No. samples positive	Probe used
Nepal	mungbean, soybean, blackgram, cowpea	19	3[a]	MYMV
Nepal	tomato	20	9 (Thai)	TLCV-Ind, TYLCV-Thai
Nepal	tomato	50	0	TLCV-Ind, TYLCV-Thai
India	tomato	2	0	TLCV-Ind, TYLCV-Thai
India	tomato	3	3 (India)	TLCV-Ind, TYLCV-Thai
			1 (Thai)	TLCV-Tai, TYLCV-Tan
Philippines	pepper	10	0	PCR (Ac1v1978/Av1c715)
Philippines	tomato	3	0	TYLCV-Thai
			0	PCR (Ac1v1978/Av1c1715)
Mauritius	tomato	34	0	TYLCV-Thai
			0	PCR

[a] Positive samples were from soybean and blackgram.

Average day/night temperatures for August, September and October were 34.9/24.0°C, 32.1/23.7°C, and 28.6/20.9°C, respectively.

Variation for fruit-set, etc. was present within most of the F_6 RILs. Uniformity was observed in only two lines, CLN 1639F_6-31 and CLN 1639F_6-100. Twenty-five heat-tolerant and 25 heat-sensitive F_6 plants were selected and advanced to the F_7 to increase the level of inbreeding and develop more homozygous mapping populations.

Higher fruit setting rates and seed numbers were found in some F_6 lines compared to the heat-tolerant parent, CL 5915-93 (fig. 4 b, c). The distribution of average fruit weight and fruit yield in the F_6 was skewed toward lower fruit weight and lower fruit yield characteristic of L 4422 (fig. 4 a, d). This skewness suggests that small fruit size was dominant. Compared to previous data obtained in 1994, F_6 and F_2 RILs have similar frequency distributions for fruit setting rate, fruit weight, and seed number.

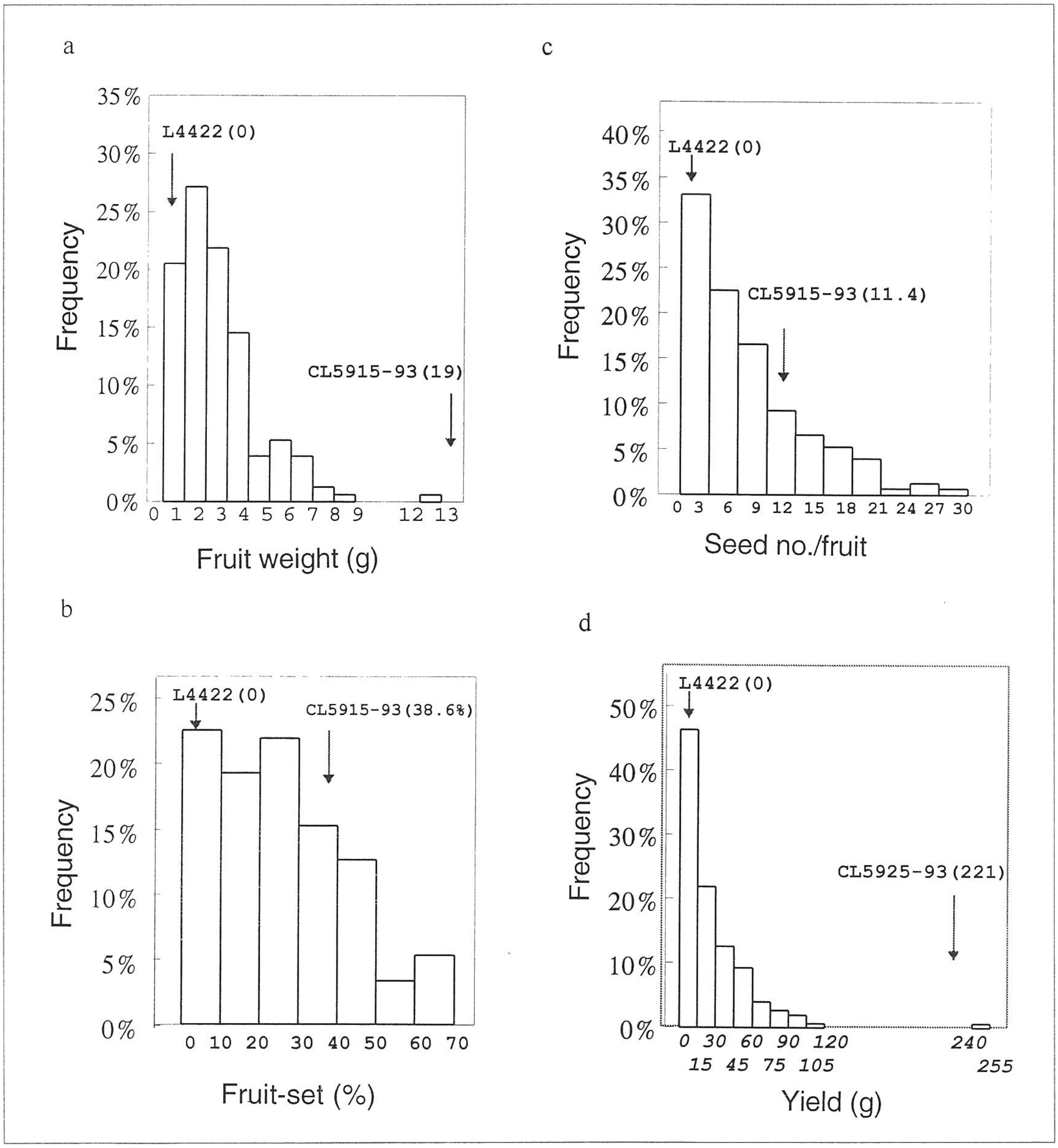

Fig. 4. Frequency distribution for fruit weight, fruit-set, seed number, and fruit yield of CLN 1969-F_6 lines

Transformation of tomato and pepper with virus resistance genes and evaluation of transformants for CMV resistance

Plasmid pCMV N/B-23 harboring the truncated CMV RNA-2 replicase gene and plasmid pBICBI 2 carrying the CMV-T coat protein gene were provided by cooperators from Cornell University, USA, and Chung Hsing University, Taiwan, respectively. Both plasmids were transformed into *Agrobacterium tumefaciens* strain LBA4404 by the freeze-thaw method.

Cotyledon explants of tomato L 4783, sweet pepper C 00157D, and hot pepper Szechwan were used for *Agrobacterium*-mediated transformation. Explants were transferred to regeneration medium containing 100 mg/L kanamycin. Regenerated shoots were then transplanted to the greenhouse after acclimation. Transformed plants were analyzed by Southern hybridization and PCR for the integration of the truncated CMV RNA-2 replicase gene or the CMV-T coat protein gene. Genomic DNA extracted from leaves of transgenic pepper and tomato plants and digested with respective restriction enzymes was transferred to Hybond-N membrane and hybridized to DIG-dUTP labeled 3 kb DNA fragment of pCMV N/B-23 or 1 kb DNA fragment of pBICBI 2 which represented the respective coding region. The presence of the CMV coat protein gene was also detected by PCR analysis.

Transgenic pepper plants were inoculated three times with CMV strain P522 isolation from diseased pepper plant sap mixed with phosphate buffer. The second and third inoculations were done 20 and 40 days after the initial inoculation. Transgenic tomato plants were sequentially inoculated with virus strains Peet's, NT 9, and then a mixture of two virus strains using the same inoculation schedule as above. The R_1 population derived from the self-pollinated transformed R_0 plants were also evaluated for their resistance to CMV. ELISA testing was done 14, 44, and 60 days after the initial inoculation.

Integration of the truncated CMV RNA-2 replicase gene into the four transgenic lines each from hot pepper and sweet pepper was confirmed by Southern analysis. The transformed pepper plants were inoculated with CMV strain P522 and subjected to ELISA. Results showed that two of the four transformed hot pepper plants appeared to be resistant to CMV-P522 and no disease symptom developed after three virus inoculations (table 18). The rest of the transgenic R_0 hot peppers exhibited delayed mild symptoms compared to control plants. The R_1 progeny of self-pollinated R_0 hot pepper plants were also tested for virus resistance (table 18). Most of the R_1 plants developed symptoms 15 days after virus inoculation and only one symptomless R_1 seedling was identified among the 209 tested R_1 plants. Disease symptoms on transformed sweet peppers appeared 4 to 12 days later than those of the control plants, although all of them developed virus symptoms. Most of the R_1 sweet peppers developed severe disease symptoms and most of them died 60 days after virus infection.

Integration of the introduced gene (CMV-T coat protein or truncated CMV RNA-2 replicase gene) in the regenerated tomato plants was confirmed by PCR and Southern hybridization. Ten of the 44 transformed R_0 plants containing the CMV-T coat protein gene were resistant to CMV infection (table 18). Only four of the 30 transformed plants carrying the truncated CMV replicase gene did not show any symptoms and most of them developed severe disease symptoms (table 18). R_1 tomato seedlings derived from the self-pollinated transgenic R_0 plants were also tested for CMV reaction. Only one of the 91 R_1 tomato plants tested so far developed no symptoms and all others showed various levels of disease development (table 18). Disease development on some of the R_1 tomatoes was delayed and less severe compared to control plants (tables 18 and 19).

Table 18. Evaluation of development of CMV disease symptoms on transgenic peppers and tomatoes

Plant	Gene	Disease symptoms[a] Severe	Mild	None	ELISA Positive	Negative
R_0						
Hot pepper	RP[b]	0	2	2	1	3
Sweet pepper	RP	2	2	0	4	0
Tomato	RP	23	3	4	25	5
	CP[c]	10	24	10	33	11
R_1						
Hot pepper						
HP1 R1	RP[b]	84	23	0	107	0
HP2 R1	RP	79	22	1	102	0
Sweet pepper						
SP1 R1	RP	57	5	0	62	0
Tomato						
CPT1 R1	CPc	9	13	1	18	5
CPT4 R1	CP	18	7	0	22	3
CPT5 R1	CP	17	4	0	20	1
CPT16 R1	CP	19	3	0	22	0

[a] Severe: dead, shoestring, or necrosis. Mild: mosaic or mottle. None: No CMV disease symptoms 60 days after initial virus inoculation.
[b] CMV RNA-2 replicase gene.
[c] CMV-T coat protein gene.

Table 19. Evaluation of resistance levels of R_1 tomato seedlings derived from transgenic R_0 plants with CMV-T coat protein gene

Plant	Days after initial CMV inoculation 9		22		65		114	
Control (L 4783)	20/21	(95)[a]	21/21	(100)	21/21	(100)	21/21	(100)
CPT1 R1	12/23	(52)	16/23	(70)	16/23	(70)	22/23	(96)
CPT4 R1	7/25	(28)	20/25	(80)	22/25	(88)	25/25	(100)
CPT5 R1	12/21	(57)	20/21	(95)	20/21	(95)	21/21	(100)
CPT16 R1	18/22	(82)	19/22	(86)	20/22	(91)	22/22	(100)

[a] No. plants showing CMV disease symptoms / no. plants tested (percentage of plants showing disease symptoms).

It appeared that transformation of tomato and pepper with the coat protein gene provided a broader degree of resistance against CMV infection compared to the truncated replicase gene. The virus strains employed to evaluate resistance were not the same strains from which the coat protein gene and replicase genes were derived and may indicate that the coat protein gene offers protection against a wider spectrum of virus strains than the replicase gene. It has been reported that resistance provided by transformation with viral replicase gene sequences is more specific than that with coat protein transgenics.

Transformation of tomato plants for fusarium wilt resistance

Cell suspensions (10^8–10^9 cfu/ml) and culture filtrates with chitinolytic activity of *S. marcescens* were applied as root dips and soil drench (5 ml/plant) to 2-week-old tomato seedlings (Fantastic, CLN 698BC$_1$F$_2$-358-4-13, and L 4783). Subsequently, the seedlings were inoculated with *Fusarium oxysporum* f. sp. *lycopersici* (Fol) by root dipping and transplanted into a perlite: sand mix (2:3 V/V). The culture filtrate of *S. marcescens* lyophilized and precipitated with ammonium sulfate and chitinase purified from ammonium sulfate precipitate were tested for their chitinolytic activity and ability to inhibit the mycelium growth of Fol.

A DNA fragment (1.7 kb) containing the coding region of the chitinase gene from *S. marcescens* was previously cloned in *Escherichia coli* by means of PCR-based gene cloning. To construct an expressible chitinase gene clone for plant transformation, the 1.7-kb DNA fragment was ligated into the *Xba*I/*Sac*I site of a binary vector pBI121 to replace the *gus* gene, and thus ensured that the insert was located downstream from the CaMV 35S promoter. The resulting construct was transferred to the *Agrobacterium tumefaciens* disarmed strain LBA4404 by freeze-thaw method.

To determine the location of the cloned chitinase in transformed *E. coli*, *E. coli* culture containing the chitinase gene was divided into three fractions, i.e., supernatant, periplasm, and cytoplasm by centrifugation, osmotic shock method, and sonification, respectively. Samples of the three fractions were then examined by SDS-PAGE. The chitinolytic activity of different fractions was also tested by the turbidimetric method.

Previous results showed that *S. marcescens* could digest chitin and inhibit Fol growth in vitro. In this study, reduced severity of Fusarium wilt symptoms in tomato plants treated with the chitinolytic culture filtrate of *S. marcescens* but not intact *S. marcescens* (table 20) suggested that its secreted chitinase may have a inhibitory effect on the pathogen.

A chitinase isolate from *S. marcescens* was tested as an antifungal agent. The results showed that the isolated chitinase from *S. marcescens* did not reveal any chitinolytic or antifungal activity. This could be because the isolated chitinase had been denatured during the isolation process.

A protein with an approximate molecular size of 57 kD, identical with one of the chitinases purified from *S. marcescens*, was produced and secreted by *E. coli* transformed with the cloned chitinase gene (fig. 5). Chitinolytic activity of this expressed protein was detected (table 21). Antifungal activity of the expressed chitinase is still being tested. However, chitinase expressed in *E. coli* may not necessarily indicate that the cloned chitinase gene will also be expressed in higher plants. Plant transformation with this cloned gene is being prepared.

A bacterial chitinase gene fused with CaMV 35S promoter and terminator of nopaline synthase was constructed and confirmed by restriction enzyme digestion (fig. 6). The resulting construct was transferred to *A. tumefaciens* and confirmed by gel analysis (fig. 7).

Table 20. Effect of *Serratia marcescens* (Sm) and its culture filtrate on development of fusarium wilt in tomato after Fol inoculation by root dipping

	Fusarium wilt severity[a]		
Treatment	Fantastic	CLN 698	L 4783
Root dip with multiple Sm soil drench	9.6 ab	8.2 a	9.4 a
Fol-inoculated control	8.6 ab	8.3 a	8.5 a
Multiple Sm soil drench	7.2 bc	7.8 a	8.8 a
Multiple soil drench with culture filtrate	6.5 c	0.0 b	4.1 b
Noninoculated control	0.0 d	0.0 b	0.0 c

[a] Mean disease severity rating on a scale of 0-10 was taken 21 days after inoculation. Individual plant reactions were scored as follows: 0 = no symptom, 5 = stunted plant with vascular browning, 7.5 = severely stunted plant with vascular browning, and 10 = plant wilted or dead.

[b] Means separation by DMRT, $P < 0.05$.

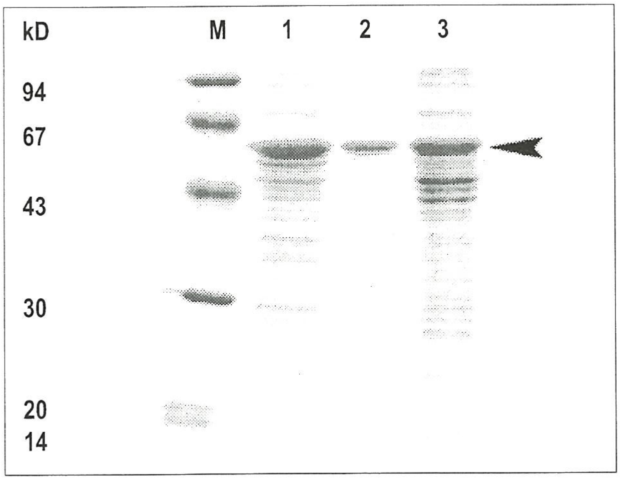

Fig. 5. SDS-PAGE analysis of the chitinase expressed in transformed *E. coli*
Lanes 1, 2 and 3, proteins in culture supernatant, periplasmic and cytoplasmic fractions of *E. coli*, respectively; lane M, m. t. markers. The position of the chitinase is indicated by an arrow.

Table 21. Chitinolytic assay for the expression of cloned chitinase gene in *E. coli*

Fraction	Absorbency reduction[a] (%)
Control blank	1.5
E. coli M15 (pQC327)[b]	
culture filtrate	15.3
periplasm	8.4
cytoplasm	17.7

[a] Data were taken 2 h after incubation of different fractions and chitin substrate.
[b] pQC327 = pQE*express* vector with cloned chitinase gene.

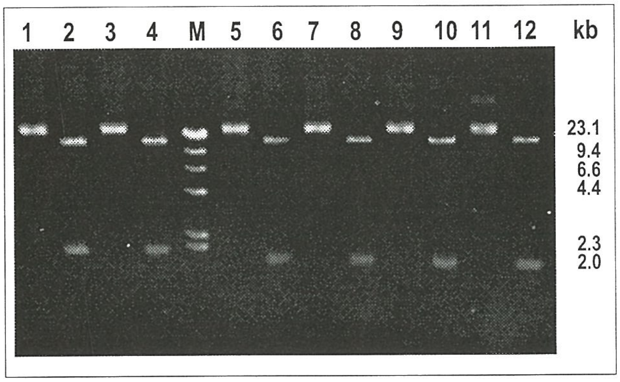

Fig. 6. Gel analysis of recombinant plasmids carrying *gus* or chitinase gene cloned from *S. marcescens*
Lanes 1 and 3, circular pBI121; lanes 2 and 4, *gus* fragments (1.9 kb) of pBI121 released by double digestion (*XbaI*/*SacI*); lanes 5, 7, 9 and 11, circular plasmids with an insert of chitinase gene; lanes 6, 8, 10 and 12, chitinase gene fragments (1.7 kb) created by double digestion (*XbaI*/*SacI*) of plasmids carrying chitinase gene; lane M, l/*Hin*dIII DNA size markers.

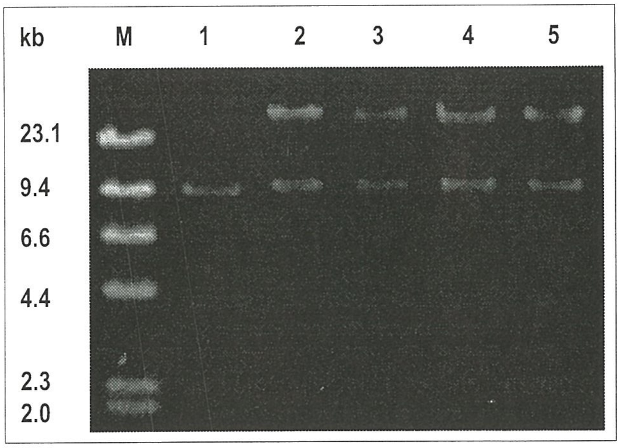

Fig. 7. Gel analysis of constructed plasmids containing chitinase gene cloned from *S. marcescens*
Lane 1, circular plasmid isolated from transformed *E. coli* JM109; lanes 2, 3, 4 and 5, circular plasmids isolated from transformed *A. tumefaciens* LBA4404; lane M, l/*Hin*dIII DNA size markers.

Legume Improvement

The legume improvement project works on two commodities: mungbean (*Vigna radiata*) and soybean (*Glycine max*) including grain and vegetable soybean. 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.

In 1995 soybean and vegetable soybean selections were sent to cooperators in 17 countries for evaluation. Three soybean breeding lines have been used to develop varieties for release in three countries, while two vegetable soybean breeding lines were popularly used in five countries. The Center continued its collaborative effort with Korea to advance early generation materials. Through shuttle breeding in various locations in Thailand, AVRDC hopes to develop widely adapted soybean and tropically adapted vegetable soybean types with multiple disease resistance.

A virus-specific DNA probe was developed to facilitate screening for mungbean yellow mosaic virus. The probe was tested and found useful for resistance screening in Pakistan and India.

Screening of mungbean germplasm for resistance to bean podborer continued. Selected moderately resistant accessions were identified and will be further evaluated to confirm their resistance. The efficacy of *Bacillus thuringiensis* against mungbean podborer was tested. A commercial preparation containing strain *aizawai* was found more effective in controlling podborer.

Regeneration and distribution of germplasm are regular activities at headquarters. Hybridization and selection of mungbean lines as well as the maintenance and distribution of the mungbean international nursery sets were done at the AVRDC Asian Regional Center (ARC) in Thailand.

This year 1500 accessions of soybeans were regenerated. The AVRDC Soybean Evaluation Trials (ASET) identified lines that yielded as high as or higher than the local checks but matured earlier. Lines were identified for homestead cultivation in Bangladesh, domestic consumption in Thailand, and as promising selections in Malaysia, Mauritius, Nepal, and Swaziland. Incorporation of the *lx lx* genes to produce lypoxygenase null lines and development of insect-resistant lines continue.

Partial shuttle breeding with Thailand resulted in the selection of AGS 190 and its release as Chiang Mai 1 (CM 1) for domestic consumption. Grain soybean lines with high fresh and dry matter yield and that can be harvested early were identified for use as green manure. Although vegetable soybean residue is lower compared to sesbania and crotalaria, cash return makes it attractive as an alternative green manure crop.

The efficacy of fishbean foliage against bruchids was tested. Fishbean powder killed bruchids for up to 1 year. A more efficient regeneration system for soybean and *Agrobacterium*-mediated transformation system for mungbean were developed.

Genetic resources activities

This year accessions with less than 1500 seeds remaining, less than 85% of the original viability, and possess special traits were regenerated.

The *Vigna* collection totals 6257 accessions of 5 species. *V. radiata* consists of 5248 accessions. The *Glycine* germplasm collection totals 14,062 accessions 12,759 of which belong to the species *G. max*. There are 13 *Glycine* species in the collection.

Only soybean was regenerated in 1995–96. A total of 1500 accessions were planted; 500 were regenerated for the first time and have been characterized based on a standard set of descriptors. The rest were in their second cycle of regeneration.

To date 6530 mungbean accessions or 91% of the mungbean collection including variants of mixed populations have seeds in long-term storage. In soybeans, 5572 accessions (45%) have seeds in long-term storage. For both groups almost all accessions have seeds in medium-term storage.

A total of 49 mungbean samples were sent to 7 countries and 4602 soybean samples to 37 countries and territories (table 1). Center scientists used germplasm for studies on iron bioavailability in mungbean and soybean, *Maruca* pod borer resistance in mungbean, screening soybean as green manure, and for soybean evaluation trials. Breeding lines of mungbean were distributed from AVRDC–ARC in Thailand.

Table 1. Recipient of AVRDC legume germplasm, 1996

Recipient	No. of samples	
	mungbean	soybean
External		
Korea	21	733
India	4	122
Taiwan	1	2671
Thailand	1	31
Vietnam	16	240
USA		64
Pakistan		55
Indonesia		56
Burkina Faso	5	6
Senegal	1	40
Costa Rica		62
Cambodia	12	44
Kenya	13	44
Others[a]		438
Subtotal	49	4602
AVRDC		
Breeding		274
Analytical laboratory	2	1
Entomology	2538	9
ARC	53	2
ARP		14
Subtotal	2593	300
Total	2642	4902

[a] Belgium, China, Congo, Ecuador, El Salvador, Ghana, Iran, Lesotho, Malawi, Malaysia, Marshall Is., Mauritius, Myanmar, Nepal, Philippines, Rwanda, Singapore, South Africa, St. Vincent and Grenadine, Trinidad and Tobago, Zaire, Zambia, Zimbabwe.

Breeding appropriate vegetable soybean

Vegetable soybean crosses were made between improved tropically-adapted, high-yielding multiple disease-resistant AVRDC *Glycine max* selection (AGS) grain soybean lines and selected vegetable soybeans. Backcross inbred generations were evaluated in Pingtung, Taiwan; and Chiang Mai and Kamphaengsaen, Thailand. Selections were based on total pod yield, consumer quality, and shelled bean.

This year 26 crosses were made to incorporate large pod and seed size, lipoxygenase (*lx*) null, and good pod appearance in selected breeding lines with good yield.

Eleven yield trials were conducted in 1995 and 3 advanced and intermediate yield trials were conducted in 1996. A combined analysis of (1995) three-season data confirmed the 1994 results that season had a predominant influence on graded pod yield, seed size, sugar and fiber content. However, unlike in 1994 the graded pod yield in spring 1995 (7.7 t/ha) was highest followed by summer and autumn (5.6 and 5.1 t/ha, respectively) which did not differ significantly (table 2). As in 1994 the sugar content was higher in autumn 1995 (table 2).

Table 2. **Influence of season on graded pod yield and other traits, AYT, 1995**

Season	Yield (t/ha)		100-	Pod		Dry	Protein	Fat	Sugar
	Graded pod	Total pod	seed weight (g)	length (cm)	width (cm)	matter (%)			(%)
95 spring	7.7a	13.6a	77.4a	5.05b	1.30b	33.7a	43.1a	20.3b	10.4b
95 summer	5.1b	9.3b	63.5c	4.99b	1.27c	31.7c	42.7a	20.5a	10.2c
95 autumn	5.6b	10.0b	73.2b	5.11a	1.37a	32.3b	42.2b	18.7c	13.4a

In one AYT and two IYTs conducted in spring 1996, 11 entries had graded pod yields (table 3) similar to the check AGS 292, but the length and width of 2-seeded pod were far larger than the check as well as the population mean. Based on summer and autumn season trials selections will be made for testing by cooperators in different countries.

Table 3. **Graded pod yield of selections with large pod size compared to check in spring, 1996**

Trial	Entry	Graded pod yield (t/ha)	100-seed weight (g)
AYTV	GC 89039-5-2	9.6[a]	63.8
	GC 91023-189-3-2	7.2[a]	68.5
	GC 91025-149-6-4	6.9	72.7
	GC 89013-3-1	4.0	76.2
	AGS 292 (ck)	8.4	69.7
IYTV 1	GC 92018-267PL-7M-1	6.3	71.7
	GC 92018-12-1	5.4	61.0
	GC 92018-261PS-3S-1	4.8	81.5
	AGS 292 (ck)	10.7	72.3
IYTV 2	GC 92005-9S-3M-1	9.2[a]	73.9
	GC 92005-27S-1S-2	9.2[a]	68.9
	GC 92005-28M-2L-2	9.0[a]	73.5
	GC 92005-72-2-4-2	7.0	76.4
	AGS 292 (ck)	10.7	72.3

[a] Yield is same as AGS 292 according to LSD P = 0.05 level.

AVRDC soybean evaluation trial

Advanced breeding lines from AVRDC and promising lines or improved varieties from partner countries were included in the AVRDC Soybean Evaluation Trial (ASET). Six AVRDC soybean evaluation trials, 42 AVRDC Glycine selections (AGS), 202 pedigree selections, and 173 selected accessions were distributed to 32 cooperators in 20 countries in Africa, Asia, and Latin America. Interest in AVRDC materials has increased with 11 cooperators from nine countries returning their evaluation results.

Three AVRDC selections, AGS 19, AGS 129, and GC 86017-170-1N, gave yields of 4 t/ha which were comparable with the highest yielder UFV-2 (5 t/ha) in Iran. However, AGS 129 matured in 127 days compared to UFV-2's 181 days.

In Laos six AVRDC selections (AGS 19, AGS 327, AGS 73, AGS 129, AGS 314, and GC 84040-27-1) yielded 2.1 to 2.7 t/ha in 91 to 97 days compared to the check's 1.1 t/ha in 104 days. In Bhutan AGS 327 and 269 gave more than 2 t/ha in 116 days compared to the check's 1.5 t/ha in 144 days.

Nestle in Singapore has been evaluating 20 AVRDC selections in Johore, Malaysia for three seasons since 1994; six organoleptically acceptable lines have a mean yield of 2.2 to 2.9 t/ha. In Vietnam three AVRDC lines, GC 86107-170-1N, GC 84040-7-1, and SRE-D-14B, gave yields of 3.4 to 3.7 t/ha in 93 to 96 days. Vietnam has officially released AVRDC's narrow-leaflet AGS 129 as G 87-5 to their farmers; it has a yield potential of up to 2 t/ha.

Trials conducted in Bangladesh using AVRDC's G 2120 M7(69-1) resulted in the line being recommended for planting in cold months.

A complete list of varieties released by national programs worldwide is shown in table 4.

AVRDC vegetable soybean evaluation trial

Promising vegetable soybean introductions and improved breeding lines from AVRDC and from other partner countries were utilized to make a set for the AVRDC Vegetable Soybean Evaluation Trial (AVSET).

Table 4. **AVRDC soybeans released by cooperators as of 1996**

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, CVMV
Taiwan 30050	AGS 17	1982	Malaysia	HY, MH
BPI Sy4	AGS 73	1985	Philippines	HY, EM, UM, LSV, BP, R, L, S, WA
La Carlotta Soy 1 (PSBSY-1)	Clark 63 x AGS 129 (LGSY 01-24)	1990	Philippines	(BP, R), EM, UM, L, (S) acceptable to Nestle
BPI-Sy 6 (Saguisag)	AGS 19	1990	Philippines	NL, HY, resistant to virus
Kaohsiung No. 9	AGS 12	1982	Taiwan	HY, NP, SSR, SQ
Kaohsiung No. 10	AGS 129	1985	Taiwan	HY, NL, BP, SSP
Tainan No. 1	AGS 66	1986	Taiwan	HY, S, MH, EM, SP, DM, BP, L, BS
Tainan No. 2	AGS 341	1993	Taiwan	NL, MH, HY, DM, (B), suited to spring and summer planting
Sukothai No. 1	AGS 9	1986	Thailand	NL, HY, NP, (R, DM, PSS)
Dowling	G 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
Nyalab	GC 30229-8	1992	Zimbabwe	HY, EM, Det
Seti Bhatta	KS 419 x KS 525	-	Nepal	HY, adapted to intercropping with maize
G 87-5	AGS 129	-	Vietnam	HY, NL, BP
Total	25		12	

[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.

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

Interest in evaluating AVRDC vegetable soybean is steadily increasing, with 10 new cooperators this year. A total of 17 AVSETs, 77 AGS lines, 129 pedigree lines, and 38 other accessions were distributed to 34 cooperators in 27 countries. Nine countries returned the data for 13 trials.

In Bangladesh out of 10 entries evaluated, GC 83005-9 gave nearly 10 t/ha of total pod yield in 102 to 108 days. GC 83005-9 was recommended by the Mennonite Central Committee for homestead cultivation.

From 1986 to 1992, the Department of Agriculture, Thailand, through the Chiang Mai Field Crops Research Center (CMFCRC), conducted a total of 58 field trials on vegetable soybeans. Trials resulted in the release of AVRDC's AGS 190 (Vesoy #4) as Chiang Mai No.1 (CM 1). CM 1 yielded 10 t/ha of vegetable soybean pod in 75 days. It is significantly higher yielding than Nakonsawan 1 (NK 1), the check. It has a 100-pod and 100-fresh seed weight of 216 g and 56 g, respectively. Fresh pod color was dark green and after boiling in water for 5 minutes, the pod tasted sweet.

Some of the newer AVRDC selections gave 5 to 10 t/ha graded pod in the 1994 and 1995 trials at the Malaysian Agricultural Research and Development Institute. Trial results showed that AGS 292, 333, and 338 are promising new selections.

In Mauritius AGS 339 and AGS 338 gave a graded pod yield of 7 and 5 t/ha, respectively.

AGS 337 and 336 gave a yield of 33 and 30 t/ha, respectively in Swaziland in an evaluation conducted by the ROC Agricultural Technical Mission.

In Nepal GC 84126-13-1-2 yielded 14 t/ha of fresh pod in 105 days.

The total number of released vegetable soybean varieties from AVRDC lines now stands at 9 (table 5).

Seed multiplication of elite and Korean breeding lines

The cooperation between AVRDC and Korea continued on its 22nd year. The cooperation has halved the time taken to bulk the seed of Korean soybean lines and release the variety in Korea.

Fourteen soybean crosses in F_6 and 27 crosses from F_2 were advanced in spring. Eight lines with powdery mildew and 20 lines with SMV-N line symptoms were discarded. Seed from 14 advanced generation lines (F_6) and 732 selected pedigrees weighing 6.6 kg were sent to Korea for planting in June.

From seeds of 27 F_3 entries planted on 16 February a total of 2909 seeds were harvested as single-seed-descent and planted on 18 June in a vinyl house for generation advance.

Table 5. AVRDC vegetable soybean released by cooperators as of 1996

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 soymilk and ice cream and soynuts, less beany flavor
Kaohsiung No.1	AGS 292	1987	Taiwan	HY, MH, DM,.EM
Kaohsiung No.2	Ryokkoh x KS 8	1991	Taiwan	HY, MH
Kaohsiung No.3	PI 157424 x KS 8	1991	Taiwan	HY, MH
KPS 292	AGS 292	1992	Thailand	HY
CM 1	AGS 190	1995	Thailand	HY, suitable for domestic consumption
GC 83005-9	GC 83005-9	1995	Bangladesh	HY, suitable for homestead cultivation

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

Evaluation of *lxlx* gene in elite lines

Elite lines derived from the *Lx1Lx2Lx3* x *lx1lx2lx3* crosses made in Japan were planted in replicated plots. The materials are now in BC_3F_2. They need to be backcrossed two more times to develop isogenic lines. Also, one set of triple nulls for *lx* genes from BC_3F_2 were advanced to F_4. The true breeding inbred line from BC_3F_3 was compared with their recurrent parents in spring. The BC_3F_3 resembled the recurrent parent in at least one cross. For the two vegetable soybean crosses, inbred lines were late flowering compared to the check. However, the grain soybean cross and its inbred line with triple nulls took the same number of days to flower.

Developing insect-resistant soybeans using Brazilian lines

Progenies of crosses between four stink bug-resistant selections (IAC 100, 80/596-2, 78-2318, and 80-4228) from Brazil and promising AVRDC lines were screened in the field without insecticides to determine their resistance level. The best surviving plants from each generation were advanced. All the materials were planted at CMFCRC and ARC, Thailand. During summer 241 lines were selected from 1286 lines selected the previous autumn based on agronomic traits and resistance to bacterial pustule and downy mildew. Further selection was based on the preliminary yield. From each cross combination, 20 high-yielding selections were selected for further evaluation (table 6).

Table 6. Mean seed weight of F_7 lines from four crosses selected for insect resistance in summer 1996

F_7 derived cross	No. of plants		Mean seed weight		Effective[b] selection intensity
	Total[a]	Selections	Total	Selection	
GC 90001	44	20	297 ± 69.5[c]	322 ± 51.5	0.35
GC 90004	65	20	146 ± 70.0	199 ± 70.9	0.76
GC 90012	101	20	267 ± 57.4	318 ± 45.2	0.89
GC 90013	31	20	203 ± 70.2	237 ± 59.9	0.48
Total	241	80			

[a] Selection based on visual observation in the field.
[b] i = S/Òp, where S is the effective selection differential | X selection - X total |.
[c] Standard deviation.

Selection of soybean for green manure

Soybeans have been used as forage and green manure crop. Vegetable soybeans when harvested have been known to return 60 to 75% of the total biomass to the soil. Grain soybeans which are sensitive to photoperiod and temperature and that can produce more biomass were selected for evaluation as green manure. Similarly vegetable soybeans with high total biomass yield were selected for comparison with sesbania and crotalaria.

Six grain soybeans were evaluated in summer for their value as a green manure crop. Green Soybean, Improved Pelican, Tropical, and G 2120 had the highest fresh and dry matter yield. Improved Pelican was the earliest to harvest in 60 days (table 7).

Among the six vegetable soybeans evaluated for dual purpose (as a vegetable and residue as a green manure) four lines produced about 20 to 23 t/ha residue and 13 to 16 t/ha total pod or 5 to 9 t/ha shelled beans in 80 to 87 days (table 8). The cash returns from the total pod or shelled bean are ~US$4300 to 5300 and $2700 to 3500, respectively. The residue from vegetable soybean is about 2/3 that of sesbania and about half that of crotalaria. However, considering the cash return vegetable soybean appears quite attractive as an alternative green manure crop.

The traditional green manure crops, sesbania and crotalaria, were harvested in 72 and 81 days, respectively. Crotalaria and sesbania gave a fresh and dry matter yield of 41 and 12 t/ha, and 32 and 8 t/ha, respectively. Vegetable soybeans compared favorably with the two green manures considering returns to the farmer.

Table 7. **Performance of grain soybeans as a green manure, summer 1996**

Entry	Yield (t/ha)		Days to harvest
	Fresh	Dry	
Green Soybean	23.3	5.2	72
Improved Pelican	22.9	5.0	60
Tropical	21.4	5.5	72
G 2120	20.8	5.0	73
Bossier Late	18.9	5.1	67
AGS 314	18.9	3.8	65
Mean	21.0	4.9	68
CV (%)	10.1	14.0	
LSD (0.05)	3.8	1.2	

Table 8. **Selections of vegetable soybean for dual purpose, summer 1996**

Entry	Fresh yield (t/ha)		Shelled bean wt. (t/ha)	Days to harvest	Dry yield residue (t/ha)
	Residue	Total pod			
GC 91023-189-3	23.0	15.9	7.6	87	6.4
AGS 190	22.7	14.5	8.6	87	7.2
GC 87021-13-B-5	20.9	12.9	5.3	80	4.6
GC 89012-5	19.7	13.7	6.5	80	5.3
KS 3	18.3	14.1	6.5	87	5.1
GC 89005-3-3-4	17.3	14.8	7.5	83	5.0
Mean	18.6	13.3	6.3	83	5.1
CV (%)	12.0	10.8	10.3		10.9
LSD (0.05)	3.8	2.5	1.1		10.0

Effectiveness of fishbean foliage in controlling bruchids on mungbean seeds

Attempts were made to control bruchid, *Callosobruchus chinensis*, a serious pest of mungbean worldwide, with fishbean, *Tephrosia vogelii*, leaf powder. Fish bean foliage is used in certain African countries to control insects and ticks. Its major insecticidal compound is rotenone. It has low toxicity to mammals, is much easier to establish than the well-known insecticidal plant neem, and is readily available throughout the year within 4 months of planting.

Freshly harvested leaves of fishbean were air-dried for several days. Dried leaves were ground into a fine powder. Thirty-two kilograms of mungbean seeds were divided into four lots of 8 kg each. Three seed lots were thoroughly coated with 1, 2, and 4 g fishbean leaf powder per kilogram seed and stored in fine mesh nylon net bags in the laboratory. The fourth seed lot was kept as untreated check. Each seed lot was divided into four replicates (2 kg). Seed samples withdrawn from the bags every 2 weeks were exposed for 24 h to bruchid adults, and insect mortality, number of first generation adults after 1 month, and percentage of seeds damaged were recorded.

The temperature during the experimental period ranged from 16 to 34°C and humidity from 44 to 95%.

Insect mortality after bruchid adults were exposed to seeds once every 2 weeks is presented in fig. 1. All three concentrations of fishbean powder killed bruchids for up to 1 year. Even the lowest dose of 1 g/1 kg seed remained efficacious for up to 1 year.

In seed samples taken during the first 10 weeks, there was no F_1 progeny, indicating that the adults exposed to fishbean-coated seeds died immediately before they could lay eggs and produce progeny. In later observations, however, even though insect mortality was 100% or approached 100%, some F_1 adults emerged. Some insects were able to lay eggs before succumbing to the toxicant. The eggs hatched successfully and larva bored in the seed and developed into adults. Fish bean, thus, does not seem to have an ovicidal effect on bruchid eggs.

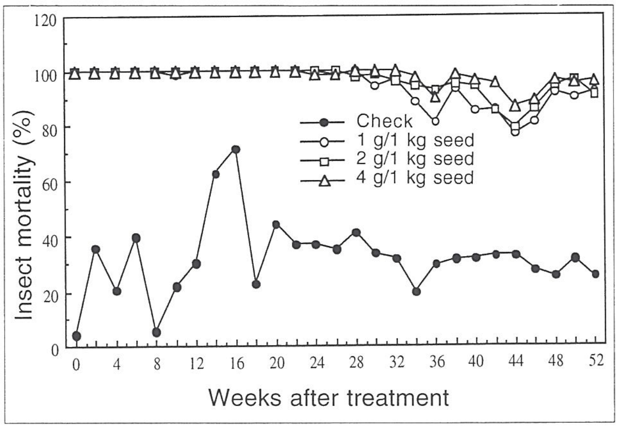

Fig. 1. **Effect of various dosages of fishbean powder on mortality of *C. chinense* adults exposed to coated seeds once every 2 weeks for 1 year**

The seed damage, therefore, resulted from the bruchid larvae feeding inside the seed and successful emergence of adults.

Testing of various Bt strains for effectiveness against *Maruca testulalis*

Legume podborer (*Maruca testulalis*) is the most destructive pest of mungbean, cowpea, and yard-long bean in Asia and Africa. Some mungbean farmers have resorted to spraying chemical insecticides to control this podborer in mungbean. Insecticide toxicants very rarely reach the insect unless sprayed frequently to kill neonate larvae before they bore in the pod or flower. In recent years *Maruca* has become even more serious.

The use of *Bacillus thuringiensis* (Bt) appears to be an attractive alternative to control podborers effectively. In this experiment *Maruca* larvae were fed with various strains of Bt sprayed on *Sesbania* leaves to determine whether Bt can control *Maruca* and which Bt strain is more effective.

Second and third instar *Maruca* larvae from a *Sesbania* field around AVRDC or from farmers' fields were collected, placed in acrylic jars, and fed with *Sesbania* leaves. Both ends of the acrylic jars were covered by muslin cloth.

Four Bt products (Thuricide, Dipel, XenTari, and MVP) were tested. Freshly harvested *Sesbania* leaves were dipped in various concentrations of the Bt products. Ten 2nd or 3rd instar larvae were reared on treated and untreated leaves. Insect mortality was recorded daily for 3-4 days. All experiments were conducted at room temperature.

LC_{50} of each product was calculated from graphs of corrected percent mortality against product concentrations. Results of the mortality test are shown in table 9. The higher the Bt concentration, the higher was the insect mortality. Dipel had the greatest mortality at lowest concentration. Insect mortality increased more steeply with increasing concentration of this Bt product.

Comparison of LC_{50} of different Bt products is shown in table 10. Dipel has the lowest LC_{50} value, 5086 DBM μ/ml, and MVP has the highest value of 24843 DBM μ/ml. Dipel is thus the most effective Bt product and MVP the least effective one.

Table 9. Mortality of *Maruca testulalis* larvae in various concentrations of four Bt products

Commercial products	Concentration (DBM μ/ml)	Mean corrected mortality	Mean mortality
Thuricide	0	10.0	10.0
	15000	73.3 ± 15.3	70.3
	30000	90.0 ± 10.0	88.9
	45000	93.3 ± 5.8	92.6
	60000	93.3 ± 5.8	92.6
XenTari	0	16.7	16.7
	2148	40.0 ± 10.0	27.9
	4296	53.3 ± 20.8	43.9
	10740	56.7 ± 20.8	47.9
	21480	66.7 ± 5.8	60.0
MVP	0	16.7	16.7
	8000	30.0 ± 10.0	15.9
	12000	36.7 ± 20.8	23.9
	16000	43.3 ± 11.6	31.9
	20000	53.3 ± 15.3	43.9
Dipel	0	40.0	40.0
	5000	66.7 ± 25.2	44.4
	15000	96.7 ± 5.8	94.4
	30000	93.3 ± 11.6	88.9
	45000	100.0 ± 0.0	100

Table 10. LC_{50} comparison of different Bt products on *Maruca testulalis*

Treatment		Value
Thuricide	LC_{50}	6,676
	LC_{95}	64,510
XenTari	LC_{50}	10,154
MVP	LC_{50}	24,843
	LC_{95}	144,580
Dipel	LC_{50}	5,086
	LC_{95}	2,765,679

Establishment and improvement of transformation systems for mungbean and vegetable soybean

The previously established regeneration system for vegetable soybean and mungbean had two problems: (1) regeneration of soybean plantlets was not consistent and (2) rooting efficiency of both soybean and mungbean was low. Hence, different regeneration protocols and rooting strategies were tried to overcome these problems. Efforts were also made to explore the optimal conditions for the transformation of mungbean VC 1973A and soybean Kaohsiung No.2.

Regeneration systems of soybean and mungbean

Kaohsiung No.2 cotyledon explants were cultured on MS medium supplemented with 1 mg/l BAP, 0.7 mg/l GA_3 and 1% sucrose. After 1 month multiple shoots were observed on 65% (78 of 120) of cultured explants, although there was no root differentiation on most of the regenerated shoots with only 1-3 shoots/regenerated cotyledon and two shoots with roots.

Immature embryos of Kaohsiung No.2 were cultured on MS medium supplemented with 13.3 µM BAP, 5 µM thiamine, and 12 µM proline for 2 weeks and transferred to MS medium supplemented with 1.7 µM BA and 0.2 µM IBA MBI. Multiple shoots were observed 2 months after the initial culture. Percentage multiple shoots were 33% for ≤ 5 mm cotyledons, 35% for 6–7 mm, 78% for 8–10 mm, and 99% ≥ 11 mm. However, there was no multiple shoot formation on the same medium for mungbean NM 92 and VC 1973A.

To improve the root formation of regenerated shoots, VC 1973A cotyledons were cultured on MS, B5, and MB medium supplemented with 2 mg/l kinetin. Roots and shoots were induced in 2 weeks, with 20% rooting in MS, 40% on B5, and 30% on MB media.

Infection of regenerated shoots with *Agrobacterium rhizogenes* was also tried to improve root formation. Seventeen regenerated shoots of VC 1973A were infected with *A. rhizogenes* strain A4 to induce rooting. Root formation was observed on one of the infected shoots which was later successfully transplanted in the greenhouse. Roots were also found on the other two shoots; however, roots did not continue to develop.

Transformation systems of soybean and mungbean

Cotyledons of germinated VC 1973A seeds were bombarded with pBI121 and pGFP with Biolistic PDS1000/He at three different pressures: 1300, 1550, and 1800 psi. Ten cotyledons were bombarded for each reporter gene and bombarding pressure combination. None of the regenerated plantlets indicated GUS activity or response to GFP fluorescent light.

Previous data suggested that VC 1973A cotyledons infected with LBA4404/pBI121 and A281/pMT1 showed better ability to regenerate and exhibited higher percentage of GUS activity. Based on these data, *Agrobacterium* strain A281/pMT1 and LBA4404/pBI121 were used to infect cotyledons of VC 1973A. DNA was extracted from regenerated plantlets on selection medium for PCR screening (fig. 2). One of the seven plantlets regenerated from cotyledons infected with A281/pMT1 showed bands corresponding to *gus*A and *npt*II genes, indicating the transformation of these two genes into plant genome. No expected bands of *gus*A and *npt*II genes were detected in genomic DNA of regenerated Kaohsiung No. 2 plantlets.

Current data indicated that a more efficient regeneration system for Kaohsiung No.2 and *Agrobacterium*-mediated transformation system for VC 1973A can be achieved.

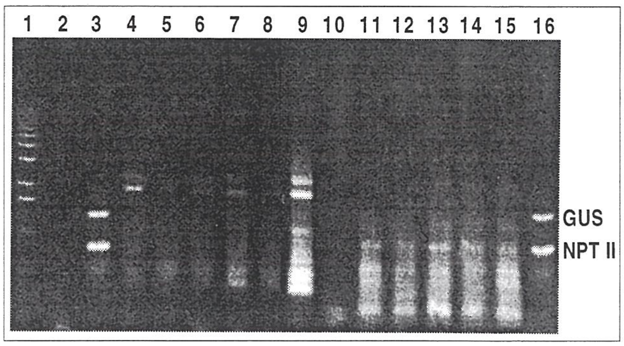

Fig. 2. PCR analysis of regenerated plants
Lane 1, DNA size marker; lane 2, blank; lanes 3–9, plants regenerated from selection medium; lanes 10–15, negative control; lane 16, positive control plasmid

Sustainable Use of Natural Resources and Inputs

The primary objective of this project is the development of technologies that maintain or increase agricultural productivity without ecologically damaging consequences. To produce high-yielding crops, large quantities of P and K must be readily available in the soil to meet the substantial requirements of vegetables. Crop recoveries of applied fertilizer nutrients are usually much less than 50%. Thus, the unrecovered fertilizers accumulate from repeated applications to increase soil availabilities. When availabilities reach a critical level, crops no longer respond to fresh applications. To determine probable contributions from the accumulated nutrients, data from a long-term experiment were analyzed and soils were fractionated to assess the sizes of moderately available P and K pools. The sizes of the pools have implications for nutrient management.

In addition to contributions from nutrients accumulated from repeated fertilizer applications, vegetables obtain nutrients from recycled crop residues, animal manures, and processing wastes. Evolving economic factors and mounting environmental concerns are likely to increase the relevance of recycled nutrients to the profitability of intensive vegetable production systems. The quantities of N, P, and K available from representative waste sources were determined experimentally. This information is necessary to determine the extent to which inorganic fertilizer rates can be reduced by incorporating wastes.

Research on home gardens and noncirculating hydroponic systems continued. Home garden research emphasized the identification of species well adapted to hot and humid weather. Species adapted to these conditions are required to maintain required levels of essential vitamins and minerals for family nutrition during the summer seasons.

Crop requirements for hydroponic cultivation systems were determined. Further research concentrated on simplification of the hydroponic systems and practices to maintain production levels during the hot and humid summer season.

K and NH_4 fixation and recovery

Effect of net K removal on exchangeable K

Potassium in soil solution is replenished from the weathering of K-bearing minerals and from nonexchangeable and exchangeable K pools. AVRDC soils contain large quantities of available K even when the exchangeable pool has been depleted to less than 40 mg K/kg soil.

In an experiment in which cabbage, sweet corn, eggplant, and cabbage were cultivated in that sequence, exchangeable K was reduced in all treatments regardless of the quantities of K applied. The four crops removed 454 kg K/ha when K fertilizer was not applied and 507 kg K/ha when 100 kg K/ha was applied. A regression of exchangeable K on net removal (cumulative K taken up by the crops minus cumulative K applied) calculated for each treatment and for each of the four crops in the sequence revealed the rate at which exchangeable K was depleted as net removal increased (fig. 1). A single regression equation was as valid for the inorganic fertilizer data as it was for the waste treatment data which suggests that the fates of K (i.e., uptake by crops, and diffusion to exchangeable and nonexchangeable K sites) from both sources were similar.

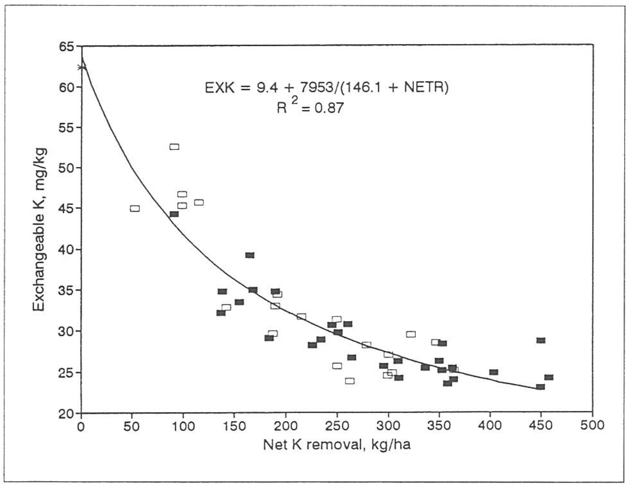

Fig. 1. The effect of net K removal (NETR = cumulative K taken up by successive crops minus cumulative K applied on exchangeable K (EXK)
Open and filled boxes represent waste and inorganic fertilizer treatment data, respectively. Mean preexperiment exchangeable K is represented by an asterisk.

The first cabbage crop drew down exchangeable K in the plow layer substantially so that this pool was not a major source for K uptake thereafter (fig. 1). Estimated marginal net decreases in the exchangeable pool were only 0.13 and 0.04 mg K/kg soil per net removal of 1 kg after 100 and 300 kg K/ha had been removed, respectively. Some K was probably taken up from the subsoil as well as from a nonexchangeable K pool.

Release of nonexchangeable soil K from textural fractions

The clay size fraction is usually regarded as the main source of nonexchangeable K, but recent studies have demonstrated that larger size fractions contribute also. However, the clay contents of AVRDC soils averaged only about 120 g/kg. Little is known about the particle size ranges that contribute to K uptake from these soils. Eighty-five percent of the particles in AVRDC soils were in the coarse silt to fine sand range (20~50 and 50~250 µm, respectively, table 1). To assess the contributions from these ranges, textural fractions of the soil were separated. To create a sink for nonexchangeable K, a planer rhizosphere was created by growing kangkong seedlings on a fine net to form a root mat. These mats were placed on gels in which the separated particle fractions were suspended. To separate the particles, subsurface soil (30~40 cm, pH 7.5, 0.07 cmol/kg exchangeable K, and 8.4 cmol/kg CEC) was crushed, passed through a 2 mm sieve, and dispersed by ultra-sonication without prior treatment. Wet-sieving, repeated centrifugation, and sedimentation were performed to separate clay (0~2 µm), fine silt (2~20 µm), coarse silt (20~50 µm), and fine sand (50~250 µm fractions). The four fractions were Ca-saturated with 1 M $CaCl_2$ to displace exchangeable K and to flocculate the

Table 1. **Relative abundance of textural fractions, K concentrations in plants, uptake, and released from four particle size fractions**

Fraction	Particle size	Particle abundance	K tissue concentration	K uptake	K released from	
					Fraction	Whole soil
	(μm)	(g/kg)		(mg/dish)	(mg/g)	
Clay	0~2	117	7.6	7.19	1198	140
Fine silt	2~20	24	7.8	7.58	1485	36
Coarse silt	20~50	413	7.1	7.44	878	360
Fine sand	50~250	442	7.5	7.28	1400	625
SE			0.44	0.35	162	

particles. The flocculated particles were then freeze-dried. To suspend the fractions in gels, a 30-ml K-free nutrient solution containing 0.3 g agarose was boiled for 20 min; the particle fractions were added and the suspension was cooled to 40~45°C. Five milliliters of the suspension, which contained about 1 g of the soil particles, was injected onto a shallow petri dish (58 mm diam, 8 mm height) and cooled to room temperature to form a gel. The particle size treatments were replicated three times.

Kangkong seeds, surface sterilized with $Ca(OCl)_2$ for 20 min, were germinated in deionized water and 15 sprouted seeds were then transferred onto each of 12 culture devices. Each device, designed to fit on the 58-mm-diam petri dishes, was resupplied with fresh K-free nutrient solution daily for 8 days so that the seedlings formed a dense root mat on a 400 mesh net. After 8 days the plants contained an average 6.55 mg per device. The root mats were then placed in contact with the particle-agarose gel for 8 days, after which the plants were removed, oven-dried weighed, and digested to determine K concentration. After the plants were removed, the gels were put into centrifuge tubes with 20 ml deionized water and heated to 90°C in a water bath. The suspension was centrifuged and the K concentration in supernatant was determined.

Table 2 shows that the K uptake from the various size fractions differed only slightly. Regardless of size range, the plants obtained 0.09 to 0.15 mg K per day from each gram of soil fraction which, when expressed on a hectare basis, averaged about 250 kg/ha per day. The low K concentrations of the tissue (7.1~7.8 g/kg range) is evidence that the crops were under K stress and therefore the root mats would have acted as strong K sinked. When adjusted for the relative abundance of each fraction in the total soil, it was apparent that under field conditions the coarse silt and fine sand fractions would contribute large quantities to K uptake. In the field, the bulk of the contribution would come from the coarse silt and fine sand fractions (20~250 μm) because these fractions contained 85% of the total soil mass.

Table 2. **The pH, EC and nutrient concentrations of the initial bulk soil and at four depths after 20 days of 5.8 mm evaporation per day**

Soil depth (cm)	pH	EC dS/m	Extract. NO_3^--N	Exch.K	Exch. Ca	Exch. Mg
			(mg/kg soil)			
Initial soil	7.50	0.05	19.1	28.7	1942	240.8
0~1.5	6.90	0.34	167.3	23.9	2105	281.7
1.5~4	7.65	0.01	3.6	23.3	1836	232.2
4~8	7.73	0.01	1.7	22.8	1861	233.0
8~12	7.95	0.01	1.3	23.2	1860	231.4
SEx	0.03	0.006	3.69	0.33	21.7	2.60

Effect of organic wastes on vegetable yields and soil properties

Nutrient releases from vegetable crop residues

The demand for nutrients during early growth by crops such as Chinese cabbage can be large. The extent to which a nutrient from an incorporated crop residue can substitute for an inorganic source during early growth depends partially on how rapidly it is released to soil solution. Resin capsules accumulate soil nutrients by diffusion through soil solution, a process that simulates nutrient diffusion to a root surface. Capsules were inserted into soil that had been mixed with ground plant residue samples to compare time courses of accumulation among sources as well as to accumulation from an unamended soil. The soil was from an AVRDC field (20-40 cm) on which available P and K had been drawn down by repeated cropping. It contained 14 mg P/kg (Olsen), and 0.12, 23, 1157, and 148 mg/kg of exchangeable NH_4-N, K, Ca, and Mg, respectively. One hundred milliliter samples of fresh sieved soil were mixed with residues of tomato or common cabbage or vegetable soybean (dried and ground), placed in covered 230 ml plastic cups and mixed to a saturated paste. The cups received 0.64 g per cup tomato residue (equivalent to 8 t dry matter/ha) or 0.27 g/cup common cabbage residue (3.4 t/ha soil) or 0.47 g/cup vegetable soybean residue (5.9 t/ha). These residue rates were approximately equivalent to twice the quantities that would be incorporated after a medium- to high-yielding crop. The nutrient concentrations of the residues and quantities of each nutrient applied per cup are listed in table 3. A resin capsule (PST-1; Unibest Inc., Bozeman, MT, USA) was inserted into the center of the volume in every cup. The saturated pastes were incubated at 25°C for 37, 66, 133, or 229 h, after which capsules were removed from the cups, washed free of soil with water, stripped of nutrients with 50 ml 2M HCl, and analyzed for NH_4^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, and PO_4^{3-}. The quantities absorbed at each sampling time are shown in fig. 2.

Releases of P, K, Ca, and Mg from the residues, as reflected by accumulation on resin capsules, followed the model $M_{res} = \ln(ct + 1)/b$ where M_{res} was the accumulation of P, K, Ca, and Mg (µg/capsule) and t was hours of incubation. Parameters b and c were estimated by nonlinear regression. The time courses for NH_4-N did not follow the model, but exhibited rapid accumulations which were probably followed by nitrification and then by denitrification of mineralized N so that net accumulation rates were not sustained. Nitrate-N accumulated for about 2 days, but was then depleted to negligible levels.

Accumulations of K, Ca, and Mg from the residues increased rapidly compared to accumulations from an unamended soil. After 229 h the ratios of K, Ca, and Mg accumulated from tomato residue to that accumulated from the unamended soil were 13, 2.5, and 3.3, respectively. Cation accumulations were in general agreement with the relative quantities of the nutrients in the tissue such that time courses differed only slightly when adjusted for the quantity applied. In contrast to the rapid releases of K, Ca, and Mg from the residues, P appears to have been immobilized for as long as 8 days. After almost 10 days, the ratio of P accumulated from tomato residue to P from the soil was only 1.1. Moreover, the rate of P accumulation from soybean exceeded that from tomato, perhaps because the mean P tissue concentration of the former was greater (table 3). Rates of P mineralization from residues may be inadequate to meet crop requirements during early growth but should supplement soil P when availability is marginal.

Table 3. Concentrations of N, P and K in residues and quantities applied per cup

	Tissue conc. (mg/g)			Quantity/cup (mg)		
Species	N	P	K	N	P	K
Cabbage	27	2.2	28	7.3	0.6	7.6
Soybean	24	2.4	9	11.5	1.1	4.0
Tomato	21	1.9	30	13.3	1.2	18.9

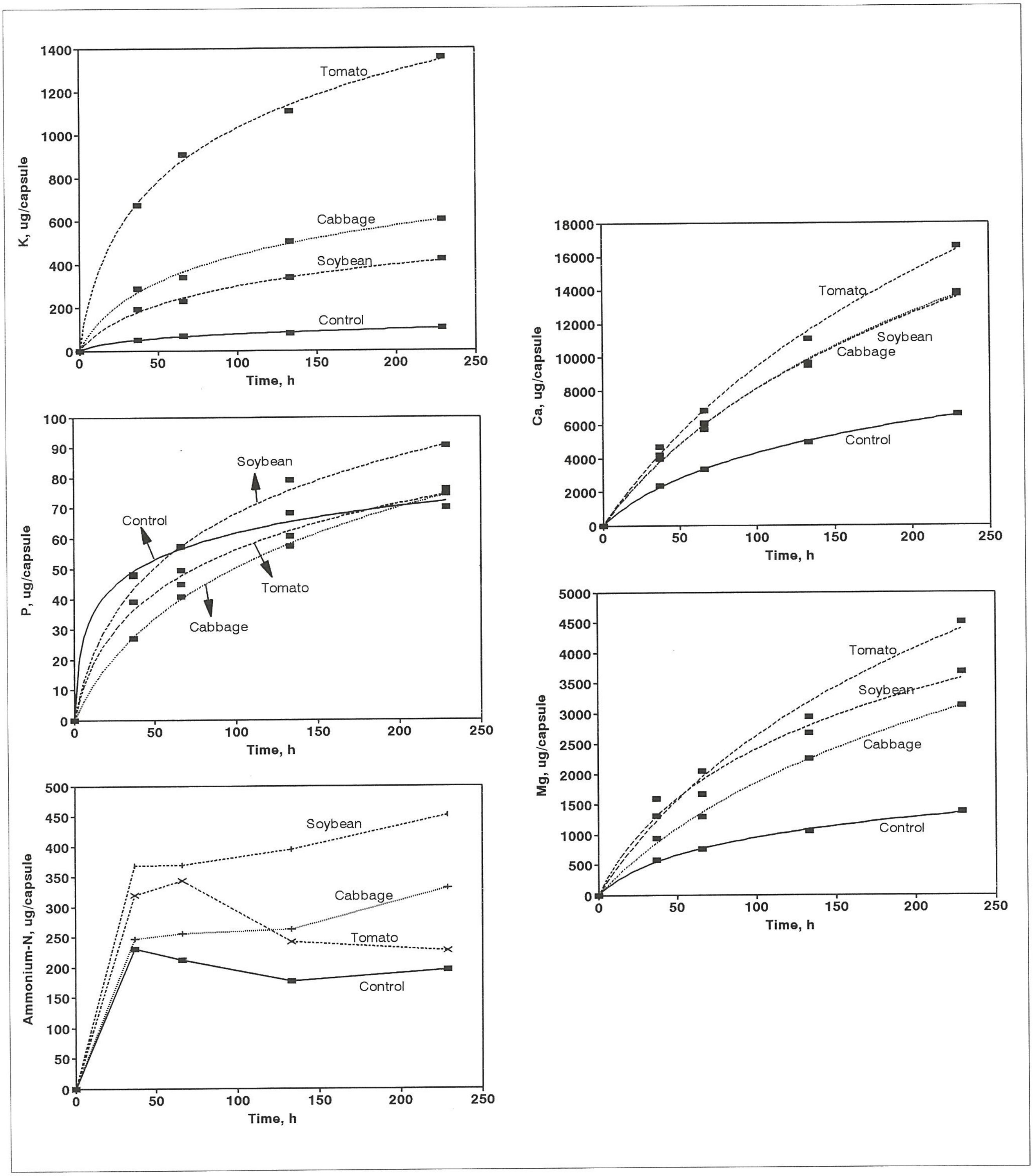

Fig. 2. Time courses of K, Ca, Mg, and NH_4-N accumulations from unamended soil and soil amended with soybean, cabbage, and tomato residues by resin capsules (PST-1)

Lines connect NH_4-N data points; lines for the other nutrients are fitted curves.

Nitrate accumulations in the Continuous Cropping Experiment

To use well composted wastes as a source of N, the material should be applied frequently to build up total soil N. The estimated rate of mineralization of N in sugarcane compost applied to the first crop of a sequence of three crops per year was 0.22 kg N/kg N. Estimates for the next five crops were 0.14, 0.09, 0.07, 0.05, and 0.04 kg/kg. Mineralization rates are assumed to be additive. The short-term rates at which nitrate-N accumulated from the repeated compost applications that have been applied to the Continuous Cropping Experiment (CCE) have not been measured even though the rates have implications for N management practices. Nitrate accumulations were monitored during the dry and wet seasons on the four compost treatments of the (CCE) field.

In one treatment (AF), compost was added every season during the past 13 years; in the second treatment (AO), compost was applied for only the first 10 years; the third treatment (OF) did not receive compost for the first 10 years but received it every season during the past three years; the fourth treatment (OO) never received compost. Sixteen plastic cylinders (37 cm diam, 15 cm height) were buried at the centers of the plots so that cylinder tops were flush with the soil surface. The soil inside each cylinder was removed, passed through a 5 mm sieve, mixed thoroughly with fresh sugarcane compost according to the CCE treatment design and returned to the cylinder. Soil samples (0-15 cm) collected at 3~6-day intervals for 20 days during the dry season were analyzed for nitrate-N. The field remained fallow during the second monitoring when cylinders were again placed in the plots, soil was removed, screened, and returned without compost additions. Soil samples collected at 10-day intervals during the wet season for about 3 months were analyzed for nitrate-N.

Time courses of nitrate-N concentrations during the dry and wet season are shown in fig. 3 and 4, respectively. During the dry season, NO_3-N averaged about 33 mg/kg after removal of the soybean crop that preceded installation of the cylinders, but increased abruptly to about 100 mg/kg within 6 days of application in treatments that received regular compost applications, either currently or terminated 3 years earlier. However, NO_3-N continued to increase slowly in AF during the remaining period whereas in AO and OF the concentrations plateaued after 6 days (fig. 3).

During the wet-season monitoring, similar but less abrupt patterns of NO_3-N accumulation were observed during the first 20 days of monitoring. However concentrations were reduced by two typhoons that occurred 30 to 40 days after initiation (fig. 4). The heavy rainfall promoted leaching and/or denitrification thereby producing low concentrations in all treatments. Net accumulation rates above background accumulation, estimated in the posttyphoon period, were 2.1 kg N/ha per day from either OF or AF and 1.2 kg N/ha per day from AO. Evidence that the accumulation from AF exceeded that of OF was absent during the posttyphoon period. Nitrate-N monitoring during both seasons demonstrated that large quantities of N are mineralized from past and current compost applications and are available to crops within a few days of removal of the preceding crop or depletion of nitrate by leaching and/or denitrification.

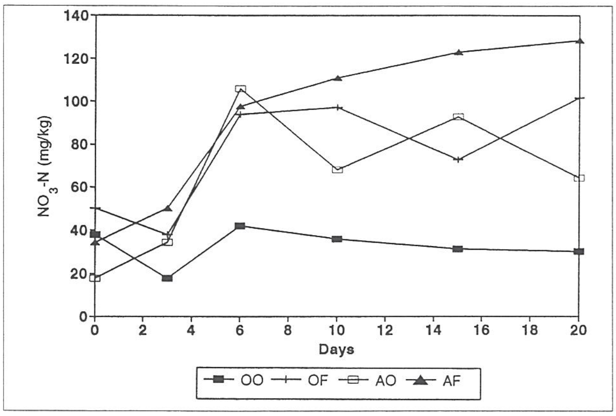

Fig. 3. Soil NO_3-N concentrations in cylinders inserted for 20 days into treatments of the Continuous Cropping Experiment, AVRDC, 1995 dry season
OO = never; AO = from 1983 to 1993; OF = from 1993 to 1996 only; AF = from 1983 to 1996

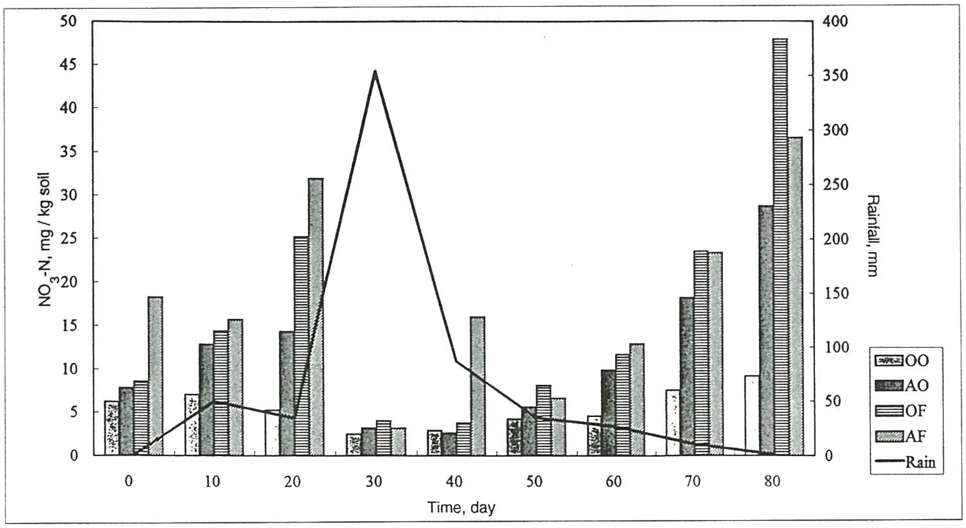

Fig. 4. Soil nitrate concentrations over an 80-day fallow period during summer 1996 from combinations of compost treatments
OO = never received compost; AO = received compost from 1983 to 1993 only; OF = received compost from 1993 to 1996 only; AF = received compost from 1983 to 1996; Continuous Cropping Experiment, AVRDC

Phosphorus recovery in the Continuous Cropping Experiment

Many AVRDC soils have long histories of inorganic P, and in some cases organic P, applications that exceed removals by crops. Applications and removals are well documented in the CCE. Fig. 5 shows cumulative P uptake by crops in the CCE beginning with the crop on which 0 and 45 kg P/ha treatments were superimposed on compost treatments. Before these treatments were established, all plots received blanket inorganic P applications that averaged 38 kg P/ha. From crop no. 12 onward, vegetables were substituted for soybean except during the summer. From crop no. 12 to 20, the difference between coefficients with and without compost to which inorganic P was not applied [coefficient differences for (AF-inorganic P)-(OO-inorganic P)] was 10 kg/ha per crop, which

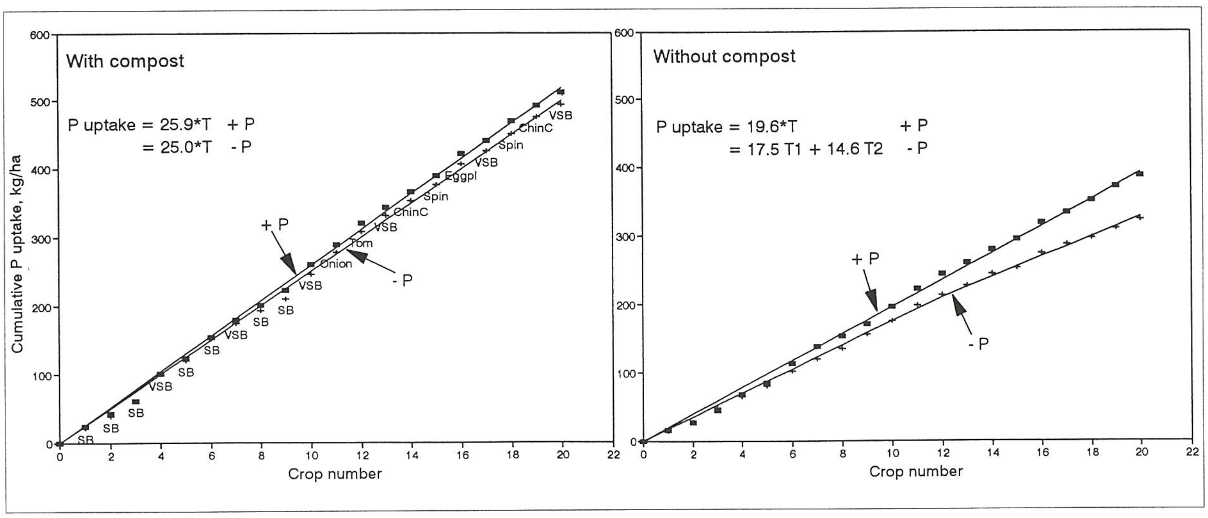

Fig. 5. Cumulative phosphorus uptake from compost treatments with and without inorganic P
VSB = vegetable soybean, Tom = tomato, ChinC = Chinese cabbage, Spin = spinach, Eggpl = eggplant
R^2 exceeded 0.99 for all regressions. T1 was crop no. to 12, T2 was crop no. beyond 12, Continuous Cropping Experiment, AVRDC, 1990–96

corresponded to an average 0.09 kg/kg recovery. The AF and OO treatments were described earlier under Nitrate Accumulations in the Continuous Cropping Experiment. The addition of inorganic P to plots that received compost increased uptake by less than 1 kg P/ha per crop [coefficient differences for (AF+inorganic P) - (AF-inorganic P)]. Mean recovery of inorganic P by the vegetables that did not receive compost was 0.11 kg/kg [coefficient differences for (OO+inorganic P)-(OO-inorganic P)]. Except for a 17% decrease in the quantity of P recovered by the mix of vegetable crops where neither compost nor inorganic P were applied, mean P uptake per vegetable crop did not differ from uptake by soybean.

Available P (Olsen extractant) from soil samples taken from AF+inorganic P, AF-inorganic P, OO+inorganic P, and OO-inorganic P treatments before planting each of the last three crops averaged 131, 135, 49, and 26 mg/kg, respectively. Even the 26 mg/kg available P supplied an average 14.6 kg P/ha per crop to vegetables after 12 crops had removed more than 200 kg P/ha without a P application.

Composted and raw wastes as nutrient sources for common cabbage

Cabbage was cultivated in two early winter seasons. Treatments were composed of raw pig manure and crotalaria, and of amendments of these two materials co-composted with rice straw. Inorganic N, P, and K treatments were included against which to measure fertilizer equivalents of the wastes. Sweet maize and eggplant, cultivated on residual treatments from the first cabbage crop but with uniform N applications, intervened between the first and second cabbage crop.

Nitrogen recovery from co-composted applications were not statistically detectable either by the crop to which they were applied or by the following maize and eggplant crops. Moreover, when the CN ratio exceeded 17, as it did for the co-composted materials applied to the first crop, N immobilization occurred (table 4). When the CN ratio was less than 11, as it was for co-composted material applied to the second crop, small fractions of N were recovered.

Nitrogen recoveries from raw pig manure and from crotalaria, which had a nutrient composition similar to that of many vegetable crop residues, were much greater (table 4). Even though apparent N recoveries from pig manure and crotalaria applied to the first crop were less than 0.3 kg/kg, unrecovered N had only a small effect on the following maize crop. Pig manure caused the only significant residual effect on N uptake by maize. The quantity of N in the pig manure was very large, 334 kg/ha compared to 194 kg/ha in the crotalaria, and therefore it was reasonable that a residual effect was detected from it. Uptake of residual N from other treatments, if present, were below statistically

Table 4. Carbon-nitrogen ratios, apparent N recovery, and N fertilizer equivalents of the wastes calculated from total dry matter (NFE-DMY) and N uptake (NFE-NUP) responses by the crops to inorganic N fertilizer

Waste	CN ratio (kg/kg)		Apparent N recovery (kg/kg)		NFE-DMY (kg/kg)		NFE-NUP (kg/kg)	
	First	Second	First	Second	First	Second	First	Second
Pig manure	11.2	9.3	0.24	0.26	0.49	0.56	0.41	0.44
Co-composted pig manure	18.7	9.1	-0.05	0.15	-0.20	0.22	-0.08	0.25
Crotalaria	13.6	15.2	0.29	0.34	0.78	0.87	0.49	0.57
Co-composted crotalaria	17.1	9.3	-0.10	0.10	-0.47	-0.02	-0.17	0.17
N-enriched straw compost	24.7	10.0	-0.04	0.11	-0.05	0.04	-0.07	0.18

detectable levels. Table 4 shows that nitrogen fertilizer equivalents calculated from dry matter yield response to inorganic N exceeded fertilizer equivalents calculated from N uptake response, similar to the observation from earlier experiments on leafy vegetables. It was evident that N from the wastes was more efficiently used to produce dry matter than N from inorganic fertilizer (fig. 6). Moreover, evidence suggested that the yield potential in the presence of wastes was greater as well.

When an application of either inorganic or organic N promoted growth, after removing the effect of season, the simple correlation between uptakes of N and P was 0.87 and N and K was 0.91. Thus, because P and K rates in the waste treatments were confounded with N rates from the mineralized N, estimates of P and K recovery due to increased availabilities of these nutrients cannot be made directly. Apparent recoveries of P (K) in the pig manure and crotalaria were estimated as the difference between actual uptake and that estimated from an equivalent uptake of inorganic N that did not receive inorganiç P (K), thereby adjusting for the response to N in the materials. The mean recovery of the average 18 kg P/ha in the crotalaria was 0.16 kg/kg whereas recovery from the average 374 kg P/ha in the pig manure was only 0.016 kg/kg. The estimated P recovery from crotalaria averaged 240% of the fraction recovered from 35 kg inorganic P/ha, whereas that from pig manure averaged only 24%. The P in pig manure was simply excessive whereas that in crotalaria was approximately equal to the total P taken up by the crop. The corresponding mean K recoveries were 0.41 kg/kg from the 95 kg K/ha in the crotalaria and 0.39 kg/kg from the 94 kg K/ha in the pig manure. The estimated K recoveries averaged 73% of apparent inorganic K recovery.

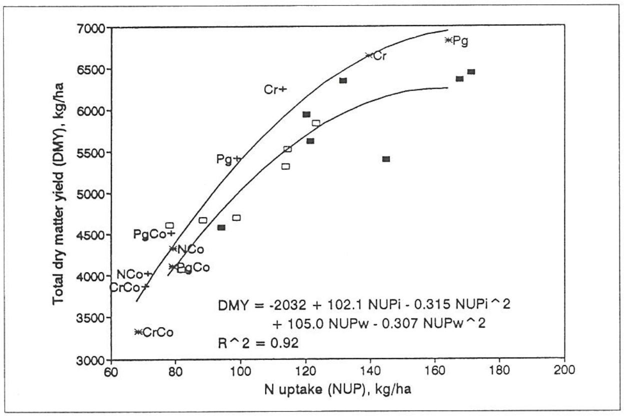

Fig. 6. Total dry matter yields from the first and second cabbage crops versus N uptake
Inorganic N fertilizer treatments are coded as filled and unfilled boxes for the first and second crops, respectively. Waste treatments are coded as asterisks and plus signs for the first and second crops, respectively. Waste treatment labels are Pg for pig manure, Cr for crotalaria, --Co when co-composted with rice straw, and Nco for straw composted with urea.

As expected, the 749 kg P/ha in the two pig manure applications caused the greatest effect on available soil P (table 5). Nevertheless a significant relationship was not detected between net P removal by the four crops and the difference between pre- and postexperiment available P. The capacity of soils to supply P even when none was applied was evident from the small reduction of available soil P even when 50 kg/ha was removed by four crops that received only N and K. As suggested by analysis of soils from the CCE, post applications of excess P accumulate in large calcium phosphate pools. The P from these pools is moderately available but it is not measured adequately by the standard extraction (Olsen) procedure.

Table 5. Available soil P from selected treatments after the second cabbage crop

Treatment	Available P (mg/kg)
35 kg P/ha[a]	30.2
0 kg P/ha[a]	26.6
Pig manure	67.9
Co-composted pig manure[b]	37.9
Crotalaria	32.2
Co-composted crotalaria	27.5
SE$\bar{x}$	3.14

[a] 75 or 125 kg N/ha and 50 kg K/ha were applied.
[b] Co-composted with rice straw.

Enhancing biodiversity through home gardens

The role of home gardening as a biodiversity resource and contributor to a significant proportion of the micronutrient requirements for a family of six in the tropics was assessed. The intention was to develop new techniques to (1) overcome seasonal deficits in vegetable supply during the hot-wet periods, and (2) enhance the sustainability of garden production; and gather relevant data on dry matter production and nutrient uptake by each species in the three existing types of gardens: monoculture, intercrop, and high-raised bed.

Data accumulated in the last 4 years were analyzed to assess the various aspects of each garden system.

Substantial seasonal variation in vegetable output from the AVRDC gardens was observed and attributed mainly to two factors: nutrient imbalance in the garden soils and lack of species suitable for summer cultivation. After 4 consecutive years of cultivation, more than 500 ppm of Olsen-P accumulated in the high-raised bed soils, whereas total nitrogen content was only slightly more than 0.1% (table 6).

Table 6. Relevant soil chemical properties of AVRDC high-raised bed garden after 3 and 4 consecutive years of cultivation

Location[a]	T-C (%)	T-N (%)	P_2O_5 (ppm)	K_2O (ppm)	T-C (%)	T-N (%)	P_2O_5 (ppm)	K_2O (ppm)
	(After 3 consecutive years)				(After 4 consecutive years)			
High-raised bed (upland condition)								
S1	0.90	0.105	245.8	47.2	0.80	0.118	491.4	53.8
S5	1.00	0.115	247.8	12.6	0.99	0.135	502.5	51.3
S2	0.96	0.120	241.8	21.7	1.29	0.125	512.3	58.5
S4	1.03	0.120	274.8	41.9	0.93	0.123	484.2	55.9
S3	0.96	0.115	253.2	21.7	0.98	0.137	555.7	58.8
S6	1.17	0.136	263.3	21.8	1.11	0.142	561.0	52.6
Average	1.00	0.119	254.5	27.8	1.02	0.130	517.8	55.1
Conf(0.05)	0.07	0.007	9.1	9.9	0.12	0.007	24.0	2.3
N1	1.03	0.124	272.1	44.7	0.89	0.120	470.5	54.5
N5	1.31	0.157	348.2	16.4	0.99	0.141	579.2	60.0
N2	1.18	0.142	291.6	16.6	1.06	0.137	596.2	52.3
N4	1.25	0.147	303.7	20.0	1.33	0.158	601.4	51.7
N3	0.92	0.112	255.2	11.5	0.98	0.129	485.5	52.4
N6	0.92	0.109	222.9	23.0	0.93	0.136	522.1	57.6
Average	1.10	0.132	282.3	22.0	1.03	0.137	542.5	54.7
Conf(0.05)	0.12	0.014	31.4	8.6	0.11	0.009	42.0	2.5
Lowland (submerged condition)								
S1	0.66	0.073	65.0	19.5	0.90	0.112	156.4	169.2
S5	0.68	0.086	74.1	16.7	0.81	0.108	211.3	71.8
S2	0.73	0.081	67.7	23.5	0.73	0.100	183.8	77.0
S4	0.90	0.117	96.3	28.8	0.80	0.092	198.9	83.8
S3	0.62	0.101	85.5	26.1	0.73	0.092	176.0	110.6
S6	0.74	0.095	82.8	26.7	0.80	0.106	202.1	76.1
Average	0.72	0.09	78.6	23.6	0.79	0.102	188.1	98.1
Conf(0.05)	0.07	0.01	8.7	3.4	0.05	0.006	14.7	27.4
N1	0.66	0.077	69.7	21.1	1.06	0.138	168.2	190.7
N5	0.76	0.099	78.5	30.3	0.97	0.083	181.2	54.7
N2	0.69	0.092	70.0	19.2	0.94	0.118	173.4	90.1
N4	0.72	0.100	84.9	23.7	0.84	0.125	211.3	76.1
N3	0.90	0.106	98.0	18.3	1.00	0.133	189.1	104.0
N6	0.76	0.094	82.2	20.6	0.80	0.106	171.4	93.3
Average	0.75	0.095	80.5	22.2	0.93	0.117	182.4	101.5
Conf(0.05)	0.06	0.007	7.7	3.2	0.07	0.015	11.7	34.3

[a] S: south row of the plot, N: north row of the plot

Based on the data collected from the monocrop garden, only 10% of all the entries for 4 years were suitable for midsummer planting (table 7).

The best crop combination for the intercrop garden was evaluated in terms of high yields. Peppermint proved to dramatically decrease mite damage in both hot and bell peppers by intercropping or direct tying onto pepper plants.

In future, the garden project will put more emphasis on technology development to overcome seasonality and to enhance the sustainability of the different production systems.

Table 7. Maximum yields of various vegetable species in the AVRDC monocrop garden

Species	Maximum yield[a] (g/m²)	DMRT[b]	Duration (days)	Planting month	Direct seeding or transplanting
Amaranth	1040	ns	44	6	ds
Broccoli	2750	ns	85	9	tr
Cabbage	1870	ns	90	9	tr
Carrot	2380	ns	114	9	ds
Cauliflower	450	ns	89	12	tr
Chinese cabbage	1440	*	35	2	tr
Celery	4050	ns	126	10	tr
Chicory	1160	ns	49	4	ds
Chingchiang	3160	*	41	11	ds
Coriander	680	*	47	10	ds
Cucumber	1690	ns	86	2	tr
Eggplant	15440	*	233	2	tr
G. chrysanthmum	1410	ns	49	10	ds
Garlic	2030	*	74	12	ds
Hot pepper	470	*	108	2	tr
Jute	1860	*	145	5	ds
Kale	1470	*	59	12	ds
Kangkong	3630	ns	56	8	ds
Kohlrabi	1530	ns	125	8	tr
Leek flower	730	ns	132	11	tr
Lettuce (heading)	3060	*	52	6	tr
Lettuce (leafy)	2260	ns	76	2	ds
Malabar spinach	2680	ns	110	6	ds
Mustard	1200	ns	66	2	tr
Okra	3830	*	115	6	tr
Onion	3510	*	59	1	tr
Pai-tsai	1390	ns	35	5	ds
Radish	7700	*	93	10	ds
Rape	800	ns	40	10	ds
Snake gourd	4480	*	151	4	ds
Spinach	1630	*	55	12	ds
Sweet corn	1200	*	57	1	tr
Sweet fennel	9090	*	95	12	ds
Sweet pepper	2300	ns	112	11	tr
Tomato(FMTT 22)	4500	*	170	9	tr
Vegetable soybean	2050	ns	91	3	ds
Welsh onion	1730	ns	94	3	tr
Yard-long bean	3360	ns	121	3	ds

[a] Average yields of 4-year trial.Same species was grown in the same and/or different months of each year in a different place in the garden. Yield data collected were statistically analyzed by seeding/transplanting months.

[b] DMRT was conducted for each seeding/transplanting month. Results given are only between the top yielder and the second best.

ns: not significant, *: significant at 5% level.

[c] The month when vegetable species was seeded or transplanted.

Studies on simple hydroponics

Studies on simple hydroponic systems that are well-adapted to local conditions and that provide safe and healthy vegetables for consumption are ongoing. Several new systems are being tested for a variety of fruit vegetables to overcome the stresses of summer production. The major nutrient elements are being analyzed on samples of nutrient solutions from each hydroponic box to determine nutrient uptake by each vegetable species in cooperation with Far East College in Tainan, Taiwan.

Attempts were made to further simplify the AVRDC hydroponic system for cultivation of leafy vegetables and to develop a more reliable and stable system for summer cultivation.

Various available local materials were tested as cultivation media for the hydroponic system; treatments using cultivation materials such as pot-tile, gravel, and fabric waste showed no growth retardation and produced satisfactory yields comparable to smoked rice husk medium. A double-layered board composed of polystyrene and hard PV was developed for the rid (plant holder) of the system and a sponge cube was adopted as a seeding medium.

With these two devices, seven leafy vegetables were successfully grown to the end of the experiment without replacing the media nor emptying surplus solution after each harvest. At harvest, the previous vegetable was taken away with the sponge cube, and a new cube with the succeeding species was just inserted into a hole of the rid.

Nutrient absorption by various leafy vegetables and tomatoes were precisely traced during the cultivation period at 1-week intervals both in winter and summer (table 8). Based on these results, weekly application rates of major nutrients were calculated and recommended.

Table 8. Major nutrient uptake by tomato cultivar FMTT 22 in a winter cultivation

Nutrients	Weeks after transplanting	Absorption (mg/plant)	mg/week/ plant
	Up to 6	4625+/-387	719
	6 to 7	5221+/-432	696
	7 to 8	5948+/-623	636
	8 to 9	6646+/-681	610
	9 to 11	7952+/-458	653
N	11 to 12	8453+/-525	584
	12 to 13	9106+/-394	653
	13 to 15	10134+/-545	654
	15 to 16	11401+/-248	887
	16 to 17	12098+/-342	813
	17 to 18	13232+/-467	721
	Up to 6	1417+/-182	220
	6 to 7	1794+/-112	440
	7 to 8	2289+/-200	433
	8 to 9	2774+/-146	425
	9 to 11	3421+/-244	324
P	11 to 12	3752+/-328	385
	12 to 13	4218+/-356	466
	13 to 15	4905+/-392	437
	15 to 16	5460+/-311	389
	16 to 17	5857+/-309	463
	17 to 18	6577+/-393	458
	Up to 6	7397+/-611	1151
	6 to 7	8894+/-880	1746
	7 to 8	10603+/-591	1495
	8 to 9	12389+/-747	1563
	9 to 11	14975+/-855	1293
K	11 to 12	15955+/-789	1144
	12 to 13	17177+/-491	1222
	13 to 15	19141+/-471	1250
	15 to 16	21081+/-464	1358
	16 to 17	22170+/-670	1271
	17 to 18	23585+/-841	900
	Up to 6	1655+/-121	257
	6 to 7	2315+/-217	770
	7 to 8	3165+/-313	743
	8 to 9	3901+/-307	644
	9 to 11	4992+/-322	546
Ca	11 to 12	5456+/-360	541
	12 to 13	5975+/-391	519
	13 to 15	6882+/-310	577
	15 to 16	7887+/-498	703
	16 to 17	8652+/-437	893
	17 to 18	10027+/-563	875
	Up to 6	492+/-48	77
	6 to 7	695+/-38	237
	7 to 8	971+/-58	242
	8 to 9	1160+/-112	165
	9 to 11	1517+/-76	179
Mg	11 to 12	1681+/-81	192
	12 to 13	1851+/-103	170
	13 to 15	2092+/-124	154
	15 to 16	2330+/-138	167
	16 to 17	2622+/-103	341
	17 to 18	3038+/-152	265

Overcoming Seasonal Stresses of Production

Summer vegetable production is constrained by high temperatures and flooding, and associated insect and disease problems, thereby substantially reducing yields of summer vegetables. To address these constraints, appropriate crop, soil, and water management regimes should be used for more sustainable and economically viable vegetable production during the hot, humid summer months.

This project aims to develop integrated technology to overcome seasonal stresses and to enhance vegetable production using environmentally friendly methods during the hot and wet periods in the lowland tropics. New and traditional techniques are assessed to evaluate their effectiveness in enhancing summer vegetable production.

Last year, a study showed that fruit setting in cherry tomato varieties Santa and AVRDC's CHT 154 can be increased through the application of tomatotone.

Permanent high beds were found to alleviate the negative impacts of overwet soil conditions during the rainy season. Yields of vegetables such as Chinese cabbage and vegetable soybean grown year-round with carrot and chili were significantly higher compared to traditional flat beds, with less leaching of nitrate below the root zone. However, water stress in the rainy season and accumulation of soil nitrate during the dry season with negligible leaching were responsible for the success of N_{min} method on flat beds.

This year, studies were conducted to develop a technology to overcome flooding stress in tomato and develop economically-feasible cultural practices that minimize bacterial wilt damage to tomato during summer. Application of both dry powder of bulb onion and Welsh onion to seedling media effectively decreased bacterial wilt incidence up to 35 days after germination.

Overcoming water stress for summer tomato

A study was conducted to develop an economically feasible technology to overcome flooding stress in summer tomato. The following treatments were used: seedling preparation using seedling pots of different sizes, shapes, and materials; different media, artificial and natural porous materials with sufficient water-holding capacity; and different water management practices. In the field, various irrigation strategies and different bed widths, heights, shapes, and field management practices were applied.

Artificial flooding was also done to determine which growth stage is most critical for flood damage and how long tomato can survive under flooded conditions. In addition, grafting studies using a tomato scion and eggplant rootstock were conducted.

Results showed that AVRDC cherry tomato CHT 154 was more sensitive to an artificial 2-day flooding treatment than the indeterminate tomato line FMTT 22 in a winter field trial (table 1). Growth retardation and the resulting yield loss increased as the growth stage in which the flooding treatment was made proceeded.

In a similar summer trial, however, early flooding substantially retarded initial plant growth and consequently, yield loss was greater in the plot which was treated at the early growth stage than at the later stage. This was because of water accumulation due to the typhoon before the treatment was commenced. On the other hand, the soil was completely dry before the treatment in the winter trial. Seedlings prepared under different water regimes did not show any significant difference in the extent of flood tolerance after transplanting.

There was a great difference in the root activity between tomatoes grafted and not grafted onto eggplant rootstocks (fig. 1). Two-day artificial flooding resulted in 23% mortality in the nongrafted tomato while all of the grafted tomatoes survived (table 2).

Table 1. **Relationship between flooding damage and growth stage of tomato**

Flood treatment	Fruit yield (t/ha)			
	CHT 154		FMTT 22	
	Winter	Summer	Winter	Summer
2 WAT[a] (6 WAT[b])	20.8a	9.6b	28.1a	11.7ab
4 WAT (8 WAT)	21.0a	14.3a	33.4a	13.8a
7 WAT (11 WAT)	15.3b	9.6b	28.8ab	9.6b
10 WAT (13 WAT)	5.5c	17.6a	24.1b	10.8b

[a] weeks after transplanting.
[b] The first flood experiment in summer was delayed by 4 weeks due to a typhoon.

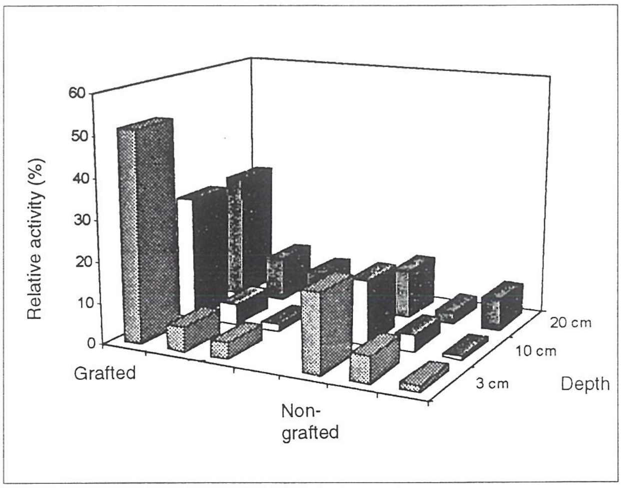

Fig. 1. **Difference in root activity between grafted and nongrafted tomatoes under artificial flood (measured by N^{15} tracer technique)**
A = directly below plant; B = 10 cm apart from plant; C = 20 cm apart from plant

Minimizing bacterial wilt damage by soil amendment

To develop economically-feasible cultural practices that minimize bacterial wilt damage to tomato, the following cultural practices were tested: (1) soil amendment to substantially decrease bacterial wilt population in infected soils using a combination of pH adjustment (calcium nitrate application), flooding, and increased soil temperature by covering the soil with a transparent plastic sheet; application of allium powder or intercropping tomato with allium; and application of soil amendment only in the vicinity of plant roots; and

Table 2. **Effect of flooding on the quality and yields of grafted and nongrafted tomato**

	pH	Acidity	Brix	Color	Death at 133 DAT	Plant dry wt. at harvest (g/plant)	Total yield (t/ha)	Virus infection % at 83 DAT
Main plot	ns	*	ns	ns	*	ns	ns	*
With flooding	4.30	0.42	5.39	1.42	20.61	139.5	36.8	31.5
Without flooding	4.27	0.37	5.06	1.46	2.57	139.9	45.5	47.7
Subplot	ns	ns	ns	ns	**	ns	*	**
With flooding	4.32	0.39	5.06	1.45	0	124.8	32.4	60.3
Without flooding	4.26	0.40	5.39	1.43	23.18	154.6	49.9	18.9

[a] This experiment was conducted in autumn 1995. Relative root activities of both grafted and nongrafted tomatoes were examined using a newly developed N^{15} tracer technique.

(2) development of seedling media to decrease the bacterial population (mixture of allium powder, used tea leaves, etc.) and provide enough amounts of nutrients for tomato growth throughout the cultivation period to keep the tomato roots off the infected soils.

Application of both dry powder of bulb onion and Welsh onion to seedling media at a rate of 1 and 2% against the media proved to be effective in decreasing disease incidence of bacterial wilt up to 35 days after germination (tables 3 and 4). When these materials were mixed with only a limited amount of soil in the vicinity of the transplanted plants (20 cm in diam, 10 to 15 cm depth), almost all the susceptible L 390 could not survive up to 50 days (table 5).

Combined treatments of soil pH and temperature increase, and flooding failed to control bacterial wilt in the susceptible check, L 390, partly due to the typhoon during the summer trial. In an autumn trial conducted on the same area using the same solarization treatments, FMTT 22 showed much better initial growth and survival rate than L 390.

Table 3. Effect of various organic materials on frequency of bacterial wilt incidence

OMA/DAT[a]	Culminative survival rate (%)						
	8	10	14	21	31	42	50
Bulb onion powder	100a	89ab	69a	57ab	51a	50a	51a
Welsh onion powder	94a	80b	71a	62a	61a	58a	58a
Tea leaf powder	95a	81b	46b	31c	24c	21b	23b
Bark compost	98a	97a	78a	48b	38b	27b	23b

[a] OMA = organic materials added; DAT = days after transplanting.

Table 4. Relationship between amount of organic materials applied and tomato survival rate due to bacterial wilt

OM/Medium (w/w)/ DAT	Culminative survival rate (%)						
	8	10	14	21	31	42	50
0.1%	94a	68b	44b	19c	17b	13b	10c
0.5%	96a	90a	65a	44b	31b	26b	26b
1.0%	96a	94a	75a	66a	62a	56a	58a
2.0%	100a	95a	77a	70a	64a	62a	61a

Table 5. Effect of soil amendment on survival rate of tomato

Treatment/ DAT	Culminative survival rate (%)				
	3	7	21	30	35
CaO[a]	100a	100a	78ab	48ab	30ab
Bulb onion	100a	100a	92a	71a	60a
Tea leaf	100a	98a	97a	55ab	39ab
Large pot nursery[b]	97a	85a	57b	3b	2b
Welsh onion	100a	98a	96a	81a	55ab
Check	100a	95a	76ab	50ab	37ab

[a] Dry powder of onion bulb, Welsh onion, and tea leaves was applied at the rate of 1%, 1%, and 0.5%, respectively, in the soil. Calcium oxide was applied at the rate of 2.5 kg in each plot (6 m^2). These materials were mixed with soil mass in the vicinity of the transplanted plant (20 cm diam., 10–15 cm depth).

[b] 20 cm diam., 20 cm length

Management of Insect Pests and Plant Diseases

Insect pests and plant diseases are major economic constraints in vegetable production in the tropics and subtropics. AVRDC is developing technologies to combat these constraints, in addition to using host-plant resistance, which emphasizes combined biological control, cultural control, the use of sex pheromones, and minimal use of chemical pesticides. This integrated approach to control pests and diseases is the keystone of AVRDC's integrated pest management (IPM) technology. Besides being sustainable, the approach significantly reduces production cost 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*, a destructive pest of crucifers in the cool-dry season. During the last 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. In addition, research was initiated to combat armyworms, *Spodoptera exigua* and *S. litura* on onion. The IPM technologies in most cases included the use of parasites, predators, sex pheromone, biological insecticide based on *Bacillus thuringiensis*, and minimum use of chemical pesticides.

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

Testing of a nuclear polyhedrosis virus for the control of diamondback moth

Nuclear polyhedrosis viruses (NPV) are important natural mortality agents in several species of lepidopterous insect pests. Because of their specificity to the target pest and relative stability in the environment, NPVs of some insect pests have been commercially produced. So far, NPV that is specific to diamondback moth has not been isolated. An NPV test formulation of a lepidopterous species *Autographa californica* (AcNPV) was obtained from Biosys. It was tested with and without adjuvants to control diamondback moth in the AVRDC experimental farm.

Eight treatments were tested on transplanted cabbage: two dosages of AcNPV alone; AcNPV + Blankophor (an adjuvant), Azatin (a neem-based product), AcNPV + Azatin, AcNPV + Azatin + Blankophore, a standard insecticide—abamectin, and an untreated check. Each treatment was replicated four times.

The products were applied weekly with a pressurized air sprayer. Each plot was observed weekly to record the number of DBM larvae and pupae on 10 randomly selected plants. During the observation just before harvest, the number of larvae and pupae of imported cabbage worm (ICW) (*Pieris rapae*) was recorded on each plant. At harvest each treatment was rated for total insect damage. Each cabbage head was weighed and the weights as well as yield per plot were recorded. Insect count, damage rating and yield data were subjected to analysis of variance and means of treatments were compared by DMRT.

The results of the test are summarized in table 1. All treatments reduced insect number to a varying extent, but only chemical insecticide abamectin gave consistently superior control over other products. AcNPV either alone or with adjuvants failed to control the pest. Treatments containing azatin alone or in combination with adjuvants significantly reduced pest damage over the control or other treatments. These treatments also had higher yields than the other treatments except for abamectin. Significantly higher head weight and lower damage rating in azatin-containing treatments could be due to azatin's effect on imported cabbage worm—it gave as good control as abamectin over this butterfly pest. During the last 2 weeks before harvest of cabbage, imported cabbage worm was especially serious and AcNPV failed to check its population.

Integrated control of crucifer insect pests

Diamondback moth, cabbage webworm [CWW, *Hellula undalis*], and cabbage head caterpillar (CHC, *Crocidolomia binotalis*) are major pests of crucifers such as common cabbage, Chinese cabbage, radish, kale, and mustard throughout Asia. The diamondback moth is most destructive during the cool-dry season, but its infestation is much less during the hot-wet season presumably due to frequent rains, an important mortality factor for this plant surface-feeding caterpillar. In hot-wet season, cabbage webworm and cabbage head caterpillar are major pests. Because of differences in the season and nature of damage of this lepidopterous pest complex, two different sets of control measures are required to combat them. Between seasons, however, all three major plus some minor pests attack crucifers.

Table 1. Effect of AcNPV, azatin, and additives on the infestation of cabbage by diamondback moth and imported cabbage worm, AVRDC, winter 1995-96[a]

Treatments	Dose	No. DBM larvae + pupae/plant				Damage rating	Weight (kg/head)	Yield (t/ha)	No.ICW L+P/plant
		19 Dec. 95	3 Jan. 96	16 Jan. 96	6 Feb. 96				6 Feb 96
AcNPV	0.16%	0.15	2.28ab	20.2b	21.18ab	4.92a	1.14bcd	27.2bcd	5.15a
AcNPV	0.32%	0.28	2.90a	17.95bc	15.03b	4.57a	1.23bc	29.5bc	3.70ab
AcNPV + Blankophor	0.16% + 0.25%	0.18	2.00ab	16.35bc	17.80b	4.82a	1.11cd	26.2cd	4.58a
Azatin	3%	0.13	1.33abc	17.98bc	26.68ab	2.02b	1.40b	32.4bc	0.63c
AcNPV + Azatin	0.16% + 3%	0.23	0.78bc	8.43cd	19.00ab	1.80b	1.41b	33.5b	0.38c
AcNPV + Azatin + Blankophor	0.16% + 3% + 0.25%	0.08	1.88ab	13.1bc	25.75ab	1.67b	1.41b	33.61b	1.2bc
Abamectin	10g AI/ha	0.10	0.05c	0.48d	0c	0.25c	2.31a	54.4a	0c
Check		0.18	2.75a	32.03a	31.1a	5.00a	0.92d	21.59d	5.30a

[a] Cultivar: Cabbage Early Autumn; Transplanting date: 12 December 1995; Plot size: 4.5 x 3.3 m; Treatment dates: 21 and 29 December 1995; 5, 11, 17, and 25 January; and 1 and 7 February 1996; Sampling dates: 19 and 27 December 1995; 3, 9, 16, 23, and 30 January; 6 February 1996; Damage rating: 0 = no damage, 5 = highest damage. Data shown are means of 4 replictes.

Means in each vertical column followed by the same letter are not significantly different at 5% probability level according to DMRT.

AVRDC has been successful in controlling DBM in the highlands by introducing parasites. However, due to the lack of effective parasites, except for *Cotesia plutellae*, diamondback moth continues to be a problem in the lowlands.

Since both cabbage webworm and cabbage head caterpillar can occur simultaneously with DBM, a package of technology was tested to combat either DBM alone or in combination with CWW and CHC. Four field experiments, two in cool-dry season and two in hot-wet season, were conducted at AVRDC to test various IPM packages for the control of crucifer pest complex consisting of DBM, CHC, CWW, and imported cabbage worm (ICW).

In the cool-dry season from November to February when DBM was the major pest, two IPM packages based on the use of DBM parasite *Cotesia plutellae* + NPV of beet armyworm + polyphagous predator *Eocanthecona furcellata* and *Cotesia* + *Eocanthecona* + a castor trap crop, gave significant control of DBM and ICW without pesticide use over the control plot. Widespread distribution of *C. plutellae* during the second crucifer crop kept DBM under control. Release of *C. plutellae* or *Oomyzus sokolowskii* did not reduce the pest population further.

In the first hot-wet season experiment, an IPM package based on the use of *Bacillus thuringiensis* (Bt) shoot treatment to control *Hellula undalis*, *Eocanthecona*, *Cotesia*, and intercropping with Indian mustard trap crop reduced infestation of cabbage by CHC and ICW (table 2). The major insect pests that attacked cabbage were ICW and CHC. In the first three observations, the pest population in both IPM package plots was drastically reduced compared to the check field. In the last observation the check plot had lower pest population than the treatment plots and its plants were very heavily damaged by the pest. Indian mustard must have attracted CHC away from cabbage and *Eocanthecona* attacked ICW.

Table 2. Effect of two IPM package practices on infestation of cabbage by imported cabbage worm (ICW), cabbage head caterpillar (CHC) and diamondback moth (DBM), AVRDC, 1996

Observation date	Pest / insects	No. larvae+pupae/plant		
		check	IPM1[a]	IPM2[b]
96/5/21	ICW	1.13	0.40	0.67
	CHC	0.03	0.07	0.13
	DBM	0.36	0.40	0.5
96/6/3	ICW	4.00	0.73	1.07
	CHC	12.43	1.57	3.0
	DBM	0	0.07	0.17
96/6/7	ICW	9.83	1.76	1.33
	CHC	65.17	18.63	26.63
	DBM	0.07	0.23	0.67
96/6/12	ICW	2.37	3.13	3.70
	CHC	6.90	16.10	34.40
	DBM	0.13	0.17	0.12
	Damage rating[c]	4.73	2.63	3.17

[a] Bt shoot treatment + *Eocanthecona* + *Cotesia* + Indian mustard trap crop.

[b] Bt shoot treatment + *Cotesia* + Indian mustard trap crop.

[c] 0 = no damage, 5 = maximum damage (80-100% destruction of cabbage heads)

Results of the second hot-wet season tests are summarized in fig. 1. Cabbage head caterpillar was the dominant pest. Cabbage webworm infestation was very sporadic. The CHC population was consistently lower in IPM plots than in the check plot. For up to 4 weeks after transplanting the IPM plots were practically free of pest infestation. However, during the last 2 weeks, pest population

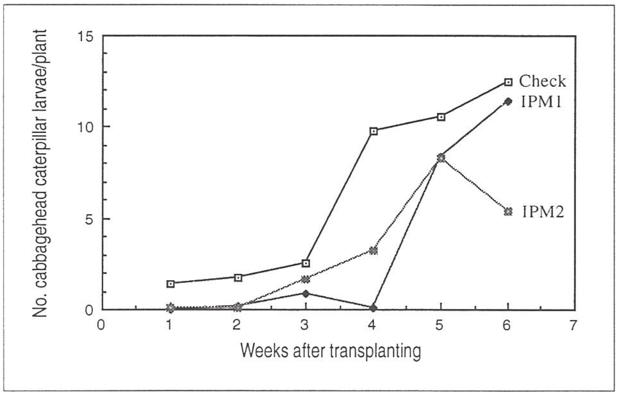

Fig. 1. Effect of two IPM practices on the infestation of Chinese cabbage by cabbage head caterpillar (IPM1: Bt shoot treatment + *Eocanthecona* + Indian mustard trap crop. IPM2: Bt shoot treatment + Indian mustard trap crop), hot season, 1996

increased substantially. The damage rating of the crop at harvest was 4.8 in the check plot and 3.6 and 3.4 in IPM1 and IPM2, respectively. The crop in the check plot was completely destroyed, but in IPM plots some plants were marketable. The IPM package has potential to control the crucifer pests, but further improvement is necessary to make it more effective.

Evaluation of effectiveness of Bt strains against *Crocidolomia binotalis*

Cabbage head caterpillar is an economically important pest of several species of cruciferous vegetables, but causes more damage on Chinese cabbage and radish. This insect occurs during the hot season (May to October) in Taiwan, but is endemic practically throughout the year in the rest of South and Southeast Asia. At present, Asian farmers frequently use chemical insecticides to combat this pest. *Bacillus thuringiensis* is effective against many lepidopterous species. Four commercial products (Thuricide, Delfin, Dipel, and MVP) based on this bacterium were evaluated in the laboratory to assess their efficacy in controlling the pest.

CHC adults were released in a cage with common cabbage where they readily laid eggs and fed on cabbage leaves. The common cabbage plant was changed everyday, enabling the rearing of several generations. Larvae were allowed to feed until they were in the 3rd instar. Third instar larvae were used for all experiments.

Several concentrations of the Bt products were tested. Several fresh common cabbage leaves were cut into 9-cm-diam discs. Three leaf discs were dipped in each Bt concentration for 10 sec and then air-dried. One leaf disc was put in each petri dish where 3rd instar larvae were released. After 48 h, old leaves were replaced with freshly dipped leaves to keep larvae feeding. Insect mortality was recorded at 1, 3, 6, 12, 24, 48, and 72 h after treatment.

CHC larval mortality in various concentrations of Bt products is shown in table 3. The higher the concentration, the greater was insect mortality. Delfin was the most effective product, with greater insect mortality observed at the lowest concentration. The LC_{50} values are: Delfin, 63.05 IU/ml; Thuricide, 474.6 IU/ml; Dipel, 1091.9 IU/ml; and MVP, 16119.86 PU/ml.

Table 3. Mortality of cabbage head caterpillar in various concentrations of Bt products

Bt product	Concentration (IU/ml)	Mean mortality (%)	Mean corrected mortality (%)
Thuricide	250	20±10	20
	500	50±10	50
	1000	90±10	90
	2000	93±6	93
Delfin	30	27±6	24
	60	47±6	45
	120	77±6	76
Dipel	500	20±10	20
	1000	40±10	40
	2000	77±16	77
	4000	97±6	97
MVP[a]	5000	10±10	10
	10000	17±6	23
	20000	67±6	67
	40000	80±10	80
	60000	37±46	97

[a] MVP: the unit of MVP is PU/ml.

Attraction of *Hellula* and *Crocidolomia* to certain naturally occurring chemicals in crucifers

Both cabbage webworm and cabbage head caterpillar have become more and more serious during recent years. CWW larvae feed on leaves and growing shoots, while CHC larvae feed initially on young leaves but later on older leaves. Farmers use chemical insecticides to combat these pests, but these pesticides also kill the parasites of both CWW and CHC and that of DBM, resulting in DBM becoming a serious pest of crucifers than either CWW and CHC.

AVRDC is developing an IPM package consisting of a sex pheromone, trap cropping, and biological control, which will minimize or eliminate the use of chemical insecticides. Because of the specificity of both CWW and CHC to crucifers, it is possible that certain chemicals in crucifers could be responsible for attracting these two pests. Sinigrin and allyl isothiocyanate are naturally occurring chemicals present in crucifers that are readily available in the market. The purpose of this experiment was to find out whether some of these chemicals are involved in the selection of crucifers by these insect pests. Manipulation of insect behavior using these chemicals could help control these pests.

Three types of traps were used: fruit fly trap, *Spodoptera* trap, and wing trap. A cotton plug soaked in either chemical was placed inside each trap. In addition, a piece of polymer coated with DDVP was also placed in each trap to kill the insects. Traps were placed randomly in a Chinese cabbage field. Trap height was adjusted to just above plant canopy.

After 24 h, the number of CWW, CHC, and DBM adults in each trap were recorded. Traps were later moved to several other crucifer fields.

No CWW or CHC adults were trapped in either sinigrin or allyl isothiocyanate-baited traps. However, significant numbers of DBM adults (564) were trapped in sinigrin-baited wing trap; the allyl isothiocyanate baited wing trap got 2 DBM adults. No adults were found in the fruitfly or *Spodoptera* trap.

It appeared that the chemicals responsible for attraction of CWW and CHC to crucifers are different than those responsible for DBM.

Mixture of urea and CaO as soil amendment to control tomato bacterial wilt

Soils from five locations in Taiwan [Ilan, Taiwan Seed Improvement and Propagation Service (TSS) in Taichung, Nantou (Puli), AVRDC, and Kaohsiung, (Chinan)] were collected. TSS, Puli, and AVRDC soils were analyzed for soil texture, pH, cation exchange capacity, exchangeable Ca, K, Mg, Na, and N, and available N. Each soil was infested with a strain of *R. solanacearum* (Pss 4) and amended with a mixture of urea and CaO (equivalent rates of 435 kg/ha of urea and 5000 kg/ha of CaO) to determine the suppressive effect on the pathogen.

Results showed that the suppressive effect of the soil amendment is soil-specific. In the soils collected at AVRDC and Chinan, the population of Pss 4 was reduced from 6.0 or 6.9 (log 10 of cfu/g dry soil) to an undetectable level 21 days after amendment (table 4). In Ilan soil, the population was reduced from 6.8 to 1.8; in the Puli soil it was lowered from 6.3 to 5.8. Reduction of the pathogen population was not observed in TSS soil. The suppressive effect is correlated with the soil pH after amending. A soil pH above 7 seems to be critical.

Table 4. Population of *R. solanacearum*[a] and pH[b] of soil from 4 different sites in Taiwan 21 days after adding a soil amendment (SA)[c]

Site	SA	Population	pH
AVRDC	yes	0.0	7.7
	no	6.0	6.9
	prob.>F	0.0001	0.0001
Pingtung	yes	0.0	7.8
	no	6.9	6.7
	prob.>F	0.0001	0.0001
Puli	yes	5.8	6.9
	no	6.3	5.6
	prob.>F	0.0008	0.0001
TSS	yes	5.8	6.1
	no	5.8	4.5
	prob.>F	0.9943	0.0001
Ilan	yes	1.8	7.3
	no	6.8	5.3
		0.0001	0.0001

[a] In log 10 [cfu/g dry soil) + 1].
[b] 20 g air-dried soil in 50 ml 0.01 M $CaCl_2$ solution.
[c] Equivalent rates of: 435 kg/ha of urea (= 200 kg N/ha) and 5000 kg/ha of CaO.
Note: Soil was incubated at 30°C. Data presented are means from two experiments

Biological control of tomato fusarium wilt

Fusarium wilt of tomato, caused by *Fusarium oxysporum* f.sp. *lycopersici* (Fol), is a threat to tomato production worldwide. It is controlled primarily by use of resistant varieties. The resistance currently available is semidurable and three races of the pathogen have now been identified. Therefore, alternative control measures may be needed in the future. The objectives of this study were to identify avirulent strains of *F. oxysporum* and bacteria that are antagonistic to Fol, and to evaluate the antagonistic bacteria and avirulent *F. oxysporum* isolate for their potential to serve as biological control agents of tomato fusarium wilt.

Since October 1995, 11 bacterial isolates that were highly antagonistic to Fol have been identified and placed in long-term storage. This brings the number of isolates in storage to a total of 41. Additionally, five avirulent isolates of *F. oxysporum* that were isolated from tomato roots were placed in long-term storage.

Five bacterial isolates (DP2, *Bacillus subtilis*; A090, *Pseudomonas aeruginosa*; H 12A; ML-1, an unidentified actinomycetes; and FP, an unidentified pseudomonad) were tested in the greenhouse for their effects on fusarium wilt development in Fantastic tomato plants grown in Fol-infested soils. Antagonistic bacteria were applied (10^7–10^8 cfu/ml) as (1) a soil drench 2 weeks prior to transplanting, (2) a root dip immediately prior to transplanting, and (3) a seed treatment immediately prior to sowing. Isolates DP2, A090, and FP applied as seed treatments significantly ($P < 0.05$) reduced disease severity, based on the extent of vascular discoloration, in one of two infested soils. Also, plants that did not receive the root dip and soil drench treatments with DP2 showed significantly less severe symptoms than some other treatments. The two actinomycete isolates failed to suppress disease severity in any treatment.

Preliminary studies with avirulent Fo isolates (A1, A2, and B1) showed that they could suppress Fusarium wilt symptoms in tomato plants when applied as drenches a few days prior to transplanting, but they were more effective when applied as root dips prior to Fol inoculation and transplanting. Further studies showed that a 24 h immersion of the tomato seedling roots in avirulent Fo inoculum was much more effective than a 5 min immersion prior to the plants being inoculated with the virulent Fol isolate (table 5). The longer exposure may allow for colonization of the roots by the avirulent forms and the subsequent exclusion of the virulent form.

Table 5. Suppression of fusarium wilt symptoms in tomato seedlings in the greenhouse by root inoculation with avirulent *F. oxysporum* isolates prior to inoculation with *F. o.* f.sp. *lycopersici*[a]

Avirulent isolate	Root treatment[b]	Disease severity rating[c] Expt. 1	Disease severity rating[c] Expt. 2
A1	24 h	2.1a[d]	2.4a
A2	24 h	3.9a	1.7a
B1	24 h	4.0a	2.8a
PDA	24 h	9.0b	9.9c
A1	5 min	7.6b	7.9b
A2	5 min	7.0b	6.7b
B1	5 min	7.6b	10.0c
PDA	5 min	9.0b	9.5c

[a] Inoculum slurry of both avirulent and virulent isolates made by blending 7 to 10-day-old PDA plate cultures in 125 ml water.
[b] The period of time roots were immersed in avirulent inoculum prior to inoculation with the virulent isolate.
[c] Disease severity rating scale 0 to 10; 0 = symptoms and 10 = permanently wilted or dead plant. Evaluated 3 weeks after inoculation with the virulent isolate Fol-14.
[d] Mean separation by DMRT ($P < 0.05$).

Avirulent Fo isolates A1, A2, and B1 and antagonistic bacterial isolates DP2 and FP were tested for their effectiveness to suppress fusarium wilt symptoms in the field. Each potential biocontrol agent was applied as (1) a seed coating and (2) as a combination of seed coating and root dip. Soil infested with isolate Fol-14 was placed in the bottom of transplant holes for all plants except the noninoculated controls to ensure uniform distribution of the pathogen in the field. Fo isolates A1 and A2 applied as combination seed and root treatments, isolate A2 applied only as a seed treatment, and bacterial isolate FP applied only as a seed treatment significantly ($P < 0.05$) suppressed fusarium wilt symptoms (table 6). Disease severity estimates in the tomato plants were made 13 weeks after transplanting using a combination of external symptoms and the degree of vascular discoloration.

Table 6. Effects of seed and root treatments with avirulent *Fusarium oxysporum* and antagonistic bacteria on fusarium wilt expression[a] in field-grown tomatoes

Biocontrol agent	Application method[b]	Disease severity
None (control, without Fol inoculation)		0.13ac
A1, avir. Fo	seed + root	0.49b
A1, avir. Fo	seed	0.51bc
A2, avir. Fo	seed + root	0.50bc
A2, avir. Fo	seed	0.63bcd
B1, avir. Fo	seed + root	0.53bcd
B1, avir. Fo	seed	0.58bcd
FP, antag. bacterium	seed + root	0.60bcd
FP, antag. bacterium	seed	0.50bc
DP2, antag. bacterium	seed + root	0.59bcd
DP2, antag. bacterium	seed	0.65cd
None (control, with Fol inoculation)		0.68d

[a] Plants were inoculated individually by placing 100 g of infested soil, isolate Fol-14, in the bottom of each transplant hole.

[b] Seed immersed in conidial (10^6 spores/ml) or bacterial (10^7–10^8 cfu/ml) suspensions in 1% carboxy methyl cellulose for 1 h and then air-dried before sowing. Roots were immersed for 24 h in water suspensions at the same concentrations prior to transplanting.

[c] Mean separation by DMRT ($P < 0.05$).

Socioeconomic Studies on Vegetables

Socioeconomic research is undertaken 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 aim is to generate information to improve the policy environment in vegetable research and production, and to improve the interaction between biophysical and socioeconomic research at the Center.

In 1995, research focused on characterization of vegetable production systems in different environments, specifically mungbean production and supply systems in Pakistan; studying the causes and consequences of seasonality of vegetable production in Taiwan; and ex-ante and ex-post evaluation to measure the impact of AVRDC technologies on vegetables.

During 1996, the project concentrated on segregating the benefits of modern technologies in mungbean in Pakistan for consumers and producers, estimating the gap in supply and demand of vegetables in various Asian countries, and understanding vegetable cultivation in rice-based systems in the Philippines.

Research results indicated that the benefits of introducing modern technologies in mungbean in Pakistan generated about US$20 million per annum, which was more equitably distributed among producers and consumers than the distribution of similar benefits in cereal crops. The supply and demand gap analysis suggested that most Asian countries failed to meet the additional vegetable demand generated through population expansion and increased incomes, thus causing an upward push in real vegetable prices. A monitoring survey on vegetables in rice-based systems in the Philippines identified the soil domains on which vegetables are concentrated in and quantified the yield and input levels of vegetables.

Characterization of pulse supply and demand systems in Pakistan

This study aimed to estimate the short- and long-term supply elasticities of major pulses, such as mungbean, gram, mash, and lentil; estimate the demand and income elasticities of major pulses in comparison with the major food items; project the future demand of pulses in general and mungbean demand in particular; and segregate the welfare effect of modern technologies in mungbean cultivation between consumers and producers.

The supply response function for each pulse was estimated separately from district-level data for the years 1970–93. The response function for each pulse was estimated with production as the independent variable and lagged production, lagged prices of each pulse, lagged prices of major crops (i.e., wheat, rice, cotton, maize, and sugarcane), proportion of irrigated area, cropped area, wage rate, and district-specific dummies as independent variables. The log linear function was specified, and all prices were normalized with the fertilizer prices. The data on these variables were gathered from various publications and official files (the World Bank is coming out with a more comprehensive publication on the data).

For the demand function, consumption and expenditure by income, province, and rural and urban group on various feed items were taken from the household, income, and expenditure surveys for the years 1986–87, 1987–88, and 1988–89. The prices of different food items were estimated by dividing expenditure with the respective consumption quantities. The expenditure share of each commodity was estimated as total food expenditure divided by the expenditure on food items.

As the main interest of the study was to estimate the demand elasticity of pulses, all other food items were aggregated into 10 main food groups. The Almost Ideal Demand (AID) model was used, and the parameters of the model were converted into elasticities using standard formulation for this purpose.

Only short- and long-term own-price supply elasticities and own-price demand and income elasticities are reported (table 1).

The short-term own-price supply elasticities for mungbean and lentil were positive and statistically significant. Gram and mash production were not responsive to their own respective prices, perhaps because of the subsistence nature of these crops. A 10% increase in mungbean and lentil price increased their production by 2.5 and 1.4%, respectively, in the short term. However, the long-term elasticity of mungbean was quite high at 1.178. The large difference in the short- and long-term elasticities of mungbean indicated the farmers' inability to adjust resources in the short term in response to price changes, mainly because most of the farm resources were plugged into expenses for subsistence crops, such as wheat, and cash crops such as rice, cotton, maize, and sugarcane.

Own-price demand elasticities of all pulses are quite high, indicating that consumers responded strongly to changes in their prices. These elasticities are comparable with other quality food, such as milk and meat, but higher than wheat which is the main staple food. Income elasticities of all pulses were positive. Mash has the highest income elasticity among pulses, and mungbean one of the lowest preferred pulse. The positive income elasticities of each pulse suggested that income increase will result in additional demand for pulses.

Table 1. Response function for the major pulses in Pakistan, 1970-93

Variable	Own price elasticities		Demand elasticities	
	Short-term	Long-term	Own price	Income
Mungbean	0.253*	1.178*	-0.689**	0.241**
Gram	-0.082	-0.320	-0.743**	0.483**
Mash	0.040	0.120	-0.728**	0.601**
Lentil	0.138**	0.340**	-0.821**	0.440**

* and ** imply that the estimated elasticities are significant at the 1% and 10% level, respectively

This contradicted the general belief that consumption of pulses in the country declined because of increasing incomes. Rather, increasing prices of pulses along with high own-price elasticity is the main cause of the decline in pulse consumption.

Total welfare benefits of new technologies in mungbean were divided into four parts: (1) production effect defined as the benefit generated from the increase in mungbean production, (2) quality improvement effect defined as the benefits generated due to improvement in mungbean quality, and (3) residual effect defined as benefits from the expanded mungbean cultivation on the fallow lands after wheat. The gains generated from increased mungbean production were further segregated into (1) expansion effect defined as benefits generated from the expansion in mungbean area, and (2) substitution effect defined as benefits generated from replacing the low-yielding Desi variety with modern varieties.

The estimated elasticities were used to segregate the benefits generated by technological innovations among producers and consumers in each component (table 2). The total benefits of the innovations were about US$20 million. Sixty-two percent of the benefits went to producers and 38% was shared by consumers. This is in contrast to the sharing arrangement in cereals, where most of the benefits of the technological generation went to the consumer. The contrast in sharing arrangements is mainly because of the difference in demand elasticity. As noted earlier, pulses have relatively high demand elasticities compared to staples, such as wheat in Pakistan. Thus, unlike in cereals, technological innovations do not cause very steep price declines in pulses.

The improvement in production contributed less than half of the total effect or 45% at US$ 9.0 million per annum. This effect can be divided into substitution and expansion effects.

Substitution effect produced US$ 5.3 million per annum. The effect contributed 27% to the total welfare generated. The share of the consumers was 63%, while producers shared 37% gain (fig. 1).

Table 2. Consumers' and producers' surplus generated through research innovations, Pakistan, 1994–95

Type of effect and surplus	Value	Percentage
Total effect	19.7	100
Consumers' surplus	7.5	38
Producers' surplus	12.2	62
– Production effect	9.0	46
• Substitution effect	5.3	27
Consumers' surplus	3.4	17
Producers' surplus	2.0	10
• Expansion effect	3.6	18
Consumers' surplus	2.3	12
Producers' surplus	1.3	7
– Improvement in quality effect	4.4	22
Consumers' surplus	1.8	9
Producers' surplus	2.5	13
– Residual effect	6.4	32
Consumers' surplus	0.0	0
Producers' surplus	6.4	32

Estimated surplus in million Rs was converted into million US$ by using the official exchange rate during 1994-95 of Rs 30.85 = US$ 1 (Government of Pakistan 1996).

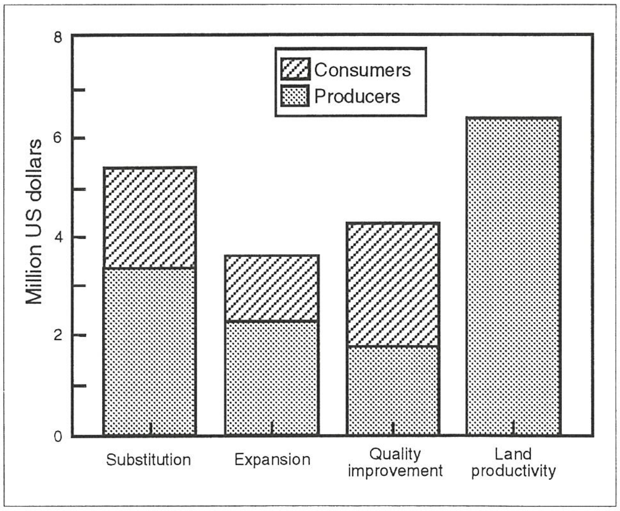

Fig. 1. Distribution of the benefits among producers and consumers

Total welfare generated due to area expansion amounted to US$ 3.6 million in 1994–95. Expansion effect contributed 18% to the total surplus generated due to research innovation. About 63% of this went to consumers and 37% to producers (fig. 1).

New varieties with bold and shiny seed improved mungbean prices both at the farmgate and wholesale level. This produced a surplus of US$ 4.4 million, which is about 22% of the total surplus generated through research innovations (fig. 1). The consumers' and producers' shares were 42 and 58%, respectively.

The land productivity effect of mungbean on the following wheat on the expanded wheat-mungbean-wheat rotation areas generated US$ 6.4 million per annum, which is about 32% of the total surplus generated. As the improvement in wheat yield due to mungbean in the rotation is only a small proportion of total wheat area, this did not affect wheat price. Therefore, all the benefits went to the producers (fig. 1).

Characterization of vegetables grown with field crops

This study aimed to: quantify input use and yields of different vegetables grown under different farming systems; quantify linkages between vegetables and other major crops in terms of input use, farm-management practices, and yield; and prioritize production constraints of major vegetables in different cropping systems.

Three types of cropping systems in which vegetables were grown were selected in Ilocos Norte, Northern Philippines. The activity was initiated with the help of the Mariano Marcos State University (MMSU) and a student fellow from Netherlands. A sample of 75 farmers growing vegetables in the rice-based system and another 75 rice farmers in the vicinity of the vegetable-growing farmers were selected for interview. The wet season crop survey has been completed.

Twenty vegetables were found to be grown during the wet season in the rice-based system of Ilocos Norte. Rice yields were higher than the national average in the study area. The yields of vegetable crops in the study area were generally lower than the national average because of the summer season cultivation. Watermelon and gourd were the highest yielding vegetables followed by sweet pepper (table 3).

Vegetables were generally grown on medium and light-textured soils (fig. 2). Land use for crop cultivation well reflects soil physical characteristics.

Table 3. Average yield of various crops in the wet season in Ilocos Norte, Philippines, 1996

Crop	No. of observations	Yield (t/ha)	CV (%)	Nat'l yield (t/ha)
Rice	133	3.9	0.6	2.8
Sweet pepper	13	8.1	0.5	4.2
Sweet potato (leaves)	1	0.5	0.0	-
Corn	4	1.7	1.1	2.0
Mungbean	16	1.2	1.9	0.7
Tomato	15	5.1	1.2	8.5
Squash	15	5.4	0.9	10.2
Bottle gourd	7	10.0	1.3	7.0
Eggplant	27	5.2	1.3	6.4
Bitter gourd	7	5.1	1.0	4.1
Cowpea	18	1.4	0.8	1.8
Jute	1	3.0	0.0	-
Green onion	5	2.9	0.5	4.7
Long bean	14	4.2	0.4	-
Okra	5	4.5	0.9	3.4
Patola	1	1.0	0.0	2.9
Green pea	1	2.0	0.0	-
Taro	3	4.5	0.3	-
Pechay	4	3.7	0.6	5.5
Watermelon	1	66.7	0.0	
Pigeon pea	1	2.0	0.0	1.9

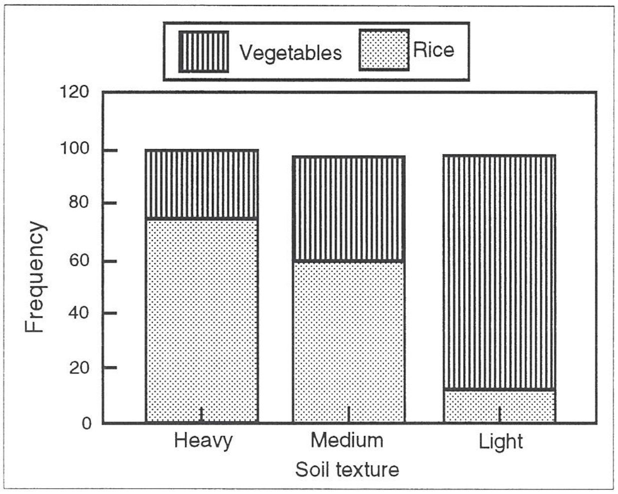

Fig. 2. Distribution of vegetables across soil textures

Average nutrient application on most vegetables was not very much higher than in rice. However, sweet pepper, onion, pechay, watermelon, and sweet potato received higher amounts of fertilizer. Relatively low amounts of fertilizer were applied to beans and corn (table 4).

On average, 1 to 4 chemical sprays were made on different vegetables, although the maximum went as high as 13. Insecticides were the main chemicals sprayed followed by fungicides. Farmers hardly used herbicide (table 5).

Agricultural economics research in Asia

With the help of the German Agency for Technical Cooperation (GTZ), a project was organized to identify data sources on different aspects of vegetables in major vegetable growing countries of Asia; conduct a comprehensive review of what has been done on agricultural economics research on vegetables, and identify the gaps in research; and improve links between vegetable economic researchers in Asia and AVRDC.

Data on various aspects of vegetable production, consumption, and distribution were gathered and comprehensive situationers on vegetables were written.

The analysis of trends in total vegetable production indicated that increase in vegetable production has slowed down in most Asian countries. Combining the growth in vegetable production with population and per capita incomes suggested that demand for vegetables far exceeded the supply of vegetables in most Asian countries. This caused the upward shift in real vegetable prices in many developing countries of Asia.

The growth rate in per capita vegetable availability, and demand derived from population, and per capita income increases are given in table 6. Except for Thailand, Indonesia, China, and Korea increase in per capita vegetable supply was far below the increase in demand in other countries. This generated pressure on vegetable prices, with real vegetable prices increasing in several countries (fig. 3).

Table 4. Average fertilizer nutrient (kg/ha) applied to different crops in the wet season, Ilocos Norte, Philippines, 1996

Crop	No. of observations	Nitrogen (kg)	CV (%)	Phosphorus (kg)	CV (%)	Potassium (kg)	CV (%)	Total nutrient (kg)	CV (%)
Rice	133	135.8	0.9	31.4	1.0	25.7	1.1	192.8	0.8
Mungbean	16	0.9	2.6	0.8	2.5	0.9	2.6	2.6	2.5
Tomato	15	164.9	1.3	57.3	1.5	57.3	1.5	279.5	1.3
Sweet pepper	10	836.0	0.9	380.4	0.9	378.4	0.9	1594.7	0.8
Corn	4	30.9	1.7	2.2	1.7	2.2	1.7	35.3	1.7
Sweet potato	1	345.0	0.0	0.0	0.0	0.0	0.0	345.0	0.0
Squash	15	137.9	2.3	57.8	2.2	57.8	2.2	253.4	2.2
Bottle gourd	7	121.5	0.9	28.9	0.7	26.6	0.9	177.0	0.9
Eggplant	27	115.6	1.0	48.6	1.3	35.9	1.3	200.1	0.9
Bitter gourd	7	57.0	0.7	31.9	1.7	8.1	1.2	97.0	0.9
Cowpea	18	37.0	1.8	17.8	1.6	17.0	1.7	71.8	1.7
Jute	1	92.0	0.0	0.0	0.0	0.0	0.0	92.0	0.0
Onion	5	241.9	1.2	87.0	0.7	87.0	0.7	415.9	0.9
Long bean	14	35.3	2.2	17.8	1.4	17.8	1.4	70.9	1.7
Okra	5	125.6	1.5	22.9	2.0	23.1	2.0	194.2	1.4
Patola	1	14.0	0.0	14.0	0.0	14.0	0.0	42.0	0.0
Green pea	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Taro	3	6.4	1.4	6.4	1.4	6.4	1.4	19.3	1.4
Pechay	4	203.6	1.3	87.3	1.2	78.5	1.4	369.3	1.3
Watermelon	1	142.9	0.0	133.3	0.0	133.3	0.0	409.5	0.0
Pigeon pea	1	70.0	0.0	28.0	0.0	28.0	0.0	126.0	0.0

Table 5. **Average and maximum number of sprays of pesticide in different crops during wet season in Ilocos Norte, Philippines, 1996**

Crop	Insecticide		Fungicides		Herbicides		Total pesticide	
	No. of sprays	Maximum	No. of sprays	Maximum	No. of sprays	Maximum	No. of sprays	Maximum
Rice	0.56	4	0.02	1	0.02	1	0.6	4
Mungbean	1.88	12	0.13	1	0.00	0	2.0	12
Tomato	3.13	11	0.53	2	0.00	0	3.7	11
Sweet pepper	3.20	12	2.50	12	0.00	0	3.5	12
Corn	0.75	2	0.00	0	0.00	0	0.8	2
Sweet potato	1.00	1	0.00	0	0.00	0	1.0	1
Squash	2.33	5	0.53	4	0.00	0	2.3	5
Bottle gourd	1.57	5	0.29	1	0.00	0	1.9	5
Eggplant	2.70	13	0.56	11	0.00	0	3.1	13
Bitter gourd	1.29	3	0.14	1	0.00	0	1.4	3
Cowpea	2.11	5	0.44	4	0.00	0	2.2	5
Jute	1.00	1	0.00	0	0.00	0	1.0	1
Onion	3.00	13	0.60	1	0.20	1	3.8	13
Long bean	2.57	9	0.64	9	0.00	0	3.2	9
Okra	2.00	9	0.20	1	0.00	0	2.2	9
Patola	2.00	2	0.00	0	0.00	0	2.0	2
Green pea	0.00	0	0.00	0	0.00	0	0.0	0
Taro	0.00	0	0.00	0	0.00	0	0.0	0
Pechay	2.00	4	0.00	0	0.00	0	2.0	4
Watermelon	6.00	6	2.00	2	0.00	0	8.0	6

Table 6. **Growth rates (%) in incomes, population, implied vegetable demand, vegetable production net of export in selected Asian countries, 1980-92**

Country	Per capita income	Vegetable demand due to incomes[a]	Population	Vegetable demand due to income + population	Increase in prod'n net of export
Thailand	8.2	3.3	1.5	4.8	6.8
Philippines	1.2	0.5	2.0	2.5	0.5
Taiwan	8.4	0.0	1.2	1.2	-1.3
Indonesia	5.7	2.3	2.1	4.4	6.1
Pakistan	6.1	2.4	3.3	5.7	4.7
India	5.2	2.1	2.1	4.2	3.6
Bangladesh	2.3	0.9	2.0	2.9	0.1
China	7.8	3.1	1.4	4.6	7.8
Korea	9.4	0.0	1.2	1.2	1.3
Sri Lanka	3.2	1.4	1.4	2.7	-1.4

[a] The demand for vegetables generated by enhanced incomes was estimated by assuming that income elasticity is equal to 0.4, except for Taiwan and Korea where vegetable consumption is already at a high level, and additional income is assumed to generate no additional vegetable demand.

Source: GDP and population growth rates are from Taiwan Statistical Data Book, 1995.

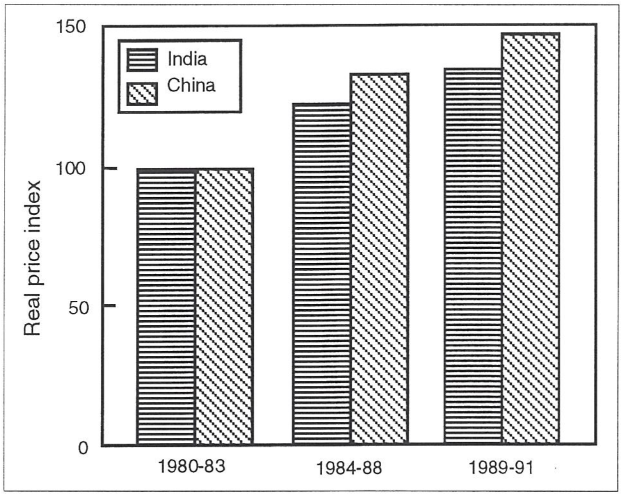

Fig. 3. **Increase in real vegetable prices in India and China**

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 20,000 chemical composition analyses were conducted during the year for such vegetables as grain and vegetable soybean, pepper, alliums, tomato, eggplant, and other crops using mainly near infrared reflectance spectroscopy (NIRS).

Effect of food processing on iron bioavailability

Effect of cooking on iron bioavailability of selected fruits

Seventeen fresh fruits were surveyed for in vitro bioavailability. Results of the analyses are shown in fig. 1. No relationship was found between dialyzable iron and iron content or type of fruit. The iron bioavailability of raw fruits, including cantaloupe, kiwi, tomato, plum, pineapple, and grapefruit was higher than 15%. These fruits have higher vitamin C and/or citric acid, which are considered major enhancing factors. Guava has low iron availability despite its high ascorbic acid content. This may be attributed to inhibitory factors, such as fiber.

Not all fruits verified demonstrated higher iron bioavailability after cooking. The enhancing ratio (ER) between cooked and raw samples ranged from 0.87 to 15.98. This ratio is not related to either iron content or bioavailability of raw fruits. Moreover, iron dialyzability was suppressed by the cooking process in some fruits, such as kiwi, star fruit, banana, pineapple, and grapefruit.

Comparison of dialyzable iron of fruits and vegetables suggested that vegetables are a better iron source in the diet (fig. 2).

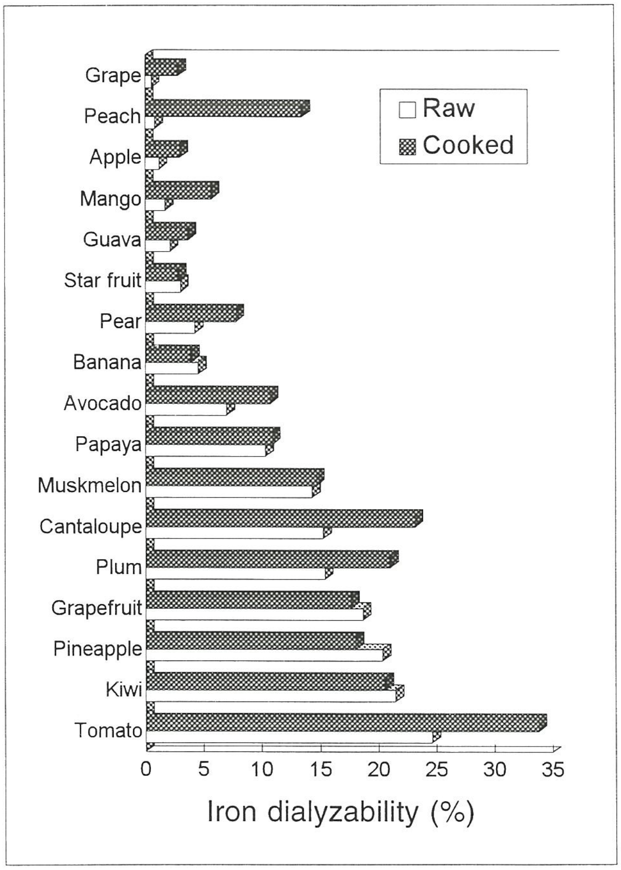

Fig. 1. Effect of cooking on selected fruits

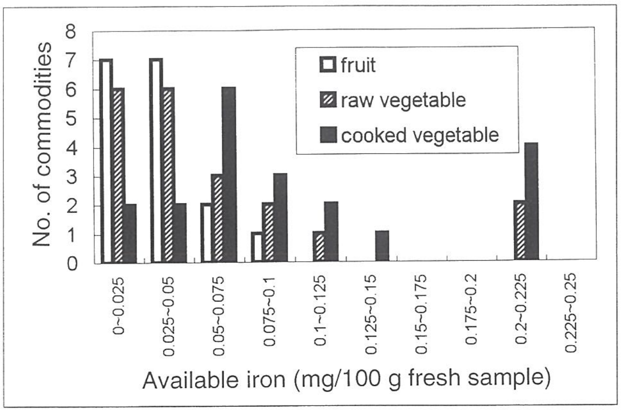

Fig. 2. Available iron in fruits, and raw and cooked vegetables

Effect of adding fresh fruits on iron dialyzability of vegetables

The potential of fresh fruits as an enhancing factor in vegetable iron was investigated. Three fruits, guava, papaya, and grapefruit, were used and added fresh to vegetable meals. The ascorbic acid contents of selected fruit samples were 81.7 mg/100 g, 79.1 mg/100 g, and 31.9 mg/100 g for guava, papaya, and grapefruit, respectively.

The dialyzable iron concentration of individual commodities and mixed samples are summarized in table 1. Enhancing (or inhibitory) effect of fruits on iron bioavailability of pai-tsai can be expressed as the difference between the dialyzable iron concentration of the mixed sample and the sum of individual samples of vegetables and fruits. An enhancing effect on iron bioavailability for both raw and cooked vegetables was observed in the case of papaya and grapefruit. On the contrary, an inhibitory effect was observed on guava, especially for the cooked sample.

Table 1. Iron dialyzability of vegetables mixing with raw fruits (ppm)

Fruit and vegetable	Dialyzable iron concentration (ppm)	
	Raw	Cooked
Guava	0.017	
Pai-tsai	0.064	0.324
Pai-tsai mixed with guava	0.069	0.268
Papaya	0.036	
Pai-tsai	0.086	0.293
Pai-tsai mixed with papaya	0.300	0.464
Grapefruit	0.097	
Pai-tsai	0.064	0.324
Pai-tsai mixed with grapefruit	0.293	0.494

These results suggested that fruits high in dialyzable iron had higher enhancing effects on iron bioavailability. Ascorbic acid, which is known as an enhancing factor, is not the only substance associated with iron bioavailability in fruits. Other enhancing or inhibitory substances are present, as suggested by the higher enhancing effects of grapefruit which has a lower ascorbic acid content, or that reversed the enhancing effect of high ascorbic acid in fresh guava. More studies will be conducted in the future on effects of possible natural constituents in vegetables and fruits.

Due to much lower bioavailability of iron and unobvious cooking effect in fruits, fruits are considered insufficient sources of nonheme iron. Because of the enrichment of ascorbic and citric acids, fruits can be considered as an enhancer rather than an iron source. The practical effect of mixing food in the diet should be further verified.

Quality evaluation of vegetables dehydrated under low temperature and humidity

A total sample of 55 common cabbages consisting of 21 varieties were obtained from the Crucifer Breeding Unit from July to November 1996 for analysis. Qualities including dry matter, fiber, sugar, and vitamin C content were analyzed (table 2). Dry matter contents (%) of cabbage harvested in July (7.72%) were higher than those in September (6.05%). Fiber and sugar content showed a little variation, but mean values did not change. Vitamin C in 100-g fresh cabbage samples were also higher in July (51 mg, 41 mg in September), probably due to the corresponding high dry matter content.

Eight varieties harvested in September were selected and dried under industrial conditions: 80°C first, followed by 60°C with low humidity system (established previously at AVRDC), for sensory evaluation including appearance of dried and rehydrated samples by 10 panels.

Table 2. **Quality evaluation of 55 samples of 21 common cabbage varieties harvested from July to September 1996**

No.	Variety	Index	Dry matter (%)		Fiber (%)		Sugar (%)		Vit. C (mg/100 g)	
			mean	SD	mean	SD	mean	SD	mean	SD
1	Reynoong No. 1	BB 145	8.17	-	10.06	-	38.87	-	57.04	-
2	T-621	BB 147	7.49	-	11.77	-	31.96	-	77.93	-
3	Processing type	BB 172	7.38	0.64	12.39	0.90	37.20	8.65	52.47	-
4	ZhongGan No. 8	BB 118	7.38	0.71	11.48	0.70	35.59	5.56	65.48	11.14
5	Blue Star	BB 154	7.23	-	11.21	-	39.30	-	47.23	-
6	V 0402	BB 208	7.18	-	11.08	-	35.00	-	71.53	-
7	Processing type	BB 170	7.09	1.07	12.06	0.91	40.62	8.19	73.41	3.18
8	Summer Queen	BB 153	6.98	-	10.66	-	45.17	-	68.51	-
9	Bss 50	BB206	6.87	-	12.33	-	28.57	-	46.18	-
10	KS Green	CB 0017	6.72	0.55	12.23	1.30	35.55	4.89	43.37	15.72
11	KF	KF	6.69	-	12.30	-	48.06	-	59.04	-
12	Copenhagen Market 55 Days No. 1	BB 125	6.66	1.01	12.43	1.18	35.24	8.10	46.33	14.86
13	KS Cross	BB 155	6.65	-	11.59	-	39.17	-	32.27	-
14	Shiafong #1	BB 006	6.62	0.74	10.55	0.96	41.64	4.52	37.20	16.52
15	Delicious	CB 0003	6.51	1.23	11.22	0.61	39.53	3.41	41.62	12.88
16	ChoonChiou	BB 110	6.49	0.98	11.24	2.00	40.91	4.05	42.84	11.35
17	Hiyakuki	BB 204	6.22	-	11.07	-	42.63	-	62.80	-
18	Summer Sea YR	BB 164	6.22	0.76	11.85	0.54	36.96	3.58	33.86	5.32
19	KK-Cross	BB 112	6.09	1.20	13.16	1.00	34.07	3.62	41.72	18.99
20	TaiWu	BB 021	5.99	-	11.37	-	33.97	-	57.92	-
21	KY-Cross	BB 008	5.78	-	10.96	-	41.86	-	37.52	-

The quality and color value of a, b, and L were also determined. Sensory scores ranged from 1 (the worst) to 10 (the best); 5 was reference BB170, which was prepared previously by a drying company. BB170 is a processing type from Japan. The sensory scores and SD in each sample are shown in fig. 3. The scores for appearance were all above 5. To explain the phenomena, correlation between color values detected by a color meter and sensory scores were made by using SAS REG procedure. The a value has higher correlation, R^2 = 0.64, with the appearance score of rehydrated cabbage than the L value, R^2 = 0.29 (fig. 4). This suggested that the Taiwanese preferred the green color in rehydrated common cabbage, unlike in Japan, where white is preferred. In addition, browning did not affect the appearance scores in dried and rehydrated cabbage among samples tested.

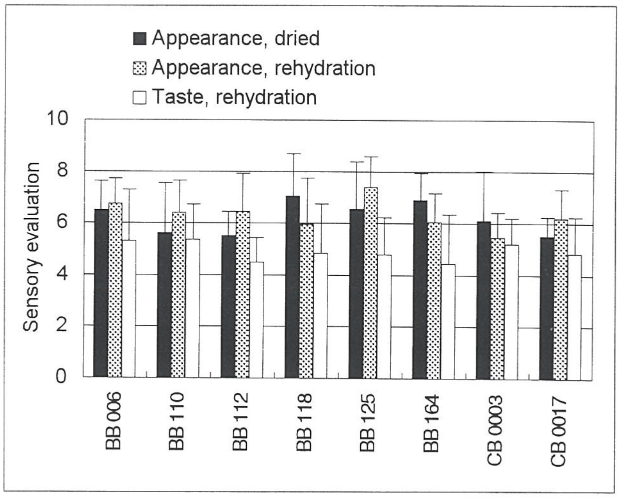

Fig. 3. Sensory evaluation of common cabbage

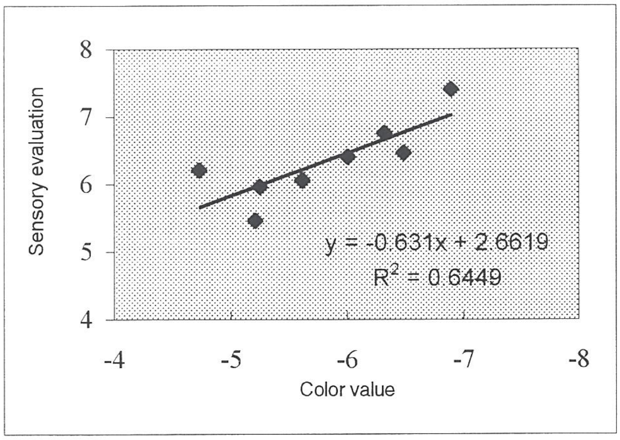

Fig. 4. **Linear regression of appearance scores of rehydrated cabbage and color values**

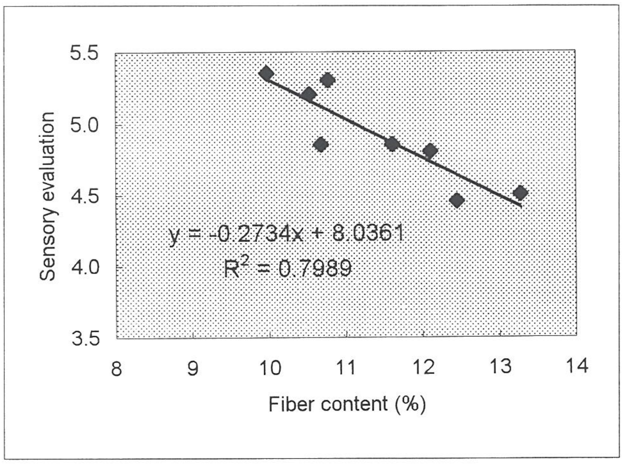

Fig. 5. **Linear regression of taste scores of rehydrated cabbage and fiber contents**

The correlation between quality and taste scores was also determined by using the SAS REG procedure. The major factor contributing to the taste sensory test was fiber content (fig. 5). Sugar, dry matter, and vitamin C seemed to have no effect on taste. The low correlation between sugar and taste scores can be explained by the addition of glucose during processing which eliminated the contribution of intrinsic sugar in taste.

High dry matter of cabbage decreased the cost of dehydration, and lower fiber content of cabbage gave a better taste. The dry matter content of two processing types—BB 172 and BB 170—were 7.38 and 7.09%, respectively. According to a variety survey, samples with dry matter content greater than 7.09, including Reynoong No. 1, T-621, ZhongGan No. 8, Blue Star, and V 0402, have potential for industrial use, especially Reynoong No. 1 which has a high dry matter content of 8.17% and the lowest fiber content of 10.06%.

Human Resources Development

Strengthening the research capacity of national agricultural research systems (NARS) through human resources development is one of three major roles of the International Cooperation Program. Emphasis is placed on research skills training to promote adaptive research and networking. So far the Center has trained more than 1200 midlevel researchers and graduate students from more than 50 countries.

Training

AVRDC headquarters trained 82 scholars from 26 countries during the year (table 1). All undertook nondegree training; 50% underwent special research skills training and 47% were women. More than 50% trained under the Crop Improvement Program (CIP) and the rest under the International Cooperation Program (ICP) and Production Systems Program (PSP).

In addition to AVRDC eight other donors supported the Center's training program: Japanese Special Project; IPM CRSP-PhilRice Collaborative Project; Winrock International; Crawford Fund for International Agricultural Research, Australia; German Academic Exchange Service; Fulan Seeds Co., Ltd.; Committee of International Technical Cooperation/Taiwan; and Agricultural Research Project-II (a World Bank Project in Bangladesh).

Training scholars work with and under the guidance of senior scientists on areas of specific interest. This year the training participants mostly worked under CIP.

Table 1. Distribution of training scholars by country and by category

Country	PF	RF	RS	RI	SPT	UST	Total
Burkina Faso					1		1
Egypt					1		1
El Salvador					1		1
Fiji					1		1
Gambia					1		1
Germany			1				1
Guatemala					1		1
India	1						1
Indonesia					4		4
Japan			2				2
Korea				1	1		2
Latvia					1		1
Malawi					1		1
Malaysia					3		3
Netherlands			1				1
Pakistan					5		5
Papua New Guinea					1		1
Philippines		2		2	2		6
Saudi Arabia					1		1
Senegal					1		1
Solomon Islands					1		1
Taiwan				1	5	29	35
Thailand					3		3
Tonga					2		2
USA						1	1
Vietnam					4		4
Total	1	2	4	4	41	30	82

PF = Postdoctoral Fellow
RF = Research Fellow
RS = Research Scholar
RI = Research Intern
SPT = Special Purpose Trainee
UST = Undergraduate Student Trainee

Research fellowship. Research fellows worked on the following research areas: production of transgenic L 4783 tomato plants expressing CMV-T coat protein gene via *Agrobacterium tumefaciens;* cytological and biochemical studies on Southeast Asian vegetable genetic resources; and communication and training-related materials production.

Research internship. Ten training scholars, including two research scholars working towards their Ph.D.s 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. Twelve training scholars, two each from Indonesia, Malaysia, Philippines, Thailand, and Vietnam, one from Korea and Taiwan, sponsored by the Crawford Fund for International Agricultural Research, Australia, participated in the 3-week master class on bacterial molecular genetics: its importance in bacterial wilt. The class is part of a joint project on bacterial wilt resistance between the Australian Centre for International Agricultural Research (ACIAR) and AVRDC. Several standard methods for ecotyping were demonstrated in the class to enhance future collaboration. A training manual on bacterial molecular genetics based on the teaching materials used in this class will come out soon.

Nineteen training scholars from Asia, the Pacific, Eastern Europe, South America, and Africa attended the special training course on Vegetable Cultivation and Seed Production on 11–30 November held at headquarters. The course was designed to allow participants to learn scientific techniques and modern approaches in producing good quality vegetables and seeds.

Short-term training. Thirty undergraduate students from eight academic institutions in Taiwan enrolled for the summer student training course. Four 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 and training.

Training materials. During the year 81 slidesets with scripts and videos were distributed to 37 training scholars.

Communication and Information

The Center continues to be a major publisher and clearinghouse of information and literature on global vegetable research information. Its Tropical Vegetable Information Service (TVIS) databases are now available online. With the resuscitation of the TVIS project, information services are being expanded with a view to make available to NARS partners the Center's information resources, mainly through computer-based electronic systems and the new TVIS Newsletter. This newsletter is intended to be the mouthpiece of the global vegetable research community.

Information and documentation

Information collection

Some 239 book titles, 85 photocopies, and 342 titles of serial publications were acquired through exchange or as gifts from 194 institutes and organizations in 51 countries. Subscriptions to 57 journals for 1997 were renewed and subscriptions to 119 serial publications were continued.

Processing information

A total of 1412 titles of books and crop documents, and 25 new serial titles were indexed and added to the Tropical Vegetable Information Service (TVIS) databases which now hold 54,619 bibliographic records and 1650 journal records. The supplementary databases contain 7915 records of TVIS thesaurus (control vocabularies), 3639 records of journal codes, and 4000 records of institutions/organization. The library collection now totals 13,763 volumes. Conversion of databases from HP 3000 to PC server, using MINISIS version 8, is ongoing and will be completed next year.

Disseminating information

TVIS SDI (Selective Dissemination of Information) services added 62 new users from 15 countries, bringing the total users to 313 in 60 countries. Two issues of the Library List (new acquisitions) and 17 issues of the TVIS SDI Bulletin were published for internal users. Sixty-nine literature searches were done on TVIS and CD-ROM databases for internal and external users.

The library recorded 4384 book and crop document loans. A total of 1533 titles of documents were photocopied and delivered to 85 external users and 75 libraries in 15 countries. The library helped disseminate news/information from the CGIAR information dissemination coordinator.

Interlibrary collaboration

Three library staff attended meetings and workshops in Taiwan. AVRDC's list of serial holdings and books were updated and added to the Union List of NonChinese Sci-Tech Serials and Union Catalog of NonChinese Sci-Tech Books in ROC. Linkages were maintained with other local libraries.

Publications and communication

Communication materials production

The Office of Publications and Communications continued to provide communication support services to researchers and staff. These services included editing, graphic and art services, documentation through photography and slides, computer graphics generation, audiovisual support, and desktop publishing. The in-house print shop ran a total of 636,939 printed pages.

Several publications, including the yearly progress report, a technical bulletin, newsletters, and special publications were produced. The Korean version of the Field Guide on Insect Pests, the first copublication arrangement for this pocket handbook, was produced recently by Horticultural Technology, a private agricultural journal in Korea. A second printing is already being planned.

The format of the AVRDC annual report which is a documentation of the Center's yearly accomplishments, was changed last year and further streamlined this year. The TVIS Newsletter, a research publication intended to be the flagship of the Center's newly expanded Tropical Vegetable Information Service, came out this year.

Promoting public awareness

AVRDC and its activities were featured in 33 published news items in two local newspapers. These included write-ups on the Center and the international staff, integrated pest management, new varietal release (cherry tomato CHT 154), diamondback moth in cabbage, work on onion and medicinal benefits from the crop, intercropping vegetables with flowers, and hydroponics.

OPC also sent promotional materials (exhibits, flyers, and publications) to three international meetings. A handful of local and international media persons and journalists from the U.S., Europe, and Indonesia visited AVRDC.

Circulation and dissemination of research information

The Center's mailing list was given a major facelift. From more than 3000 names, the list was pared down to 2200 names which include about 600 libraries, 1200 general (board members, donors, IARCs, NARS collaborators, media, former staff, training alumni), and 400 CTA (Technical Centre for Agricultural and Rural Cooperation) members. CTA continued to provide support for information dissemination to CTA member countries. An order-entry database for book sales was set up and was pretested for use next year.

More than 6000 copies of Center publications were mailed to over 2500 individuals/organizations including libraries, R and D organizations, NARS cooperators, media representatives, donors, AVRDC training alumni, board members and former staff, and others in 78 countries and territories. Publication sales totaled almost US$ 9000. A distribution agreement was signed with a book agent from the Rep. of South Africa who can handle book distribution for the African region. A major inventory of Center publications was also undertaken.

Collaborative Research and Networks

The emphasis of the collaborative research and network project is to encourage the NARS to take an active role in initiating subregional collaborative networks in which AVRDC plays a catalytic and partnership role. The aim is to enhance the research and development capacities of the national programs.

Collaborative Vegetable Research Program for Southeast Asia (AVNET– II)

The final workshop of AVNET-II held on 2-5 September 1996 was attended by participants from Indonesia (13), Malaysia (11), Philippines (13), Thailand (33), AVRDC (8), ADB (1), and 11 observers. During the workshop, researchers from each country presented the results of activities under the two subnetworks.

The two subnetworks and their objectives are: Subnetwork 1–Field verification and technology packaging for selected vegetables (chili, yard-long bean, cucumber, and tomato): (1) identify and select promising varieties and evaluate them under farmer's field conditions in selected seasons and locations; (2) identify suitable tissue culture medium for garlic and shallot especially for genotypes that grow slowly or not at all in the standard medium; and Subnetwork 2–Disease and pest management; (1) promote the use of improved bacterial wilt-resistant tomato varieties by farmers in participating countries, (2) develop an acceptable and feasible integrated BW disease management system for effective control of the disease, (3) identify superior pepper genotypes with resistance to CMV and CVMV and desirable characteristics, (4) confirm and verify the presence of strains and other viruses, and modify breeding strategies, if necessary, and (5) introduce, establish, and adopt the technology of using parasitoids and other nonchemical control measures to control crucifer pests in both highlands and lowlands.

AVNET-II has fostered and nurtured the spirit of teamwork initiated in AVNET-I. By training the trainers AVRDC has helped develop a pool of skilled horticultural specialists and strengthen research capacity in each of the NARS. Knowledge base of the NARS extension staff and farmers was also enhanced.

Exchange of valuable high-yielding and disease-resistant germplasm helped in improving the yield and quality of vegetables produced by farmers. Better research facilities and research environments were set up for more impact-directed researches. Duplication of research efforts in the region was minimized and rapid information exchange facilitated the generation of appropriate research results.

The private sector showed keen interest in the results of the network and indicated interest in becoming partners of the network. The participants discussed this issue and decided to include the private sector in future network activities.

Subnetwork I
Field verification and technology packaging for selected vegetables (chili, yard-long bean, cucumber, and tomato)

Among the chili varieties tested LC Serdang from Malaysia and Jatilaba from Indonesia gave consistently higher yields in the wet season in the Philippines, bringing higher net income and return on investment. Jatilaba was also earlier maturing and resistant to TMV and ToMV diseases.

Several AVRDC tomato varieties were well adapted to all the four countries in both rainy and dry seasons. In the Philippines hybrid tomato seed production was highly profitable with 179% return on investment. In Malaysia there is potential to get a net return of US$ 3700/ha in the lowlands.

For cucumbers preference for shape, size, color, and taste of the fruits differed for each country. As a result the yield is only secondary in importance.

The Philippines officially released a new yard-long bean variety from the line CSL 19 and named it as PSB-PS-2 for commercial production during the wet season. In the dry season BPI-PS-3 gave an estimated income of US$ 4563/ha. Kp #5 was also promising in the Philippines. Results from Indonesia revealed that CSL 19 when cultivated in the lowland had desirable consumer qualities such as longer pod length and pod shelf life, and heavier and more fiber content than those cultivated in middle elevation areas.

Micropropagation protocols of garlic and shallot through appropriate tissue culture techniques have been successfully developed in the Philippines. Two technical bulletins, "Tissue culture system for garlic and shallot" and "AVNET-II garlic and shallot accessions" have been produced for distribution to extension staff and the private sector. A collaborative network for field testing tissue cultured materials has also been established. Micropropagation enables rapid multiplication of virus-free planting materials using minimum space and cost compared to conventional methods.

Subnetwork II
Disease and pest management

Bacterial wilt

The results of varietal screening for bacterial wilt resistance showed that three AVRDC tomato lines, CL 5915, CL 1131, and L 285, were resistant in all the four AVNET countries. In Malaysia an AVRDC variety, CL 5915-206D4-2-5-0, was found to have BW resistance, desirable market qualities, and high yield and will be promoted to farmers in lowlands after further evaluation. Each country has identified a combination of resistant variety plus one or more of the following methods to effectively and economically manage BW: urea+CaO soil amendment, crop rotation, solarization, summer plowing, use of antagonistic microorganisms, and grafting of tomato onto wild resistant rootstock. In a combining ability study line H 7997 appeared to have good general combining ability to confer resistance to BW in all three locations studied: AVRDC, Philippines, and Indonesia. The pathogen from different countries has varying degrees of virulence suggesting the need to evaluate BW-resistant materials in multilocation trials.

Chili viruses

Among the chili varieties identified as resistant to cucumber mosaic virus (3), chilli veinal mottle virus (5), and tobacco mosaic virus (1), VC 160A, LV 3633, and PBC 569-5 showed resistance to either CMV, CVMV, or both in all the four countries. Jatilaba was resistant to TMV. Some of the resistant varieties have very good horticultural characteristics and could be extended to farmers after demonstration.

Several stains of CMV and CVMV have been isolated in all four countries which necessitates the need to screen for resistance to individual strains.

IPM of crucifer pests

An integrated pest management technology using parasitoids *Cotesia plutellae*, *Diadegma semiclausum*, *Diadromus collaris*, *Trichogrammatoidea bactrae*, *Brachymeria* sp.; nuclear polyhedrosis virus (NPV);

Bacillus thuringiensis (Bt); and in some cases Indian mustard as a trap crop plus minimum use of pesticides has been successfully piloted in all four countries. Parasite rearing facilities established in AVNET-I are efficiently used in AVNET-II in all the countries.

Indonesia. Indian mustard and rape are effective trap crops for DBM and *Crocidolomia binotalis.* In warmer mid-elevation areas *Diadegma* has established very well and is doing a good job of controlling DBM. There is 50% survival of the parasite *D. semiclausum* when it is released in the lowland. A total of 21 men and 4 women farmers participated in pilot field application of IPM. In their field pesticide application was reduced by 78%; their net return increased by US$ 307/ha.

Philippines. AVNET-I and II have catalyzed the development of a project to train trainers and farmers field school (FFS) by the Department of Agriculture, International Institute for Biocontrol, and the Asian Development Bank (ADB). IPM of DBM has been piloted in four regions in Luzon, the biggest island in the country. Training on IPM was provided to 176 agricultural technicians (60% women) and 1154 farmers (70% women) in 31 municipalities in 9 provinces. IPM was practiced by 49 farmer cooperators in 7 provinces whose increased net income due to IPM ranged from US$ 2781 to $10,984. Two new parasitoids have been identified to control cabbage moths. Indian mustard as a trap crop was also effective against cabbage moth. *Telenomus* sp. and *Microplitis manilae* were found effective against cutworm. A lowland-adapted strain of *D. semiclausum* which can survive at 35°C has also been identified. In IPM fields insecticide sprays were reduced from the usual 15-36 times to 1-9 times which increased the yield from 19 to 72 t/ha. The cost of production was reduced from US$ 3902 to $1104/ha. A simple multipest IPM scheme for *Crocidolomia* with Indian mustard as trap crop along with supplemental application of microbial pesticides to control *Spodoptera* and other caterpillars is ready for farmer adoption.

Malaysia. The use of netting to cultivate cabbage and other crucifers has resulted in considerable reduction in pesticide use. Forty master trainers and 74 agricultural technologists and 1340 farmers have been trained on IPM in 362 training sessions and 89 demonstrations. Among the trained farmers 90% adopted IPM. The profit by adopting IPM is US$ 8939 compared to the non-IPM field profit of $ 3551.

Thailand. An NPV pilot project with a capacity of 1000 L and which regularly supplies NPV at cost to farmers has been established. IPM training was conducted for 26 trainers, primarily agricultural universities, colleges, and Department of Agricultural Extension (DOAE) staff. A total of 1447 farmers and DOAE staff were trained on IPM in 13 training sessions.

South Asian Vegetable Research Network (SAVERNET)

SAVERNET was started in November 1991. A joint planning meeting was held in Dhaka, Bangladesh on 24–27 February 1992 to develop a work plan and a midterm review workshop was conducted on 12-15 September 1994 in Bangalore, India to assess network activities. The final workshop of SAVERNET–I and the joint planning meeting for follow-up activities were held in Kathmandu, Nepal from 23 to 28 February this year to discuss and exchange final results, determine research impact, and develop a plan for future activities.

During the meeting, the 68 delegates from the six member countries of Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, AVRDC, and the local organizing committee unanimously concluded that SAVERNET is an effective framework for cooperation. The member countries pledged commitment to sustain the activities initiated in the first phase.

SAVERNET has the same subnetworks and objectives as AVNET. Its research accomplishments include the following:

- The six member countries exchanged 96 varieties of 13 vegetable crops (table 1); 9 tomato and 3 varieties each of eggplant, hot pepper, and onion which were identified to be better than local checks are being advanced for testing in farmers' fields.
- Several AVRDC tomato lines were identified as resistant to bacterial wilt in all member countries and also to leaf curl virus (tables 2 and 3).

Table 1. Superior varieties identified in evaluation trials in different countries under SAVERNET

Trial location	Variety	Mean yield (t/ha)	Characteristics
Onion			
Bangladesh	Arka Niketan	39.5	high marketable yield
	Agrifound Dark Red	37.6	heavy bulb weight
	ON 0043[a]	19.8	good storage
	Tahirpuri[a]	29.4	good storage
Sri Lanka	Arka Niketan	18.7	low storage losses
	Pusa Red	16.4	low storage losses
	Kalpitiya[a]	16.5	high storage losses
Tomato			
Bhutan	Pusa Sheetal	45.7	less pest and disease incidence
	Nozimi[a]	46.7	high nonmarketable yield, more pest and disease incidence
India	Ratan (SD)	41.6	more marketable yield, heavy fruit weight
	Arka Vikas[a] (SD)	54.5	low marketable yield
	T-89 (D)	30.2	heavy fruit weight, bacterial wilt-resistant
	Pusa Early Dwarf[a] (D)	31.9	
Nepal	Arka Vikas (IND)	34.4	heavy fruit weight
	Monprecos[a] (IND)	34.7	tall plant height
	Pusa Ruby[a] (IND)	26.6	early-maturing
	Manik (D)	35.0	heavy fruit weight
	T-245 (D)	30.3	high-yielding
Sri Lanka	Manik (D)	33.0	tolerant to bacterial wilt
	T-245[a]	47.0	tolerant to bacterial wilt
	KWR[a]	39.5	high marketable yield, tolerant to bacterial wilt
Pakistan	T-89 (D)	21.7	heavy fruit weight
	Punjab Chhuhara (D)	24.4	high marketable yield, heavy fruit weight
	Roma[a]	19.6	less marketable yield
India	Pant Bahar (IND)	30.4	heavy fruit weight
	Pusa Ruby (IND)	35.8	heavy fruit weight
Chili			
India	MI-2 (fresh/dry)	4.9/1.4	high-yielding
	KA-2 (fresh/dry)	6.5/1.6	long fruit length, dark green fruit
	Bhaskar[a] (fresh/dry)	7.3/1.8	high-yielding
	Pusa Jawala[a] (fresh/dry)	3.6/0.9	long fruit length
Bangladesh	MI-2 (fresh/dry)	11.9/3.1	early-maturing
	KA-2 (fresh/dry)	10.4/2.5	long fruit length and girth
Eggplant			
Bangladesh	Pusa Purple Long	42.6	long fruit length
	Pusa Kranti	59.5	early-maturing
	Pant Rituraj	49.1	maximum fruit diameter
	Uttara[a]	50.1	maximum no. of fruits per plant
	Khatkhatia[a]	30.0	poor yield, high plant height
	Islampuri[a]	24.3	heavy fruit weight

[a] local check; SD = semideterminate; D = determinate; IND = indeterminate

Table 2. **Promising bacterial-wilt resistant varieties/lines identified in selected SAVERNET countries**

	Varieties
Bangladesh	
tomato	BL 323, BL 341, CL 80-0-7-1, CL 5915-9304-4-1, CL 5915-9304-4-1, CL 6046-1-1-2-3-2-7-0, CL 474-BC$_1$F$_2$-265-4-19, TM 076, TM 077, 079, TM 082, TM 084, TM 087, TM 091, TM 092, IND x CHN, TM 008 x TM 006, TM 006 x CHN, IND x TM 006, IND x TM 010, TM 006, Manik, T-C, T-D, Doutyl 90CRS2, TM 080
eggplant	Pant Rituraj, Thinnevelly White, Khatkhatia
India	
tomato	BL 312, BL 410, CL 8d-0-7-1, CL 5915-93D-4-1-0, CL 1143-0-10-3-0-1-10, CL 5915-206-D4-2-2-0, CL 65-349-D5-2-0, CL 675-BC$_1$F$_2$-285-0-21-0
Nepal	
tomato	BL 333, 323, 341, 342, 355
Pakistan	
tomato	BL 350, 342, 341, 333, L 285, CLN 657-BC$_1$F$_2$-285-0-21-0, CLN 65-349-D5-2-0
Sri Lanka	
tomato	BL 312, BL 350, BL 341, BL 342, BL 333, BL 410, BL 162, BL 311, L 285, CL 5915-206-D4-220, CL 475-BC$_1$F$_2$-265-4-19, CLN 65-349D5-20, T-245, T-146, Vihara 1, Vihara 2, KWR, B 17, B 15, B 13
capsicum	921376, 921379, PBC 204, PBC 375, PBC 473

Table 3. **Promising TLCV-resistant varieties/lines identified in selected SAVERNET countries**

	Varieties
Bangladesh	
tomato	TM 054 x TM 008, TM 039 x TM 008, TM 008 x TM 054, TM 691 x TM 073, TM 077 x TM 079, TM 081 x TM 089, TM 054 x TM 008
India	
tomato	TyKing, Ty-Gold, Big Strike, Fiona, BL 982, LA 1777, CLV 3727F1, CLV 3752 F1, Hirseptylc 91 Se, Pimhirtylc 91 J1, Pertylc 91, PDVR No. 7, H88 #31, H88 #155, P-10, H 86-26-2, H-24, H-36
chili	PDAC 26, PDAC 24, HOE 808
Pakistan	
tomato	TyKing x *L. hirsutum* x *L. chilense*
Sri Lanka	
tomato	BL 982, LA 1777, Jackal, Fiona, TyKing, R 8990

- Tomato leaf curl virus was confirmed to be present in five countries, except Bhutan. Screening for resistance to the virus indicated that 18 varieties may have resistance. The virus was confirmed in pepper in Nepal and Northern India, with three varieties identified as resistant.
- Parasite rearing facilities for crucifer pests were completed in all six countries. In India, large-scale release of parasites has been successfully done in farmers' fields. Within 3 years, the results from using integrated pest management practices resulted in a saving of US$60/ha. If IPM is adopted nationwide, the benefit could be US$6 million in India alone.
- Year-round tomato production is now possible in Bangladesh using a combination of AVRDC's heat-tolerant varieties, tomatotone (a hormone), and raised beds in plastic-covered tunnels. Tomato varieties tolerant to high temperature, high moisture, and salinity have been identified in India.
- Six working groups were formed during the meeting to continue on-farm trials; tomato, eggplant, and hot pepper improvement; off-season vegetable production; and IPM. Each working group prepared a detailed work plan for future activities.

Collaborative Network for Vegetable Research and Development for Central America (REDCAHOR)

The agreement establishing the network was signed late this year by the president of the Central American Bank for Economic Integration (CABEI), director general of the Inter-American Institute for Cooperation on Agriculture (IICA), and director general of AVRDC. Funding for the network activities will come from the International Economic Cooperation Development Fund (IECDF) of the ROC Ministry of Economic Affairs and CABEI. The two entities signed a memorandum of agreement in late 1995 to fund the project. Implementation of network activities will begin in 1997 after the appointment of a network coordinator.

Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam (CLVNET)

CLVNET, funded by the Asian Development Bank, was established in mid-1996 with the signing of a technical assistance agreement between AVRDC and ADB. It is coordinated by the AVRDC–Asian Regional Center based in Thailand. The network was created to promote increased production of vegetables in the participating countries through the establishment of a collaborative research program. It aims to upgrade the NARS through the development of improved vegetable germplasm and adaptive research technologies; strengthen research capability of NARS scientists in crop management practices, including IPM; and establish databases on vegetable information in each of the participating countries, including information on vegetable promotion, marketing, and production constraints. CLVNET focuses on training, germplasm collection and maintenance, IPM of diamondback moth in crucifers and bacterial wilt in tomato, economic survey, and database management. Network activities for the year include training activities and joint meetings of coordinators.

Under the training component, 6 training scholars from subnetwork 1 are undergoing the 5-month regional production training course at ARC in Kamphaengsaen, while 3 from subnetwork 2 attended a 1-month course. These researchers are working on regionally important crops. In addition, three researchers underwent a 1-month training course on the conduct of research on bacterial wilt of tomato. This training was conducted by Kasetsart University in cooperation with AVRDC and was completed in November.

The training program on IPM—control of diamondback moth in crucifers—will be held at AVRDC headquarters in 1997. The 2-week training on economic survey and data analysis will be conducted at ARC.

A joint steering and national coordinators meeting was held in November in Bangkok. An ADB representative also attended the meeting. Overall plans and activities as well as financial status of the project were discussed during the meeting.

AVRDC–Asian Regional Center

The AVRDC Asian Regional Center (ARC) based in Thailand was established in 1992 to undertake applied and adaptive research on AVRDC crops and regionally important crops, such as mungbean and other vegetables in cooperation with the Thai national program counterparts; coordinate subregional networks, such as the Cambodia, Laos, and Vietnam vegetable research network (CLVNET) which started implementation this year and the China program; and conduct training and information activities to improve the research capacity of the NARS in the region.

The Swiss Agency for Development and Cooperation (SDC)-supported project on Human Resource Development for the Mekong Region Countries started this year with major emphasis on training and germplasm collection and maintenance in the three countries of Cambodia, Laos, and Vietnam.

ARC continues to distribute and exchange vegetable and legume materials under its germplasm exchange program in collaboration with headquarters. Multiplication and characterization of several locally important vegetables, such as okra (lady's finger), luffa, eggplant, bitter gourd, and basil are ongoing.

Under the manpower development program, 32 training scholars completed the 14th regional training course on vegetable production and research. The 15th training course commenced in the last quarter of the year.

Research activities and adaptive trials

A total of 125 research studies on AVRDC and regional crops were conducted by ARC and by the participants of the 14th Regional Training Program in collaboration with national program scientists. On-farm trials were conducted on tomato, pepper, vegetable soybean, and cabbage. As part of the Asian vegetable research network (AVNET), research and on-farm trials were conducted by AVRDC–ARC researchers in ARC experimental fields and in farmers' fields. Vegetable soybean KPS 292 (AGS 292) was tested in cooperation with the Department of Agriculture (DOA) and Department of Agricultural Extension (DOAE). ARC and DOAE also undertook seed production for this variety.

Mungbean

Research on mungbean (*Vigna radiata*), a regional crop, focused on the specific needs of targeted regions of Asia in addition to the following major requirements: high and stable yield, large seed, uniform maturity, nonshattering pods, wide adaptability, varied crop duration to fit in different crop rotations and cropping seasons, and resistance to diseases, particularly powdery mildew (PM), cercospora leaf spot (CLS), mungbean yellow mosaic virus (MYMV). Shuttle breeding with the Nuclear Institute for Agriculture and Biology (NIAB) of Pakistan is still continuing as a collaborative mungbean project.

This year, promising lines identified in the dry season from various trials were multiplied in the early wet season. These lines constitute the International Mungbean Nursery (IMN) 96 which were supplied to cooperators all over the world.

Development of genotypes for the Southeast Asian region. More than 100 advanced lines derived from different crosses and backcrosses were evaluated in six sets of replicated trials along with standard checks for yield and other important plant characteristics. From these trials, lines with higher yield, improved seed size and plant type, top pod bearing character, and uniform maturity have been identified. Several lines with resistance or tolerance to powdery mildew were also identified. Intervarietal crosses between AVRDC lines and exotic genotypes were made to incorporate desired plant traits.

Development of genotypes for South and North Asia. Nearly 170 lines with resistance to MYMV, large seed size, high yielding ability, uniform maturity, nonshattering pod, and varied crop duration (55–85 days) were evaluated in nine sets of replicated trials for yield and other agronomic parameters during the dry season. The most promising lines from these trials were identified. These materials were developed under the shuttle breeding program between AVRDC–ARC and NIAB, Pakistan. Pure seed of promising lines from these trials were multiplied to constitute a separate set of mungbean nursery for the cooperators in South and North Asia. In addition, nearly 200 F_3 progenies and 52 F_5–F_9 families derived from several crosses between AVRDC and NIAB lines were grown for generation advancement and further selection.

Breeding for resistance to insect pests. Twenty-seven lines with resistance to bruchids were derived through crosses between VC 3890A and a wild resistant donor, *Vigna sublobata* acc. TC 1966, using RFLP technique. The lines, along with parents and standard check, were evaluated for yield, seed size, and plant type. Promising lines were identified for further evaluation. Most of the lines also displayed a good level of resistance to powdery mildew. Another set of 27 lines selected for resistance to bruchids from different crosses involving V 2709 and V 2802 as resistant parents were evaluated along with the parents and check in a replicated trial for yield, seed size, plant type, and other important traits. In addition, 166 lines derived from different crosses involving varieties TC 1966, V 2709, and V 2802 were studied for morphological and seed characteristics.

Of 2356 mungbean accessions from the AVRDC germplasm collection screened for resistance to bean podborer in summer 1995 at AVRDC, 20 accessions were found resistant. These accessions were multiplied for further studies. All the lines had small seed and pod with marked differences in plant type and crop duration.

Shuttle breeding with NIAB, Pakistan. The shuttle breeding material received from Pakistan consisted of 250 selections mainly from F_3 populations derived from crosses between 14 AVRDC accessions and NM 92. They were advanced to the F_4 generation in the late dry season at ARC. From these populations, nearly 500 single plant selections were further made based on yield, plant type, seed size, maturity characteristics, and resistance to CLS. Half of the seed of each accession was sent to NIAB for screening against MYMV in summer to confirm the resistance. The other half was planted at ARC for seed multiplication and further evaluation. The materials are quite promising and are expected to provide new superior varieties.

Screening of mungbean breeding accessions resistant to bruchids (*Callosobruchus chinensis* and *C. maculatus*). Mungbean is an important and valuable food legume in Asia. However, major constraints limit its yield potential, especially damage by insect pests, such as the bruchids *Callosobruchus chinensis* and *C. maculatus* which are very destructive pests of stored mungbean. This study screened 16 advanced breeding lines which carry resistance to bruchids and good agronomic characters: TC 1966 (*V. radiata* var. *sublobata*), a wild ancestor of cultivated mungbean which is completely resistant against bruchids; V 2709 and V 2802 with moderate to high levels of resistance; VC 3890A, 1973A, 2778A, 2768A, 1178A, and CN 60, advanced AVRDC breeding lines recommended in China, Cambodia, Korea, Philippines, Thailand, USA, Vietnam, and many other countries; and progenies of backcrosses between the high-yielding and bruchid-susceptible accessions with TC 1966 to incorporate the bruchid resistance genes.

Significant differences were observed in oviposition, emergence, and damage of the first generation adults ($P < 0.05$). There was a significant positive correlation between the rate of damaged seeds and the rate/number of emerging adults. TC 1966, $(VC\ 3890A)^2$/TC 1966-23, and $(VC\ 3890A)^2$/TC 1966-53 were rated highly resistant. The progeny $(VC\ 2778A)^7$/TC 1966 was rated highly resistant to *C. chinensis* and resistant to *C. maculatus*. The other four progenies varied from resistant to moderately susceptible. Resistant cultivar V 2709 showed resistance to *C. chinensis* and moderate resistance to *C. maculatus*, but V 2809 was moderately susceptible.

Garlic

An improved procedure for propagation of virus-free garlic was developed. With this method, it takes only 4 years for the bolting type and 5 years for the nonbolting type to develop from meristem culture to elite seed. An economic analysis showed profits during propagation in various seed grades, ranging from the nucleus to the elite seeds. By using virus-free garlic, both yield and quality of the bulbs and pedicel increased significantly.

Using inflorescence meristem culture a total of about 5000 multishoots or multibulbils can be obtained through four culture cycles in 1 year. Factors such as garlic genotype and culture medium influenced the number of multishoots significantly, while the daylength had much to do with multibulbil induction.

Protocols to isolate DNA from garlic were shown to yield up to 500+ ng/ml DNAs with good quality from 20 garlic cultivars and lines. Furthermore, DNA yield isolated from the younger tissues was higher than that from the older test plants.

Eighty-five random primers were screened for application in RAPD analysis. Five were chosen for use in genetic identification of 31 garlic cultivars and lines. The cultivars and lines can be genotypically differentiated individually except for three pairs which may possess the same genetic background in pairs; these had different names.

In vitro-cultured buds of four garlic cultivars were used to estimate radiosensitivities and rate of mutation irradiated by ^{60}CO-ray. Two mutants, Tai-R1 and Cang R2, proved to be genetical variations based on agronomic characters and the analysis of peroxidase isozyme.

Cherry tomato

Seven cherry tomato varieties (CH 151 to 157) were evaluated for their yield potential at AVRDC–ARC, Kamphaengsaen during summer, rainy, and cool seasons. Yield was affected by environmental factors, such as high temperature (over 32°C) and excessive rainfall (over 130 mm in 1 day in May), resulting in poor fruit-set and reduced yield. Favorable conditions for tomato production exist during the cool months. Similar results were obtained in two trials (summer, April–June 1995 and late rainy season, August 1995–January 1996): yields were much lower compared to the trial conducted during the cool season (October 1995–March 1996). The later trial performed well both in terms of yield and number of fruits per plant. CH 154 had the highest marketable and total yield, followed by CH 153, and CH 155. Although these three varieties had good yields, they are susceptible to cracking. The cherry tomatoes grown during summer and rainy seasons produced 25 and 36 small fruits per plant, respectively. During February to April, CH 154 (Sweet Cherry) was tested among consumers in Bangkok. Random sampling showed good acceptance because of its oblong shape, deep red color, and sweet taste. CH 155 ranked higher in taste than CH 154. However, it had more fruit crack and a bigger shoulder.

Vegetable soybean

Four varieties (Shironomai, AGS 333, AGS 334, and White Lion) selected from previous trials based on good yield performance and adaptability under Kamphaengsaen conditions and three others (Bangkok Land from a private company, TVB 1 from the Department of Agriculture, and KPS 292 as standard check) were tested and evaluated in the cool season (December 1995–February 1996) and the rainy season (April–July 1996). Wide variation in yield was observed between the two seasons. Marketable yield ranged from 2 to 29 t/ha. The yield of vegetable soybean grown during the rainy season was higher than that grown in the cool season. AGS 333 gave the highest yield in both seasons, but it was late maturing. AGS 633 had the greatest number of pods per plant and the highest pod weight per plant for both seasons. Pods of AGS 333 were slightly smaller than KPS 292, but they were still accepted in the local market. AGS 333 thus has good potential under local conditions, because it gave high yield and performed well even under poor growing conditions.

Germplasm multiplication and exchange

Sixty-six sets of mungbean under the 21st International Mungbean Network were distributed to cooperators in 15 countries. Twenty kilograms of vegetable soybean and soybean materials were distributed to more than 50 institutions while around 2 kg of vegetable materials were distributed as part of the AVRDC germplasm exchange program.

The multiplication of okra and basil was completed in early 1996 and that of luffa at the end of the year. Characterization of these materials is under way. Multiplication of bitter gourd collected from all over Thailand has just begun.

Germplasm exchange between AVRDC–ARC and cooperating countries in the region, especially China, continues.

Training and information exchange

Thirty-two training scholars from 10 countries in Asia, Africa, and the Pacific completed the 14th Regional Training Course in Vegetable Production and Research. The 15th Regional Training Course, which commenced in October, has 31 participants from 12 countries.

The two research fellows from China under the GTZ-ARC project completed their fellowships in August. Meanwhile, six CLVNET-sponsored researchers from Cambodia, Laos, and Vietnam, are undergoing a 5-month training course at ARC, with emphasis on adaptive trials.

Phase II of the 3-year project on human resources development for the Mekong countries supported by the SDC started in July. This project aims to strengthen the capabilities of the various NARS in Asia, particularly the Mekong region, promote vegetable research and development through training, promote the role of women in vegetable research and production, improve genetic resources conservation, and disseminate genetically improved materials. Under the project, researchers and extension officers from various agricultural agencies in the Mekong region are attending training courses at ARC.

Networking

ARC coordinates two subregional networks: the Asian Development Bank-funded CLVNET, which was established in mid-1996 with the signing of a technical assistance agreement between AVRDC and ADB, and the China program.

Collaborative Vegetable Research and Development Network for Cambodia, Laos, and Vietnam (CLVNET)

The network was created to promote increased production of vegetables in the participating countries of Cambodia, Laos, and Vietnam through a collaborative research program. CLVNET aims to upgrade the national agricultural research systems through the development of improved vegetable germplasm and adaptive research technologies; strengthen research capability of NARS scientists in crop management practices, including IPM; and establish databases of vegetable information in each of the participating countries, including information on vegetable promotion, marketing, and production constraints. More details are reported under the section on Collaborative Research and Networks (page 135).

China program

SDC is now funding most of the collaborative work between AVRDC-ARC and China. This project, an expanded continuation of the AVRDC–China Vegetable Project, is now under the Mekong Region Human Resources Development Project. One of the objectives of this project is the enhancement of the linkage among Cambodia, Laos, and Vietnam, and China, particularly on sharing of technologies and vegetable germplasm and resources.

Symposia and workshops

AVRDC–ARC staff attended several workshops and symposia in China and Cambodia, Laos, and Vietnam, the Sino-American Symposium in Research Development in China, Third Asia-Pacific Conference on Agricultural Biotechnology, national workshops on vegetables in Thailand, and the meeting on the ACIAR-funded project on mungbean in Australia.

AVRDC–Africa Regional Program

The AVRDC–Africa Regional Program (ARP) conducts vegetable research and provides training and information services to the African national programs. The program has 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 (SADC). Countries covered include Angola, Botswana, Lesotho, Kenya, Malawi, Mauritius, Mozambique, Namibia, Swaziland, Tanzania, and Zambia.

The highland tomato project aims to develop cultivars with resistance to tomato leaf curl virus and late blight; and introduce, evaluate, and promote the adoption of tropical tomatoes in the hot humid regions of Africa. So far, several consistently good performers were identified for further evaluation. In the tomato hybridization program, backcrossing continued to improve the performance of popular local African highland varieties. Better genetic materials are now available for further breeding work. These new lines carry resistance to tomato mosaic virus, root-knot nematode, fusarium wilt, and tolerance to tomato yellow leaf curl virus.

Under CONVERDS research is conducted on strategic vegetables and training and information services are provided to the national agricultural research programs. Since its inception, ARP has trained 95 NARS personnel.

Adaptation trials of tomato germplasm to the African highlands

Trials were conducted to test the adaptability of introduced tomato germplasm to the African highlands and recommend promising germplasm for further tests with the aim of releasing them as commercial varieties and/or as parent materials in further breeding work.

Three sets of tomato germplasm were evaluated at ARP. Elevation of the site is approximately 1290 m above sea level. Soil type is loamy clay with a pH range of 6.0 to 6.5. Mean temperatures during the growing season ranged from 17.6 to 20.7°C.

The first group consisted of three high beta-carotene lines from AVRDC compared with two local checks, Marglobe and Moneymaker, and one hybrid, FMTT 22. The trial was laid out in RCBD with three replications.

The second group had nine AVRDC-ARP selections in the AYT. The trial was conducted to provide the Tanzanian national program with more data for the preliminary release of the best lines in 1996 or early 1997. As in previous tests, Marglobe and Moneymaker served as local checks. The trial was laid out in RCBD with three replications.

The third group was composed of 28 new AVRDC-ARP selections tested against local checks

Moneymaker and Marglobe. The trial was laid out in RCBD with two replications. Each plot was 1.2 x 6.0 m, with rows spaced 60 cm apart in double-row beds and 50 cm apart between hills in the row. A total of 24 plants made up each plot.

Significant differences in yield, fruit weight, and fruit per plant were observed in the high beta-carotene trial. Marglobe, Moneymaker, FMTT 22, and one high beta line, CLN 1315 BC_1F_3 57A-30-26, showed largely similar yields (table 1). Marglobe and FMTT 22 produced the largest fruits. Fruit size of CLN 1315 BC_1F_3 57A-30-26 was comparable only to Moneymaker. Fruit of the high beta line had no cracking and were firm, but tended to have more catface and comparable soluble solids content as the local checks (table 1).

Entries in the advanced trial did not differ significantly in marketable yield (table 2). Marglobe produced the biggest (176 g), but lesser fruits. In contrast, Moneymaker tended to produce many small fruits. Among the ARP lines, the largest fruits (126 g) were observed in ARP 366-4.

The advanced lines had better storability than the local checks. ARP 367-1 did not have any rotten fruit after 1 month under ambient storage. In contrast, 100% of the fruit samples of Moneymaker were rotten long before the end of the storage experiment. Similarly, almost all fruit samples of Marglobe (97%) did not last long in storage. The long shelf life and resistance of ARP lines to major problems such as ToMV, root-knot nematode, and fusarium wilt, constitute their major advantages over the local varieties.

Yields of the entries in the observational trial did not differ significantly (table 3). Highest yield was recorded in ARP 366-4-23 (67 t/ha) whereas local checks Marglobe and Moneymaker yielded 56 t/ha and 48 t/ha, respectively.

Majority of the ARP selections had moderately firm to firm fruits. ARP 365-3-25, ARP 365-3-19, and ARP 366-2-11 showed good shelf life with an average of 2 rotting fruits out of 10 samples per replicate. In

Table 2. Yield and yield components of selected indeterminate tomato entries, AYT, AVRDC-ARP, Arusha, Tanzania

Variety/Line	Mkt. yield (t/ha)	Mean fruit weight (g)	Fruits/ plant (no.)	% MY	% rotten fruits
Marglobe (ck)	103.3	176.0	17.6	94	97
ARP 366-3	100.2	114.6	27.4	98	33
ARP 366-2	89.6	110.8	26.2	97	17
ARP 365-2	88.9	118.7	22.9	96	10
Moneymaker (ck)	85.5	87.4	31.1	94	100
ARP 365-1	79.0	113.4	21.3	95	13
ARP 367-1	78.0	106.5	23.6	97	0
Mean	ns	**	**	*	**

Table 3. Yield and yield components of the best yielding entries among 30 tomato lines evaluated in an observational trial, AVRDC-ARP, Arusha, Tanzania

Entry	Mkt. yield (t/ha)	Mean fruit weight (g)	Fruits/ plant (no.)	Fruits/ truss (no.)
ARP 366-4-23	67.3	103.4	27.5	5.5
ARP 365-1-11	64.8	109.1	25.0	5.6
ARP 365-3-19	64.3	136.5	20.5	5.3
Marglobe (ck)	56.2	124.7	19.7	4.6
Moneymaker (ck)	48.3	70.8	29.1	6.6
Mean	53.3	102.0	23.2	5.7
CV (%)	16.1	13.7	14.7	17.8

Table 1. Yield and other components and fruit characters of one high beta-carotene tomato line vs. checks in a replicated yield trial, AVRDC-ARP, Arusha, Tanzania

Variety/line	Mkt. yield (t/ha)	Mean fruit wt. (g)	Fruits/ plant (no.)	MY (%)	Solids (° brix)	Cracking (%)	Catface (%)	Firmness
Marglobe (ck)	65.8	142.5	14.1	90	2.9c	4.6	2.8	firm
Moneymaker (ck)	60.8	116.5	17.8	91	3.2c	2.5	4.9	soft
FMTT 22 (ck)	57.3	147.6	11.6	88	4.2a	1.5	1.6	firm
CLN 1315 BC_1F_3 57A-30-26 (HB)	57.0	117.9	15.5	92	3.1c	0.0	3.1	firm

contrast, Marglobe and Moneymaker averaged 8 and 10 rotten fruits, respectively, during the storage period.

Tomato multilocation evaluation trials

This activity aims to evaluate the general adaptability of a set of tomato varieties chosen by the Tanzanian national vegetable program as source of improved varieties for official release.

Two groups of tomato cultivars, one determinate and one indeterminate, comprised the materials. Ten indeterminate tomato cultivars and breeding lines (6 from AVRDC-ARP) were chosen to constitute the indeterminate set. The determinate set consisted of seven entries (2 from AVRDC-ARP). These trials were conducted jointly with the national program of Tanzania.

Five locations were chosen for the trials, namely, Iringa, Morogoro, Dodoma, Tengeru, and Madiira (ARP). Iringa, Tengeru, and Madiira exemplify the cool highland locations, while Dodoma is a cool and dry area, and Morogoro is relatively warmer as it is located at a lower elevation.

The trial at each site was laid out in RCBD with three replications. Marglobe and Moneymaker served as local checks for the indeterminate group. For the determinate group, Roma VF served as the check.

The results of the multilocation trials are summarized only for marketable yields in tables 4 and 5. Significant variety, location and location x variety interaction were observed in both trials of indeterminate and determinate cultivars.

Except for Marmande, the various indeterminate varieties tested had fairly similar marketable yields of around 60 t/ha. Although a complete stability analysis is yet to be done, the standard deviation of variety yields pointed to the instability of Marmande. The most stable entry was ARP 365-3 with an SD of 8.8. The most favorable location was Madiira-ARP and HORTI-Tengeru, with mean yields higher than 70 t/ha; in contrast, the poorest was Dodoma with a mean yield of only 37 t/ha. Dodoma is cool, but its dry environment could have contributed to poor results.

Marglobe produced the largest fruits (132 g) and Motelle (69 g) and Moneymaker (73 g) the smallest. Most ARP lines had fruits around 100 g.

Fruits of all ARP entries were firm. In contrast, checks Moneymaker and Marmande produced soft fruits. In a separate study on keeping quality, Marmande, Motelle, and Moneymaker had the shortest storability when kept at ambient condition, lasting only 5 days in store. ARP ID-1, ARP 367-2, ARP 366-1, and ARP 365-3 stored the longest at 19 days.

Table 4. Marketable yield (t/ha) of 10 indeterminate tomato entries in Tanzania's 1996 multilocation trial

	Locations						
Entry	Iringa	Morogoro	Dodoma	Tengeru	Madiira-ARP	Mean	SD
ARP 367-2	x45.6a	y67.7ab	x40.9a	z83.9 ab	z80.4a	63.7a	17.6
ARP 366-4	wx51.8a	yz65.4ab	w45.6a	yz72.6bcd	z81.5a	63.4a	13.1
ARP 365-1	y57.9a	y61.9ab	x42.8a	yz71.1bcd	z80.0a	62.7a	12.5
ARP 366-1	xy54.9a	yz65.7ab	x40.2a	yz68.8bcd	z76.2ab	61.2a	12.5
Motelle	xy53.9a	xy54.3bc	x41.1a	z93.5a	y62.4b	61.0a	17.6
Marglobe (ck)	y53.6a	y67.6ab	x34.8ab	y63.3cd	z85.0a	60.8a	16.5
ARP 365-3	yz56.8a	z63.0ab	y44.9a	yz69.1bcd	z67.4ab	60.2a	8.8
Moneymaker (ck)	x43.0a	y64.6ab	x29.6ab	yz73.7bc	z80.3a	58.2a	19.1
ARP HT/ID-1	xy41.6a	z73.8a	x32.6a	y56.2d	z81.5a	57.2a	18.5
Marmande	x19.9b	y43.5c	x18.8b	z74.8bc	z79.7a	47.3b	26.0
Mean	x47.9	y62.8	w37.1	yz72.7	z77.4	59.6	
CV = 15.4%							

Critical difference: Location, Variety, Location x Variety = ** Mean preceded by the same letter within the same column or followed by same letter within the same row are not significantly different at 5% probability level (DMRT).

The results suggested that there was not much difference in yield potential among different entries (except Marmande). Fruit firmness and long storage life, as well as resistance to ToMV, fusarium wilt, root-knot nematode, and tolerance to TYLCV make the best among the ARP lines good candidates for release in Tanzania.

Among the determinate varieties, Rossol and ARP/HT/D-2 consistently outyielded the other entries in the multilocation trial (table 5). Mean yields of these two entries across sites did not differ significantly but both were distinctly superior to the other varieties, including check Roma VF.

The most favorable locations based on mean site yield were Morogoro, Dodoma, and Tengeru. Poorest location was Madiira-ARP. Smallest fruits were produced by Roma VF (42 g); largest was Caraibo (97 g). The two ARP lines produced fruits weighing around 60 g.

After 10 days in ambient storage, the only entries whose fruits had not started to rot were ARP D-2, ARP D-1, and Rossol. Fruits of the ARP lines were particularly firm and maintained this state for sometime under storage.

Rossol and ARP/HT/D-2 may be recommended for further tests and/or outright release to Tanzanian tomato growers. Both entries were consistently good yielders in all locations and were good keepers, an important trait in many highland locations in Tanzania relatively distant from consumption centers such as Tanga and Dar-es-Salaam.

Screening ARP tomato lines for resistance to tomato mosaic virus, fusarium wilt, and root-knot nematodes

To identify tomato lines resistant to tomato mosaic virus, fusarium wilt, and root-knot nematodes, screening studies were conducted on ARP lines. Tomato seed were germinated in plastic pots. For the tomato mosaic virus screening tests, 2-week-old seedlings were mechanically inoculated with ToMV. 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 tests, one isolate from Mbeya (Tanzania) was cultured on potato dextrose agar (PDA) for 7 days. Three-week-old seedlings were inoculated. One isolate of *Meloidogyne javanica* was maintained on susceptible tomato plants. Eggs of this isolate were used for the inoculation of tested plants.

Nine AVRDC-ARP tomato lines were screened for resistance to tomato mosaic virus and fusarium wilt and two tomato lines for resistance to root-knot nematodes. All ARP tomato lines were found resistant to fusarium wilt. The tomato lines segregated for resistance to tomato mosaic virus (table 6). The two lines tested (ARP 365-3 and ARP 367-2) were resistant to root-knot nematodes.

Table 5. Marketable yield (t/ha) of 7 determinate tomato entries in Tanzania's 1996 multilocation trial

			Locations				
Entry	Iringa	Morogoro	Dodoma	Tengeru	Madiira-ARP	Mean	SD
Rossol	y91.4ab	z118.4a	y89.9a	y81.0ab	x52.2a	86.6a	21.3
ARP HT/D-2	z104.1a	y83.5b	y74.3ab	yz91.7a	x48.0a	80.3ab	18.9
Caraibo	xy62.3c	z100.5ab	z83.4ab	yz81.6ab	x58.3a	77.2 b	15.4
Roma VF (check)	yz74.6bc	z88.9b	z83.7ab	yz70.9ab	y60.3a	75.7b	10.0
Romitel	z99.3a	yz85.4b	y76.7ab	y68.1b	x46.3a	75.2b	17.7
Mecline	y59.3c	z83.5b	z83.9ab	yz78.5ab	yz64.8a	74.0 b	10.1
ARP/HT/D-1	y57.4c	z79.1b	yz65.3b	yz61.3b	y45.1a	61.6c	11.0
Mean	y78.3	z91.3	z79.6	z76.2	x53.6	75.8	
CV = 12.7%							

Critical difference: Location, Variety = **; Location x Variety = * Mean column and row separation by DMRT at 5% probability level.

Table 6. Response of ARP tomato lines to tomato mosaic virus inoculation

Tomato line	No. of inoculated plants	No. of infected plants	% of infected plants
365-1	68	4	5.8
365-2	66	7	10
365-3	49	4	8.1
366-1	65	5	7.6
366-2	42	0	0
366-3	33	0	0
366-4	87	6	6.8
367-1	40	2	5
367-2	42	2	4.7
Moneymaker	48	48	100

Field screening of tomato accessions for resistance to tomato yellow leaf curl virus

To identify tomato accessions and breeding lines with high levels of resistance or tolerance to tomato yellow leaf curl virus, 20 accessions (including progenies of crosses between the resistant *Lycopersicon chilense* LA 1969 and cultivated tomatoes) were field screened in Morogoro, Tanzania. Seed of tomato accessions were germinated in plastic pots. One-month-old seedlings were transplanted to the field. The experiment was in RCBD with three replications. Disease incidence was assessed by recording the number of plants showing leaf curl symptoms.

TYLCV incidence in checks Moneymaker and Roma VF was 100 and 95%, respectively. The progenies from crosses between *L. chilense* and cultivated tomatoes, Chiltylc 94-2, Chiltylc 94-4, and Chiltylc 94-6, showed less than 50% infection. ARP lines 365-1, 366-1, and 367-2 also showed good field resistance to TYLCV (table 7).

Table 7. Field screening of tomato accessions for resistance to tomato yellow leaf curl virus in Morogoro

Tomato accession	Disease incidence[a] (in % of infected plants)	Tomato accession	Disease incidence (in % of infected plants)
365-1	40a	Jackal	64ab
365-2	64ab	TY-20	78b
365-3	63ab	Chiltylc 94-1	69ab
366-1	53ab	Chiltylc 94-2	38a
366-2	54ab	Chiltylc 94-4	48ab
366-3	59ab	Chiltylc 94-5	63ab
366-4	69ab	Chiltylc 94-6	45a
367-1	48ab	Multichiltylc 95	61ab
Columbia	50ab	Moneymaker	100c
Lignon C-8	50ab	Roma VF	95c
Mean	61.0		
CV (%)	18.1		

Values were transformed with arcsin before analysis.

[a] Numbers followed by the same letter are not significantly different at the 5 % level (DMRT).

Field evaluation of ARP tomato lines for resistance to fusarium wilt and root-knot nematodes

The experiment was conducted at Makutupora research station (Dodoma, Tanzania) to confirm the resistance of ARP tomato lines to fusarium wilt and root-knot nematodes under natural infection conditions. Seed of ARP 365-3, 366-4, and 367-2 were germinated in seedling trays. Moneymaker and Marglobe were used as checks. Seedlings were transplanted 39 days after sowing in an experimental area previously found to be infested by fusarium and nematodes. The experiment was laid out in RCBD with six replications. Symptoms were recorded visually at the end of the trial.

The ARP tomato lines evaluated for resistance to fusarium wilt and root-knot nematodes were resistant to fusarium wilt under field conditions. However, a few plants were infected by nematodes.

Evaluation of tomato late blight resistance sources

Experiments were conducted in two locations, namely Seatondale Research Station (Iringa) and Madiira Research Farm (Arusha) to test late blight resistance sources for their potential use in various geographic locations or as resistant stocks in breeding. In these two regions, 100% late blight infection is routinely observed on tomato crops.

In an attempt to identify sources of resistance to tomato late blight, 12 *Lycopersicon* accessions were screened under field conditions (table 8).

Table 8. **Disease severity ratings of *Lycopersicon* accessions evaluated in two locations in Tanzania**

Accession no.	Madiira Center-Arusha	Seatondale Center-Iringa
LO 3683	0	1.38
LO 3684	0	1.00
LO 3707	1.81	0
LO 3708	1.34	0
WV 700	4.74	1.70
WV 106	4.71	3.03
Fline	5.58	5.68
TS 33	4.96	4.96
TS 19	4.49	4.16
L 3975	5.71	5.78
Moneymaker	4.96	5.06
Roma VF	5.71	3.84

Disease severity rating on a scale of 0 to 6 in which 0 = no symptoms; 1 = 1 – 10% leaf area affected; 2 = 11 – 20% leaf area affected; 3 = 21 – 40% leaf area affected and/or 1 – 10% stem area affected; 4 = 41 – 70% leaf area affected and/or 11 – 50% stem area affected; 5 = 71 – 90% leaf area affected and/or 51 – 100% stem area affected; 6 = 91 to 100% leaf area affected or dead plant.

Seed were germinated in seedling trays and 1-month-old seedlings were planted in the field. The disease severity was rated weekly, beginning 1 month after transplanting. Disease severity ratings were made according to a scale of 0 to 6. *L. peruvianum* (L 3707), *L. pimpinellifolium* (L 3708), and *L. hirsutum* (L 3683 and L 3684) were the most resistant accessions. A high level of resistance was also noted in WV 700 at Seatondale station. However, this accession was susceptible under Madiira conditions.

Adaptability trials of onion germplasm under African highland conditions

This activity is aimed at identifying and distributing the best onion materials to the African national programs for further testing and/or use in commercial production, or further breeding work.

Five evaluation trials to select cultivars with high yield, resistance to major diseases, good storability, low splitting and low bolting rate, and good bulb size and bulb shape uniformity under the highland conditions of Africa were carried out. Group I consisted of two sets (20 and 5 entries) of yellow onions from AVRDC headquarters. Group II consisted of three sets (9, 8, and 4 entries) of red onions from the Natural Resources Institute, UK and AVRDC. Most of the Group II trials were designed to confirm the performance of several red onion varieties that did well in earlier trials.

The design in all trials was RCBD, with three replications. Plot size was 1 x 6 m except in Group II/Set 5 which was 2.4 x 6.0 m. Distance between rows was 10 cm and distance between plants within the row was 15 cm. Texas Grano served as the check for the yellow onion trials and Bombay Red for the red onion trials.

Samples were also taken and stored under ambient conditions for storability analysis.

In Group I/Set 1 trial of yellow onions, Texas Grano 509 and Houston gave the highest yields (table 9), significantly outyielding Texas Grano (check). They also possessed good bulb shape and size uniformity (table 9), although they were not more uniform in size and shape when compared to Texas Grano.

In Group I/Set 2 trial of yellow onions, Equanex and Mercedes gave similar yields as the check, Texas Grano. No other significant differences were observed.

Among the Group II/Set 1 trial of nine red onions, Rio Raji Red and the two versions of Red Bandana outyielded local cultivars Bombay Red (check) and Red Creole (table 10). Moreover, these cultivars showed thinner necks and none or lower bulb splitting than Bombay Red and more uniform bulb size and shape (table 10). The same cultivars performed very well during the 1995 trials, indicating possibly stable yields over time. Significant differences were also noted in the yield and other traits of eight red onions tested in Group II/Set 2 (table 11). Highest yielding entries were Redbone and Bombay Red. Both had practically similar bulb sizes; % marketable yield did not differ.

Table 9. Yield and other components and bulb characters of the best yellow onion cultivars in a replicated yield trial, AVRDC–ARP, Arusha, Tanzania, 1996 (Group I/Set 1)

Entries/Cultivar	Mkt. yield (t/ha)	Mean bulb weight (g)	% MY	Size uniformity	Shape uniformity	No.of bulbs	Bulb shape
Texas Grano 509	44.3a	222a	98a	4.0ab	4.0ab	1.2	high globe
Houston	43.8a	191ab	99a	3.7ab	4.0ab	1.0	high globe
Texas Grano (ck)	28.0b-e	189ab	98a	4.0ab	4.7a	2.2	high globe
Grand mean	34.5**	168.3*	98**				
CV (%)	21.6	22.2	2.2				

Mean column separation by DMRT at 5% probability level

Rating scale: Bulb uniformity for size and shape: 1= not uniform, 2 = less uniform, 3 = moderate, 4 = uniform; 5 = very uniform.

Table 10. Yield and other components, bulb size/shape uniformity, bulb shape and color of red onion cultivars in a replicated yield trial, AVRDC–ARP, Arusha, Tanzania (Group II/Set 1)

Cultivar	Mkt. yield (t/ha)	Mean bulb wt. (g)	Neck thickness (cm)	% splitting	Size uniformity	Shape uniformity	Bulb shape
Rio Raji Red	33.2a	159.8a	1.2c	0.0a	3	5	flat globe
Red Bandana 94	32.0ab	154.3a	1.2c	1.6ab	3	3	flat globe
Red Bandana 95	30.0abc	153.4a	0.9d	0.5b	3	3	flat globe
Bombay Red (ck)	25.1c	105.4ab	1.7a	9.9b	1	3	flat globe
Red Creole	17.1d	83.8b	1.2c	2.3b	3	3	flat
Grand mean	24.7	117.6	1.3	3.1			
CV (%)	13.0	26.2	8.1	91.8			

Mean column separation by DMRT at 5% probability level.

Rating scale: Uniformity for bulb size and shape: 1= not uniform, 2 = less uniform, 3 = moderate, 4 = uniform; 5 = very uniform.

Table 11. Yield and other components and plant and bulb characters of red onion cultivars in a replicated yield trial, AVRDC–ARP, Arusha, Tanzania (Group II/Set 2)

Variety	Mkt. yield (t/ha)	Mean bulb weight (g)	% MY	No. of leaves	Neck thickness (cm)	Bulb diam. (cm)
Bombay Red (ck)	22.5ab	106.7bc	98.9	10.4a	2.0a	5.0c
Redbone	27.2a	110.8bc	96.8	6.7 c	1.1 c	5.2abc
Red Creole	17.5bc	77.1d	98.2	10.2a	1.6b	5.2abc
Grand mean	19.8 *	95.8	97.4	8.9 **	1.4 **	5.3 *
CV (%)	15.3	11.1	3.4	10.2	11.2	6.9

Mean column separation by DMRT at 5% probability level.

Bolting and splitting are undesirable traits which lower yield, lead to small bulb size and weight, poor quality, and poor storability. Kana Red had 34% bolting whereas Bombay Red showed 6% bolting. Redbone appears to be more desirable than Bombay Red due to its small neck size although a more elaborate storability study needs to be done. Local variety Bombay Red had the thickest neck and is known to be a traditionally poor storer.

Highly significant differences in mean yield and other characters were observed in the Group II/ Set 5 trial of four red cultivars (table 12). The highest yielder was Red Bandana with 39 t/ha. Only Bombay Red bolted during the experiment. Red Bandana had the best uniform bulb size and shape and did not exhibit splitting. This study and earlier trials show that this cultivar is very promising for Tanzania where red-skinned varieties are preferred. Future multilocation trials in Tanzania and the other SADC countries where red onions are preferred should include this cultivar.

Table 12. Yield and yield parameters of four red onion cultivars, AVRDC–ARP, Arusha, Tanzania, July to November, 1996

Cultivar	Mkt. yield (t/ha)	Mean bulb wt. (g)	Bolting rate (%)	Splitting rate (%)	Uniformity Size	Uniformity Shape
Red Bandana	38.7a	169.2a	0	0.0b	4.0a	4.0a
Tropicana	24.3b	89.4b	0	8.3a	2.3b	3.0b
Bombay Red	24.1b	101.3b	28	0.1b	3.0b	3.3b
Red Creole	20.1b	90.6b	0	0.3b	2.7b	3.0b
Mean	26.8 *	112.6 **	7	3.0**	3.3**	2.2*
CV (%)	12.5	10.6	-	64.0	12.4	8.7

Adaptability trials of other global crops under African highland conditions

ARP selects new cultivars with high yield, resistant to major diseases, and possessing desirable characters that give them comparative advantage over local varieties, and distributes the best materials to the African national programs for further testing and/or use in commercial production. Evaluation trials of other global crops of the Center were conducted on cabbage, cauliflower, and eggplant in 1996.

Cauliflower. Five cauliflower varieties (Pant Shubra, Pusa Snow Bell E, Pusa Deepali, Kathmandu, and Mikado 55 days) were screened in a trial laid out in RCBD with three replications. No local check was included.

Pusa Snow Bell E was the highest yielder, but its yield was not significantly different from Kathmandu. Pusa Snow Bell E and Kathmandu were the most vigorous with long and broad leaves, while Panta Shubhra and Mikado 55 days were moderately vigorous with short and broad leaves. Pusa Deepali was stunted with very tiny leaves and was excluded from further analysis.

Both Panta Shubhra and Mikado 55 days curded and matured much earlier than either Pusa Snow Bell E and Kathmandu. Pusa Deepali buttoned in 5 days and bolted completely 10 days after transplanting. Curds in all varieties were uneven in shape. Both Pusa Snow Bell E and Kathmandu had irregularly oval but compact curds. Panta Shubhra and Mikado 55 days had irregular, loose, and exposed curds.

Cabbage. Ten varieties of common cabbage were evaluated in a replicated trial laid out in RCBD with three replications. Local check Glory of Enkhiuzen yielded higher than the other varieties (78 t/ha). However, it was among the late varieties, maturing at 74 days after transplanting. Copenhagen Market, Koppen Ball, Golden Acre, and Rare Ball all matured early (about 65 days after transplanting). Glory of Enkhiuzen also produced the heaviest head (2.5 kg). Golden Acre, Koppen Ball, Rare Ball, and Copenhagen Market produced the firmest heads. Only Remenco and Copenhagen Market exhibited head cracking.

None of the other varieties tested could be considered to replace Glory of Enkhuizen as a variety for the Arusha region.

Eggplant. Eight eggplant varieties (Pusa Grant, F-100, Pintung, Long Purple, Cruz, Black Beauty, Slim, and Black Beauty Tz., the local check) were evaluated in a trial laid out in RCBD with three replications.

Significant differences in yield were observed in this trial. Black Beauty Tz. was the highest yielder with 30 t/ha, although its yield did not differ significantly from that of Long Purple with 27 t/ha. Lowest yielder was Cruz with 14 t/ha. Black Beauty Tz. had the heaviest fruit (287.7 g) whereas Pusa Grant had the lightest (91.5 g). F-100 had the most fruits per plant (8.1). Postharvest shelf life varied from 6 to 12 days. Black Beauty and two other new introductions had the longest shelf life.

Among the new introductions from AVRDC, none may be considered to replace Black Beauty Tz. in yield, fruit weight, and other measures of consumer acceptability in the Arusha region such as having oblong, large purple fruits with shiny luster.

Survey of major vegetable diseases occurring in East Africa

In collaboration with the Kenya Agricultural Research Institute, extensive surveys were conducted in central, eastern, and rift valley provinces in October to identify the major diseases affecting vegetable production (with emphasis on tomato crops) in Kenya. The identification of fungal, bacterial, and viral diseases was based on symptomatology.

The most damaging tomato diseases identified in these areas were early and late blight, tomato mosaic virus, root-knot nematodes, and tomato yellow leaf curl virus. Black rot was the most important cabbage disease. Powdery mildew, watermelon mosaic virus-2, and zucchini yellow mosaic virus were found on squash crops.

Distribution of major tomato diseases in 3 provinces of Kenya

Disease name	Location
early blight	central, eastern, rift valley
late blight	central eastern, rift valley
powdery mildew	central, eastern
bacterial canker	rift valley
bacterial spot	rift valley
tomato mosaic virus	central, eastern
tomato yellow leaf curl virus	central, eastern
root-knot nematodes	central, eastern, and rift valley

Effect of cultural practices and fungicide spraying for control of tomato late blight

Late blight is one of the most serious fungal diseases of tomato crops in the African highlands. So far, no commercial tomato varieties with high levels of resistance have been reported. An experiment to identify an effective integrated management technique (chemical and cultural practices) for control of tomato late blight was conducted at Seatondale Research Station. Roma VF seeds were germinated in trays and 1-month old seedlings were transplanted to the field. The experimental design was a split-plot (fungicide treatment was the major factor) with three replications.

Statistical analysis was performed using MSTAT. The disease incidence was assessed weekly up to 60 days after transplanting.

Four cultural practices (pruning, no pruning, staking, no staking) and six fungicide treatments were used. About 1.2 g/L fungicide was used.

Evaluation of cultural practices and fungicide sprayings showed that the application of fungicides reduced the incidence and the severity of late blight compared to the untreated control (table 13). However, the degree of disease control did not differ among fungicide treatments. Cultural practices had no effect on incidence and severity of late blight. This may be because Roma VF is a determinate type that does not normally require staking and/or pruning. The different fungicide treatments had a significant effect on yield with treatment 4 (combination of Ridomil-Mancozeb applied alternately at weekly intervals) giving the highest yield. Cultural practices had no significant effect on yield and no significant interaction was observed.

Table 13. Effect of fungicide treatments to control tomato late blight on marketable yield, number of marketable fruits per plant, and average fruit weight

Fungicide[a] treatment	Yield (t/ha)[b]	No. of mkt. fruits/plant	Avg. fruit weight (g)
T1	35.1b	34.4a	34.4a
T2	20.2d	20.5c	32.5ab
T3	39.3a	38.3a	35.3a
T4	29.1c	28.7b	32.5ab
T5	36.3ab	33.5ab	34.8a
Control	6.4e	7.3d	28.4b

[a] T1= Mancozeb at 7-day intervals, T2 = Ridomil at 14-day intervals, T3 = Ridomil + Mancozeb alternately at 7-day intervals, T4 = Ridomil at 21-day intervals, T5 = Ridomil at 21-day + Mancozeb 7 and 14 days after Ridomil application

[b] Means within a column followed by the same letter are not significantly different at P = 0.05 according to DMRT.

Evaluation of some insecticides for control of diamondback moth in cabbage

Cabbage production is severely limited by diamondback moth (*Plutella xylostella*) in the highlands of Eastern and Southern Africa. A study comparing the ability of nine insecticides (including extracts from the neem plant) to effectively control DBM was carried out in Tanzania. Specifically, the study determined the effectiveness and the frequency of application of commonly used insecticides and some plant-derived insecticides against diamondback moth.

Cabbage seeds were sown in seedling trays. Four-week-old seedlings were transplanted to the field. Nine insecticides including two biological insecticides were evaluated. The insecticide application began at the first observation of moth damages. The insectides were applied at two different frequencies, once a week and once every 2 weeks. The experiment was arranged in split-plot design with three replications. The insecticide treatment was the major factor and the frequency of insecticide spraying was the subplot.

Based on the number of DBM larvae per plant, endosulfan, profenophos, and neem treatments provided good protection (table 14). There were no significant differences in total yields between sprayed and unsprayed plots. However, significant differences between yield of clean heads (i.e., heads without any insect damage) and damaged heads were noted between insecticide treatments and the control (table 15).

Table 14. Count of *Plutella* larvae 3 days after insecticide spraying at two frequencies

Insecticide	Number of larvae[a]	
	Frequency of insecticide application	
	Weekly	Biweekly
Diazinon	1.7c	9.0ab
Lambda cyhalothrin	2.3c	19.3a
Endosulfan	0.3c	0.7c
Profenophos	3.0bc	3.7bc
Pirimiphos methyl	1.7c	14.0a
Deltamethrin	3.0bc	19.3a
Dimecron	1.7c	17.7a
Neem	5.3abc	1.7bc
Melea volkense	17.3a	18.0a
Control	11.0ab	17.0
Mean	4.7	12.0
CV = 34.24%		

Critical difference: insecticide (I), frequence of spraying (F), IF**

[a] Means within the same column followed by the same letter are not significantly different at 5% probability level (DMRT).

Evaluation of fungicides for control of tomato powdery mildew caused by *Oidium lycopersicum*

An experiment was conducted to evaluate the effectiveness of different fungicides and fungicide combinations for the control of tomato powdery mildew at Arusha, Tanzania. Seed of tomato var. Marglobe were germinated in seedling trays. Tomato seedlings were transplanted to the field 39 days after sowing. The experiment was laid out in RCBD with three replications. One month after

Table 15. Cabbage head yields (kg/plot)

Insecticide	Frequency of insecticide application					
	Total		Clean heads		Damaged heads	
	7-day interval	14-day interval	7-day interval	14-day interval	7-day interval	14-day interval
Diazinon	22.0	20.1	21.5ab	7.0c	0.5cd	13.1b
Lambda cyhalothrin	22.7	22.1	19.1abc	16.3b	3.6c	5.7cd
Endosulfan	21.9	23.4	20.6ab	21.0a	1.3cd	2.5de
Profenophos	22.8	22.6	22.8a	21.5a	0.0d	1.1e
Pirimiphos methyl	23.4	23.4	21.1ab	17.0b	2.4cd	6.4c
Deltamethrin	21.4	20.3	17.9bc	15.7b	3.5cd	4.6cd
Dimecron	25.1	22.6	16.7c	3.1d	8.4b	19.5a
Neem	19.9	19.9	20.0abc	18.7ab	0.0d	1.1e
Melea volkense	20.4	20.8	7.4d	6.0cd	12.9a	14.4b
Control	20.9	19.4	6.1d	4.6cd	14.8a	14.8b
Grand mean	21.8					
CV (%)		6.5		19.4		39.9

[a] Numbers followed by the same letter are not significantly different from each other at 5 % probability level according to DMRT.

transplanting, tomato plants were inoculated with powdery mildew. The inoculum was prepared by washing infected tomato leaves in sterile water and the solution was sprayed on the experimental area using a knapsack sprayer. The fungicide treatments included Bayleton, Benlate, Bayleton plus Dithane M-45, and Benlate plus Dithane M-45. The rates of fungicide applications were: Bayleton (1 kg/ha), Benlate (0.5 kg/ha), and Dithane M-45 (2 kg/ha). Where two fungicides were combined half the rate of each was mixed for spraying.

Powdery mildew severity was significantly reduced in treated plots (fig. 1). When applied separately, Bayleton and Benlate provided as good disease control as when they were combined with Dithane M-45 (table 16).

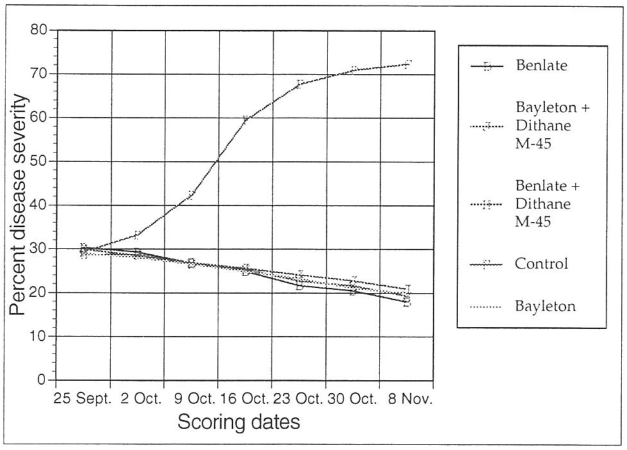

Fig. 1. Effect of fungicide applications on severity of tomato powdery mildew

Table 16. Effect of fungicide application on tomato powdery mildew incidence and severity

Treatment	Disease incidence (% of infected plants)	Disease severity (% of leaf area affected)
Control	90.0	72.3a
Bayleton	78.3	20.0b
Benlate	81.3	18.0b
Bayleton + Dithane M-45	80.0	20.9b
Benlate + Dithane M-45	76.7	19.3
Grand mean	81.4ns	30.1**
CV (%)	5.95	18.01

Mean value followed by the same letter in the column is not significantly different at 5% probability level according to DMRT

CONVERDS training program for African researchers and extension specialists

ARP's training program is geared towards enhancing the capacity of African researchers and extensionists, particularly those in the Southern African countries, for effective research and extension on vegetable crops. The target of this project, extended into Phase II for another 3 years by BMZ/GTZ, is to train a total of about 100 SADC NARS personnel.

Courses range in duration from as brief as 3 to 4 weeks for the short-term, highly specialized courses, to 5 months for the regular vegetable production course.

Training involves a blend of practical activities and theoretical classroom lectures. Classroom lectures are given by invited lecturers from universities, NGOs, and other international organizations in Tanzania, Kenya, other SADC countries, and by ARP technical staff. Backstop support from the AVRDC headquarters is also provided.

In 1996, the 3rd SADC Regional Vegetable Production Training Course was conducted from 1 July to 28 November. Twenty-two participants from 10 countries completed the course. A three-week short course on virus diseases and their management was carried out on 1–22 June with a total of 10 participants from 7 countries. For the first time, one scientist from Mauritius, a recent member of the SADC organization, participated. ARP has now trained a total of 95 NARS personnel, well surpassing the target of 75.

A modest 26-room hostel, with its own water and power supply, was constructed from core funds. A cafeteria, classroom, and office complex will be built soon.

Cooperative Programs

AVRDC maintains cooperative research programs with the national agricultural research systems in the Asian region. These research programs include germplasm evaluation and exchange, and adaptive research and trials on various globally and regionally important vegetables.

AVRDC–Bangladesh Agricultural Research Project

The project, funded by USAID, continues on its 7th year. The project objectives include strengthening of vegetable research to improve vegetable production; exploration of vegetable seed production potential; promotion of homestead gardening directed at improving the nutritional level of the population; and introduction and development of adaptive technologies for year-round vegetable production and consumption in Bangladesh for farmers and consumers.

More promising lines have been identified from the introduced materials in tomato, okra, kangkong, mungbean, malabar spinach, eggplant, chili, summer cauliflower, garden peas, and vegetable soybean. These lines are under preliminary yield trials. The use of new varieties may likely increase production by about 30-50% and raise consumption and income as well. To further strengthen the year-round tomato research program, cherry type heat-tolerant tomato hybrids introduced last year from AVRDC were tested and found quite promising both with and without the application of tomatotone. Seed production has also been undertaken locally by introduction of the parent lines from AVRDC.

More than 300 demonstrations on summer tomato were arranged using lines TM 0111 and TM 0367 developed from AVRDC germplasm during summer and summer rainy season.

Adaptive trials on selected crops

Tomato

Twenty-six tomato genotypes from AVRDC and SAVERNET were evaluated in a germplasm evaluation trial. Ten lines gave more than 80 t/ha yields, with TM 0848 having the highest yield of 110 t/ha, followed by TM 0827 (90 t/ha).

A trial on 12 processing tomato lines from AVRDC identified five lines with good processing characters and high yields: PT 4678A, PT 4671, PT 4716A, PT 4719B, and CLN 1351H. These will be included in regional trials.

Three high beta-carotene tomato lines and a check, FMTT 22 from AVRDC, were tested in winter. Line CLN 1314 BC_1-F_3-51-25-16-6-11B gave the highest yield (62 t/ha) followed by CLN 1314 BC_1-F_3-51-25-16-6-2 (60 t/ha). Both lines are rich in beta-carotene with 6.9 and 5.4 mg/100 g, respectively.

In the RYT, seven AVRDC lines were evaluated for yield and yield components. TM 0620 had the highest yield of 84 t/ha, which was statistically at par with TM 0611 (78 t/ha) and Ratan (79 t/ha), the local check. These two lines have been selected for release.

Three cherry tomato hybrids from AVRDC, TM 0830 (CHT 499), TM 0831 (CHT 500), and TM 0832 (CHT 501), were found promising in 2 years of testing at the Bangladesh Agricultural Research Institute (BARI). For local seed production, the male parents of these hybrids (CH 95, 96, and 97), and the female parent (CH 45) were used. Seed production was quite successful, and crops grown from these seeds in summer performed well.

Vegetable soybean

In a trial of 11 AVRDC vegetable soybean lines, AGS 337 gave the highest pod yield of 15 t/ha, followed by AGS 335 (11 t/ha), AGS 338 (10 t/ha), and AGS 333 (10 t/ha) under summer conditions.

Pepper

An evaluation trial of elite SAVERNET chili varieties revealed that Sri Lankan lines MI-2 and KA-2 were the best yielders with 3.1 and 2.6 t/ha dry yields and 12.0 and 10.7 t/ha green fruit yields, respectively.

Mungbean

A PYT of selections made from six promising AVRDC mungbean breeding lines showed that VC 6148-B-17-2B and VC 6147-B-10-2B, with mean yields of 0.9 and 1.0 t/ha, respectively, were the best entries and were selected for advanced trials.

An observation trial at IPSA on five mungbean varieties (NM 89, 90, 88, 96, and NM 54) from AVRDC showed that line NM 89 was quite early and matured in < 60 days, with an average 25 pods/plant, medium grain size, and 1000-grain weight of 33 g. NM 90 and NM 88 were also found promising.

Onion

A SAVERNET trial conducted during winter 1995–96 revealed that Agrifound Dark Red and Arka Niketan from India gave the best performance under Bangladesh conditions. Yields were 42 and 41 t/ha, respectively, compared to the local check's 28 t/ha.

Eggplant

A germplasm evaluation trial on 52 lines including exotic, local, and SAVERNET materials was conducted in winter 1995–96. Twenty-two promising lines were selected based on yield and other desirable characteristics. Line BL 034 gave the highest yield of 92 t/ha. Selected lines will be tested in PYTs. In the SAVERNET elite variety trial, 12 AVRDC varieties were evaluated for performance. Khatkhatia from Bangladesh gave the highest yield of 73 t/ha, followed by Pusa Kranti (56 t/ha) and PPL (57 t/ha) from India.

Radish

Radish line RH-021 is a high-yielding variety with good seed production ability under local conditions. However, the line showed phenotypic variability among populations. Mass selection technique was thus used to obtain uniformity in the line. A population of 1000 plants was grown for selection. The line produced good quality roots with an average weight of 467 g. Considering all parameters, 150 roots were selected and transplanted in isolation for seed production. Acceptable homogeneity was attained and the new line is ready for regional testing.

Indian spinach

A trial on 10 Indian spinach lines was conducted in 1995–96 at BARI. Two promising lines—ID 010 with greenish-red stem and ID 016 with green stem with yields of 19.1 and 18.6 t/ha, respectively—were selected for regional yield trial in the coming season.

Kangkong

Broad leaf variety KG 002 from AVRDC was found promising in 4 years of testing. It was also promising under the regional yield trials across locations in the country. This new kangkong variety yielded an average of 52 t/ha compared to the local variety Gima Kalmi with 45 t/ha.

Okra

The impact of a new okra variety, OK 0285, was studied among eight randomly selected women farmers. The okra variety had no virus infection and produced about 12 t/ha worth about US$ 3100 in 4 months. Twenty percent of the total produce was used for domestic consumption.

Cabbage

The seed-producing cabbage line CE 001 and hybrid Atlas-70 were sown and harvested after 110 and 120 days. Atlas-70 produced very compact and unfirm heads while 8–10% loose heads were observed in CE 001. Yields of Atlas-70 (62 t/ha) and CE 001 (60 t/ha) were not statistically different from each other. CE 001 produced abundant seeds under local conditions, which is a very desirable trait for successful cabbage cultivation as well as for initiating improvement and hybrid production programs.

Garden pea

A regional yield trial on garden pea lines GP 002, GP 008, and GP 015 showed that GP 015 was early flowering and took only 44 days. GP 002 was the highest yielder with 14 t/ha, followed by GP 015 with 13 t/ha, and GP 008 with 11 t/ha. GP 002 was selected for more regional yield trials.

Other local vegetables

One hundred sixty-six lines of pumpkin were collected from all over the country and were evaluated in winter 1995–96. A collection of 43 small local bitter gourds (known locally as ucche) were evaluated in winter to select the best lines. Also, an interesting collection of 11 local underutilized vegetables, namely bathua (*Chenopodium album* L.), shaknotey (*Amaranthus viridis* L.), thankuni (*Hydrocotyle asiatica* L.), nunia (*Portulaca oleracea* L.), molencha (*Jussiaea repens* L.), helencha (*Enhydra fluctuans* L.), Tak palang (*Rumex vesicaris*), laffa sak, pat sak (*Corchorus* spp.), rai sak (*Brassica* spp.), and fenugreek (*Trigonella foenum graecum*), were collected across the country and tested in winter. These vegetables are common in different parts of the country and some are very important for their medicinal value.

Protected cultivation

Three protected cultivation experiments were conducted at BARI, Joydebpur and several other locations. The first on summer tomato production with tomatotone under polythene protection tested tomato lines TM 0111 and TM 0367 under different agroecological zones. Fruit yield per plant ranged from 550 to 774 g and highest plant yield was produced by TM 0367 at Pahartali followed by TM 0111 (767 g) at Joydebpur. Lowest incidence of bacterial wilt was observed at Pahartali for TM 0367. Both tomato lines produced reasonable yields under different locations when grown with tomatotone under polytunnels during summer, confirming that tomato can be grown in Bangladesh during the summer rainy season. However, the technology should be tested further in different agroclimatic zones for wider adaptability.

In another experiment, three AVRDC cherry tomato hybrids [TM 0830 (CHT 499), TM 0831 (CHT 500), and TM 0832 (CHT 501)], were evaluated during summer at BARI. All three lines flowered within 30 days after transplanting. CHT 500 produced the highest number of fruits (105), followed by CHT 501 (101). Mean fruit weight ranged from 14.5 to 15.8 g. CHT 500 also produced the highest yield per plant (1.7 kg) followed by CHT 501 (1.5 kg). These three varieties will be further evaluated in different summer months under the different agroclimatic regions of the country.

In a third experiment on cauliflower, heat-tolerant lines CL 026 and CL 134, which produce curds in summer, yielded an average of 320 and 370 g good quality curds in August. Marketable yields of 13 and 15 t/ha were recorded. To determine their adaptability range, the two lines are sown every month in summer from March to July.

Other activities

A total of 247 lines/varieties were introduced during the year (table 1) for testing in cooperation with the Horticulture Research Center, Pulses Research Center, Institute of Postgraduate Studies in Agriculture, Bangladesh Institute of Nuclear Agriculture, and BARI. In collaboration with HRC, BARI registered and released 14 new vegetable varieties (table 2): three new varieties of tomato, two hyacinth bean, one each of radish, Chinese cabbage, bottle gourd, garden pea, edible podded pea, bush bean, okra, red amaranth, and onion. Protected cultivation for summer rainy season tomato and cauliflower has been standardized for growing these crops from May to October.

Seed of the three cherry tomato hybrids (CHT 499, 500, and 501) can now be produced locally. Mungbean NM 92 has been submitted for registration. Some crosses with NM 92 have proved promising and demonstrations in different locations have been conducted. Also, it is now possible to grow asparagus in Bangladesh. A collaborative effort between the AVRDC project and BARI showed that asparagus has a great export potential.

Other research areas on vegetables included germplasm collection, evaluation, and maintenance; varietal improvement; production technology; seed production technology; and technology transfer.

In collaboration with two NGOs, homestead demonstrations on nutritious vegetables were arranged in summer. Data from the program indicated that farmers consumed 40–50% of their vegetable produce, especially kangkong, okra, red amaranth, Indian spinach, and yard-long bean. In addition, demonstrations on new varieties and production technologies for okra, summer tomato, mungbean, kangkong, amaranth, china sak, bati sak, radish, garden pea, cabbage, eggplant, vegetable soybean, bottle gourd, beans, and other vegetables were organized at different locations. These generated interest on vegetable production and consumption among farmers.

Table 1. Vegetable germplasm introduced in 1996

Crop	No. of lines
Tomato	10
Vegetable soybean	17
Chinese cabbage	4
Summer squash	2
Spinach	1
Eggplant	32
Bell pepper	3
Pepper/chili	70
Mungbean	36
Onion	38
Okra	4
Cauliflower	1
Kangkong	2
Muskmelon	1
Fenugreek	1
Radish	1
Asparagus	3
Yard-long bean	5
Cucumber	6
Bottle gourd	1

Table 2. Vegetable varieties developed and registered by BARI in 1996

Vegetable	Variety name
Tomato	BARI Tomato 3 (TM 0126)
	BARI Tomato 4 (TM 0111)
	BARI Tomato 3 (TM 0367)
Radish	BARI Mula 3 (Pinky-RH007)
Chinese cabbage	China Copi 1 (CCE 029)
Hyacinth bean	BARI Seem 1 (HC 0010)
	BARI Seem 2 (HC 0084)
Bottle gourd	BARI Lau 1 (BG 0033)
Garden pea	BARI Motor Shuti 1 (GP 0001)
Edible podded pea	BARI Motor Shuti Seem 1 (GP 0007)
Bush bean/ French bean	BARI Jhar Seem 1 (FN 0006)
Okra	BARI Dherosh 1 (OK 0285)
Red amaranth	BARI Lal Shak 1
Onion	BARI Piaj 1 (ON 0043)

In training, 48 participants from 12 organizations attended a 6-day trainer's training course on hybrid production of solanaceous vegetables and cucurbits. A discussion-cum-training on summer tomato production techniques was arranged for 31 trainers from BARI, NGOs, and the private sector. In-country training on production technology and technology transfer of mungbean was organized for 50 participants. A training for NGOs was organized from 27 September to 3 October on new vegetable varieties and technologies. Twenty-eight transfer-of-technology training courses for 860 extension workers, NGOs, and farmers were also arranged.

Farmers' field demonstrations were arranged throughout the country on new vegetable varieties, technologies, and nutrition models. Nine farmer's field days were organized in collaboration with BARI for 868 farmers and extension agencies including NGOs.

The project also disseminated AVRDC publications to national institutions, NGOs, and other private agencies.

AVRDC–Philippines Outreach Program

The Philippine Outreach Program (POP) continues to undertake research on several vegetable varieties, evaluate AVRDC varieties and technologies in adaptive trials, and determine their suitability to local conditions and needs.

Since its establishment, POP has distributed selected promising lines, many of which came from AVRDC, to various universities, colleges, and research stations all over the country for testing. Results of these adaptive trials provide the basis for release of new varieties for commercial production.

In 1996 seven new seed board varieties extracted from AVRDC materials were approved by the National Seed Industry Council (NSIC) for commercial production (table 1). This brings the total number of AVRDC-improved materials released in the Philippines to 20 broken down into seven varieties each of mungbean and soybean, one tomato, three Chinese cabbage, and two sweet potato.

Table 1. Seed board varieties from AVRDC materials released in the Philippines, 1996

Crop	AVRDC name	Seed board name
Grain soybean	GC 50265-2-18-7	PSB-Sy4
	G-0062	PSB-Sy5
Vegetable soybean	AGS 191	PSB-Vs1
	AGS 190	PSB-Vs2
	AGS 186	PSB-Vs3
Mungbean	VC 3876	PSB-Mg2
	VC 2764 (Y)	PSB-Mg3

Adaptive trials

Soybean

Eight test entries were evaluated against one national and one regional check in RYT during the 1994–96 dry and wet seasons. Results from 10 wet and 11 dry season trials from eight cooperating stations showed that: IPB Sy 85-03-11, EG Sy 93-18-07 (GC 50265-2-18-07), IPB Sy 85-16-08, and LG Sy 12-12 outyielded the check PSB Sy3 by 16, 12, 11, and 10%, respectively, during the wet season. During the dry season, IPB Sy 85-03-11, IPB Sy 85-16-08, EG Sy 93-62, LG Sy 12-12, and EG Sy 93-18-07 outyielded PSP Sy3 by 41, 37, 28, 11, and 9%, respectively. The entries were moderately resistant to bacterial pustule, rust, and virus diseases.

Because of the promising performance from four-season across-location trials, EG Sy 93-18-07 (GC 50265-2-18-7), EG Sy 93-62 (G-0062), IPB Sy 85-0-3-11, and IPB Sy 85-16-08 were recommended and approved for release by the Philippine seed board (table 2).

Table 2. AVRDC soybean and vegetable soybean lines approved for commercial release, 1996

Line	Varietal name	Pedigree	Yield (t/ha) WS[a]	Yield (t/ha) DS[a]	Chem. analysis (%) Protein	Chem. analysis (%) Oil	Special characteristics
Soybean							
G 0062	PSB-Sy5	IPL-Sy2 x PI 230971	2.0	2.0	33.6	19.4	High bean yield, early maturity, big seed, resistant to soybean rust and bacterial pustule
G 50265-2-18-7	PSB-Sy4	Q68 x TN #3	2.3	1.7	36.8	20.2	High bean yield, early maturity, big seed, resistant to soybean rust and bacterial pustule
					(dry weight basis, %))		
Vegetable soybean							
AGS 186	PSB-Vs3	Yoshida I	8.8	7.1	40	20	High fresh pod yield, good eating quality, resistant to soybean rust and bacterial pustule
AGS 190	PSB-Vs2	Special Malabini x Wakasima	9.6	7.4	40	20	High fresh pod yield, good eating quality, big seed, resistant to soybean rust and bacterial pustule
AGS 191	PSB-Vs1	Special Malabini x Wakasima	14.8	8.6	40	20	High fresh pod yield, good eating quality, big seed, resistant to soybean rust and bacterial pustule

[a] WS = wet season; DS = dry season

Vegetable soybean

Six selected vegetable soybean lines (AGS 186, 190, 191, G 10478, 10500, and 10503) were pilot-tested in two locations during the dry season and seven sites during the wet season to evaluate their performance across locations and encourage the use and cultivation of vegetable soybean. Of these lines, AGS 191 and AGS 190 were most promising in terms of fresh pod yield, seed size, and eating qualities. Their mean number of graded pod yields per 500 g, mean pod lengths and widths were within the acceptable international standards. AGS 191 had a mean yield of 8.6 t/ha across locations, followed by AGS 190 with 7.4 and AGS 186 with 7.1 t/ha, respectively. AGS 191 had the biggest 100-seed weight of 57.7 g, followed by AGS 190 with 56.2 g, and AGS 186 with 49 g.

During the wet season, AGS 191 with a mean yield of 15 t/ha, significantly outperformed all entries in seven test sites, followed by AGS 190 with 10 t/ha. Both had comparable 100-seed weights of 69.6 and 65.8 g. Results indicated that these promising lines have wide adaptability and are not much affected by location or agroclimatic conditions. Lines AGS 186, 190, and 191 were recommended for release (table 2).

Mungbean

Ten entries evaluated in RYT in the dry season in Los Baños, Laguna yielded on the average 5 t/ha due to insufficient irrigation and severe soil moisture stress at flowering stage. Only IPB M85-45-4 outperformed the check varieties MG 50-10A and PSB-Mg1, but the differences were not significant. EGM-4488 had the heaviest seed weight of 6.1 g/100 seeds. No incidence of cercospora leaf spot was observed, but all entries were rated moderately resistant or resistant to virus diseases.

In the wet season, 11 entries were evaluated. The grand mean bean yield was 7 t/ha (IPB M85-34-4). None of the six highest yielders outyielded the national check. Heaviest seed weight was observed in EGM-3995 (5.4 g/100 seed). All entries were rated moderately resistant or resistant to virus diseases. In all, two AVRDC lines, VC 3876 and VC 2764 (Y) with 1.3 t/ha consistently outperformed the check BPI-Mg9 (1.2 t/ha) in 12 tests during the wet season across locations from 1993 to 1995 by 6 and 10%, respectively.

During the dry season, a mean of 13 trials showed that VC-3876 (1.1 t/ha) and VC 2764 (Y) outperformed BPI-Mg9 (1.0 t/ha). These were approved for release for commercial production by the National Seed Industry Council.

Tomato

In two sets of general yield trial (GYT) planting during the dry season evaluation for determinate tomatoes, entries CL 5915-93D4-1-0-3 and CL 143-0-10-3-0-1-10 significantly outyielded the check Pope with 40 and 34 t/ha total yields. For indeterminate tomatoes, FMTT 95, 18, 105, and 115, with yields ranging from 18.4 to 21.7 t/ha significantly outyielded the check Pope (8.8 t/ha) during the dry season. During the wet season, CL 5915-93-D4-1-0-3 outperformed the two checks, Pope and Maigaya, but with no significant differences.

In RYTs, eight table tomato lines were evaluated during the dry season. FMTT 138, an indeterminate F_1 hybrid, significantly outyielded (59 t/ha marketable yield) the check, Pope, during the dry season, but was comparable to the check (9 t/ha) during the wet season. It also had the biggest mean fruit size of 100 g during the wet season.

Chinese cabbage

In GYT, the entries showed significant differences in marketable head yield and head solidity. Hybrid #85-202 (10.4 t/ha) and Hybrid #85-216 (1 1.3 t/ha) had statistically comparable yields to the heat-tolerant check, Reyna Elena (with 11.8 t/ha). Hybrid #85-216 had the most solid head of 0.4 g/cc and also the highest mean head weight of 390 g.

Under the hot-wet conditions of the lowland tropics, the yield performance of AVRDC Chinese cabbage hybrids 85-202 and 85-216 were comparable to the heat-tolerant check, Reyna Elena.

AVRDC–ROC Cooperative Program

Promising AVRDC vegetable varieties/lines are evaluated in the field in different seasons and locations in Taiwan in cooperation with the national agricultural research program of ROC. The trials at AVRDC headquarters are supported by the Council of Agriculture, ROC and conducted 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.

A total of 15 AVRDC vegetable varieties have been named and released by the national program in the past years. In 1995, all the mungbean planting areas grew an AVRDC-released variety, Tainan No.5. Two fresh market tomato hybrids, Taichung ASVEG No.4 and Hualien ASVEG No.5, occupied 89% of the total growing areas for summer tomato production. For vegetable soybean, the growing area of Kaohsiung (KS) No.1 was decreased from 91% of the total areas in 1994 to 64% in 1995 because of the promotion of new varieties, Ryokkoh (Ryokkoh-74 was named Kaohsiung No.5 in 1996) and Kaohsiung No.2. These varieties have significantly contributed to farmers' incomes.

Regional yield trials

A total of 32 RYTs were conducted in cooperation with Tainan and Kaohsiung DAIS in 1995–96. The purpose of the RYT is to evaluate promising AVRDC varieties/lines of vegetable soybean, mungbean, and cherry tomato along with locally developed varieties at different locations in various seasons.

Vegetable soybean

Fourteen entries including three check varieties of vegetable soybean were evaluated at seven locations in summer 1995, three locations in autumn 1995, and eight locations in spring 1996 (table 1). Differences in pod yields among the

Table 1. Marketable pod yield (t/ha) of vegetable soybean RYTs in 1995–96

	AVRDC			Putzu		Likang		Mean[a]		
Entry	SU95	AU95	SP96	SU95	SP96	SU95	SP96	SU95	AU95	SP96
KVS 490	7.0	6.0	5.8	9.1	10.5	7.0	3.6	7.0	5.7	5.8
KVS 508	6.9	5.3	6.9	8.5	8.2	6.5	3.7	7.0	5.4	5.5
KVS 565	6.3	5.7	6.1	7.4	8.6	6.2	4.4	6.2	5.5	5.7
KVS 568	5.9	5.3	8.8	12.1	10.9	3.6	4.0	7.2	5.4	7.3
GC 87010-34-3-1	7.2	6.0	6.4	9.5	7.7	5.7	4.7	6.9	4.8	5.4
GC 87010-66-1-19	3.7	6.2	8.2	9.9	7.9	6.4	6.1	6.7	6.2	5.9
GC 87012-20-B-2	4.4	5.2	6.6	10.6	9.1	5.6	3.3	7.1	4.6	5.8
GC 87012-20-B-8-2	5.7	4.9	6.3	9.5	7.9	5.1	3.6	7.0	5.1	5.3
TS 81-105	6.9	5.2	7.2	10.1	7.8	3.5	3.8	6.8	4.9	5.6
TS 81-115	4.8	4.7	7.0	7.0	9.5	5.2	5.8	5.7	4.6	6.2
TS 81-135	5.2	4.5	8.0	9.5	8.7	6.8	5.5	7.0	4.9	5.8
KS No. 2	3.4	4.1	7.0	5.3	6.7	4.7	6.2	5.2	4.3	5.3
KS No. 3	5.8	5.8	5.8	7.9	9.5	4.8	3.9	6.4	5.7	5.4
Ryokkoh	3.8	3.7	5.9	5.9	6.8	3.5	5.0	4.8	3.3	4.5
Mean	5.5	5.2	6.9	8.8	8.6	5.3	4.5	6.5	5.0	5.7
LSD 5%	1.1	1.9	1.4	1.7	1.7	2.9	1.3			

[a] SU95: mean of 7 locations; AU95: 3 locations; SP96: 8 locations; SU = summer, AU = autumn, SP = spring.

entries in each trial were significant. Among 14 entries, KVS 568 had the highest yield of 7 t/ha in both summer and spring across locations. It outyielded the check variety KS No.2 by 38% and KS No.3 by 13–14%. In autumn 1995, an AVRDC line, GC 87010-66-1-19, performed very well with the highest mean yield of 6 t/ha, which was 43% higher than the check KS No.2, irrespective of locations. Moreover, KVS 568 produced extremely high yields of 12 and 11 t/ha in the summer and spring crop, respectively, at Putzu.

The yield performance of vegetable soybeans varied with location and season. In summer 1995, Hualien had the highest average yield of 10 t/ha; in autumn, AVRDC produced the best yield of 5 t/ha; while in spring 1996, Putzu gave the highest mean yield of 7 t/ha. The economic potential of the Hualien area should be explored for vegetable soybean production. Generally, the yields of marketable pods were higher in summer than in autumn and spring crops.

Mungbean

Ten AVRDC mungbean lines including the check variety Tainan No.5 were evaluated in 1995–96 RYTs at three locations. In summer 1995, VC 4152B produced the highest yields in both Tungshih (1.9 t/ha) and Yenshiue (1.6 t/ha) with a mean yield of 1.5 t/ha at three locations compared to 1.4 t/ha of Tainan No.5. The highest 100-seed weight of 6.9 g was obtained from VC 4828B. Tungshih produced better yields than other locations.

In spring 1996, VC 3737A gave the highest yield of 1.8 t/ha at AVRDC. Irrespective of locations, the two top yielders were VC 3737A and VC 6040B. Both yielded 1.4 t/ha compared to Tainan No.5's 1.1 t/ha. VC 4828B still had the largest seed size with a 100-seed weight of 6.4 g, while VC 3737A had a relatively small 100-seed weight of 5.5 g.

Cherry tomato

Cherry tomato has become popular in Taiwan. Variety Santa 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.

Three AVRDC cherry tomato lines were tested along with Santa as a control at four locations in summer and autumn 1995. CHT 154 was still the best performer in both seasons in terms of marketable yield and fruit size (table 2).

Table 2. Yield and horticultural characteristics of cherry tomato RYTs in summer and autumn, 1995

Entry	Yield (t/ha)								Fruit weight (g)							
	Tainan		Hsiko		AVRDC		Mean[a]		Tainan		Hsiko		AVRDC		Mean[a]	
	SU	AU	SU	AU	SU	AU	SU	AU	SU	AU	SU	AU	SU	AU	SU	AU
CH 154	41.2	50.3	47.5	53.2	11.5	80.5	48.5	58.9	10.0	10.7	9.8	12.7	6.5	6.5	8.7	10.0
CH 155	49.8	47.7	37.0	48.2	13.5	71.0	48.1	53.2	9.6	11.1	9.1	12.4	5.8	6.3	8.3	9.
CH 157	47.1	39.6	32.4	61.1	11.7	76.4	41.7	52.7	7.5	8.3	6.7	10.3	3.9	5.1	6.0	7.9
Santa	32.8	35.4	21.4	27.6	6.4	62.9	26.7	35.7	11.1	14.3	8.9	12.5	6.6	6.8	8.4	11.2
Mean	42.7	43.2	34.6	47.5	10.8	72.7	41.3	50.1	9.6	11.1	8.6	12.0	5.7	6.2	7.9	9.8
LSD 5%	6.5	7.1	4.7	21.7	2.5	13.9	0.8	0.7	1.0	1.0	0.7	0.7				

[a] mean of 4 locations; SU = summer, AU = autumn, SP = spring.

Irrespective of locations, it produced 48 t/ha and 59 t/ha in summer and autumn, respectively. It outyielded Santa by 82% in summer and 65% in autumn crop. The fruit size of CHT 154 was comparable to Santa in summer but slightly smaller than Santa in autumn season.

Release of cherry tomato CHT 154. Based on the results of RYTs and demonstration trials conducted in 1994–96, AVRDC cherry tomato line CHT 154 was named as Tainan ASVEG No.6 on 5 July and released to farmers by Tainan DAIS. Tainan ASVEG No.6 is a semideterminate type cherry tomato with a small oblong fruit (7-10 g) similar to Santa. It is heat-tolerant, resistant to fusarium wilt, and tolerant to leaf curl virus and TMV. It has uniform fruiting and is easy to pick, a trait which can save on harvesting labor. The new variety produces good quality cherry tomatoes with excellent color and firmness, and less fruit cracking. It is expected to be grown on about 560 ha in Taiwan in 1996–97.

Collection and evaluation of nonprincipal vegetables

AVRDC has successfully grown and identified promising varieties of several nonprincipal and principal vegetables in the search for improved lines with potential 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.

Lettuce

Three trials were conducted to evaluate selected varieties of leaf, crisp-head, butterhead, and romaine lettuce in 1995–96. Differences in yields in each trial within the lettuce type were significant. For butterhead lettuce, the highest yield was obtained from Solista ez 84 with 54 t/ha in autumn 1995. Nevada, Regina 71, and V 1016, all performed well in two or three seasons (table 3). Felicia was the best performer in the summer 1996 trial. For crisp-head lettuce, Sun was an excellent variety which produced very stable high yields in all three crop seasons with an average yield of 44 t/ha. In addition, Greenfield, Georgia, and V 1008 had mean yields above 29 t/ha (table 3). Sun and V 1008 formed better heads under high temperature conditions than other varieties, although their heads were not as solid as those in autumn.

Among the leaf lettuce entries, Rapidmor Oscura VML and Marsala performed well, and were considered promising. Prizemor Oscura VML had the highest yield of 70 t/ha in autumn 1995 (table 3); however, it was not tested in summer due to insufficient seeds.

Romaine, a new type of lettuce introduced in Taiwan, is similar to leaf lettuce but is more crispy, which makes it easily acceptable to local consumers. Similar to last year's results, Augustus and Maravimor Clara VML were the stable high yielders among the romaine lettuce entries. Augustus, particularly, produced an excellent yield of 70 t/ha in autumn and also gave the highest yield of 23 t/ha in the summer trial (table 3).

Table 3. Top performers in lettuce observation trials, 1995–1996

Kind/Entry	Yield (t/ha)			Days to harvest (DAS[b])		
	AU95	SP96	SU96	AU95	SP96	SU96
Butterhead						
Regina71	50.6	24.5	—[a]	71	42	—
Felicia	—	21.5	30.0	—	45	39
Kagranager Summer	31.8	16.6	21.4	52	34	39
Nevada	50.4	23.6	23.6	73	42	39
V1016	45.5	21.8	24.6	70	41	38
Mean of all entries	43.0	19.3	20.6	67	40	37
Crisp-head						
Calmar	40.3	24.8	17.6	72	44	32
Greenfield	39.2	26.3	—	69	46	—
Sun	41.3	40.3	49.2	69	45	39
Georgia	47.0	33.2	10.7	67	41	28
V1008	42.3	22.8	24.2	67	41	39
Mean of all entries	39.8	24.5	22.4	68	42	36
Leaf						
Red Salad Bowl	33.4	9.1	12.2	60	34	39
New Red Fire	38.3	25.7	9.2	63	41	39
Marsala	40.1	24.3	16.2	73	41	39
Prizemor Oscura VML	69.6	25.2	—	70	39	—
Rapidmor Oscura VML	43.4	24.5	19.2	57	41	28
Mean of all entries	40.8	18.1	12.8	63	38	33
Romaine						
Parris Island	50.1	27.6	10.0	66	43	28
Augustus PVP	70.5	20.8	23.2	71	36	38
Romulus PVP	59.0	13.9	16.1	72	34	30
Maravimor Clara VML	49.3	20.4	16.7	69	36	39
Mean of all entries	54.2	24.3	16.5	68	39	34

[a] —: no data.
[b] DAS = days after sowing.
Note: SU = summer, AU = autumn, SP = spring.

Results of lettuce trials revealed that autumn is the most favorable season for growing any type of lettuce, producing better yield and quality than any other season. In contrast, the majority of lettuce varieties are sensitive to high temperature, which causes immature bolting resulting in low yields in summer. The search for heat-tolerant varieties will be continued to improve lettuce production in summer.

Snap bean and yard-long bean

Two trials were conducted to evaluate the general performance of collected bush and pole snap bean varieties in 1995–96. Thirty entries of bush snap beans were planted on 6-m-long single-row plots in both autumn 1995 and spring 1996 crops, while 14 pole snap bean entries were planted on 4.8-m-long two-row plots in the same seasons. The experimental layout was RCBD with three replications.

Two observation trials were conducted to evaluate 24 varieties of yard-long bean in 1995–96. The trials were planted on 4.8-m-long two-row plots without replication.

The results of bush snap bean trials indicated significant differences in yields among the entries in both seasons. Among 30 varieties of bush snap beans, Paradise performed well and was stable in both seasons. In autumn, Paradise produced the highest yield of only 7 t/ha and matured 64 days after sowing, but in spring, it yielded 21 t/ha, which was the best yield among the entries, and matured early at 58 DAS. Pulobaeda also gave a high yield of 20 t/ha in spring crop. The mean yield in spring 1996 was 16 t/ha, which was almost four times that of autumn 1995.

The average yields of 14 pole snap bean varieties were 21 t/ha and 5 t/ha for spring and autumn crop, respectively. Jemmy was the earliest variety in both seasons and produced the best yield of 25 t/ha in spring 1996. In addition, Witsa also performed well with stable high yields in both seasons. The low yields of autumn 1995 in both bush and pole snap bean trials were mainly due to poor stands caused by heavy rains and high incidence of powdery mildew disease.

Yard-long bean yields varied with varieties in each trial. Among 24 entries, the yields ranged from 1 to 10 t/ha and 2 to 10 t/ha for autumn 1995 and spring 1996, respectively. The highest yields were obtained from Tun 207 and Tun 210 in respective crops. Tun 205, Tun 207, Tun 210, and Tun 211 performed well and were stable in both crop seasons.

Broccoli and cauliflower

Twenty varieties of broccoli were evaluated in autumn 1995. The head yields ranged from 11 t/ha (Pirate) to 20 t/ha (Triumph No.2 F_1) with a mean of 14. t/ha (table 4). The tested varieties matured in 54–77 days after transplanting. Green Jewel was the second highest yielder with 18 t/ha of medium to large heads. Dark Horse F_1 was the earliest variety (54 DAT) and had a promising yield of 16 t/ha.

Fifty varieties of cauliflower were also tested in autumn 1995. The head yields varied with entries ranging from 4 to 40 t/ha, while the maturity ranged from 42 to 108 DAT. Guardian was a very vigorous variety which produced a lot of leaves and side shoots (73 t/ha, table 4). It was the best yielder, but matured later (98 DAT). Fremont Firs, Minuteman, and Ravella F_1 RS were promising varieties with yields higher than 25 t/ha. The early maturing varieties identified were Chin Tai No.10, Meigetsu F_1, and Mikado 40 Days, which matured in 42–53 DAT. Chin Tai No.10, the earliest variety, yielded 19 t/ha, while the other two varieties produced only 12–13 t/ha of heads.

Table 4. Top performers in broccoli and cauliflower observation trials, autumn 1995[a]

Variety	Days to harvest	Total yield (t/ha)	Head yield (t/ha)
Broccoli			
Green Jewel	68.8	54.4	17.7
Dark Horse F_1	53.9	34.5	16.2
Galleon	59.2	46.7	15.6
Gallaent (S-130)	66.8	56.3	15.7
Triumph No.2 (524) F1	68.4	56.4	19.5
Mean of 20 varieties	67.3	52.6	14.5
Cauliflower			
Guardian	98.0	112.9	40.3
Fremont Firs	85.1	78.7	28.8
70 Days Medium	94.6	63.5	22.7
Minuteman	83.3	68.0	27.7
Ravella F_1 RS	90.3	65.1	25.6
Mean of 50 varieties	71.7	50.7	18.2

[a] Planting dates: sowing: 15 September; planting: 13 October 1995.

Germplasm collection and evaluation of tropical leafy vegetables

Leafy vegetables are very popular and important in Taiwan, occupying a total of 37,000 ha in 1995 or about 22% of total vegetable planted 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 are collected by AVRDC from the field, through germplasm exchanges, regional centers, and Chinese overseas missions, and evaluated and multiplied at the Center. The collections focused on Southeast Asia, South Asia, China, and Africa. To date, the total germplasm collection of leafy vegetables consist of 844 accessions of 32 vegetables from Southeast Asia; 43 accessions of 5 vegetables from South Asia;

118 accessions of 13 vegetables from China; and 26 accessions of 10 vegetables from Africa.

A total of 167 entries of six leafy vegetables including amaranth, kale, mustard, kangkong, pai-tsai, and rape were evaluated under the nethouse in 1996. These entries were collected from Indonesia, India, Ghana, and 19 other countries and territories. Kangkong and all *Brassica* species were collected mainly from Indonesia.

Among 136 amaranth entries, 42 accessions were either wild types or early bolters and were unmarketable. Nine varieties yielded more than 20 t/ha and the rest of the entries produced yields less than 10 t/ha. The highest yield was obtained from Tot 2337 (39 t/ha). Other promising performers were Tot 2353, Tot 2331, Tot 1801, and Tot 2358 yields of 26–29 t/ha.

For kangkong, 8 out 12 varieties produced more than 30 t/ha yields from multiharvests. Tot 1923 had the highest yield of 40 t/ha, while Tot 1929 produced the lowest yield of 15 t/ha. The other promising entries were Tot 1922, Tot 1917, Tot 1924, Tot 1918, and Tot 1927. They all yielded higher than 35 t/ha.

Among the 12 entries of rape, six varieties yielded higher than 10 t/ha. The top yielders were TB 570 (17 t/ha), TB 599 (14 t/ha), and TB 574 (12 t/ha). TB 602 was the best performer among the three mustard entries, while pai-tsai TB 591 was a very high yielder (37 t/ha).

Seed production and distribution

Seed of AVRDC-released varieties and promising lines were multiplied to supply demonstration trials or RYTs nationwide. AVRDC also produced stock seeds of released varieties for the national seed production system with the support of the Provincial Department of Agriculture and Forestry (PDAF) and Council of Agriculture, ROC.

In 1995–96, 11 kg of cherry tomato CHT 154 (Tainan ASVEG No.6), 350 kg of mungbean Tainan No.5, 1450 kg of three soybean varieties, Tainan No.1, Tainan No.2, and Kaohsiung No.10, and 1430 kg of three vegetable soybean varieties, Kaohsiung No.1, Kaohsiung No.2, and Kaohsiung No.3 were produced. These stock seeds passed through all inspections by the Seed Laboratory of the PDAF. They are being distributed to the national program.

Other activities

The reception of domestic visitors is one of the major activities of the ROC cooperative program. In 1996, a total of 49 groups, consisting of 3310 individuals from ROC visited AVRDC. The visitors included members of farmers' associations, officials and researchers of agricultural research institutions, high school teachers, and high school and college students. In addition, a total of 106 international visitors were received by the program.

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[a] Left during 1996 [b] Assumed office during 1996

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Hideo Imai, Ph.D., Deputy Director General
Tung-hai Huang, MBA, Director of Administration
Nancy C. Chao, Assistant Comptroller
Jeng-hua Chen, B.S., Superintendent, Buildings and Maintenance
Sui-fang Wu, B.A., Manager, Food and Dormitory Services

Crop Improvement Program

Program Director: C. George Kuo, Ph.D.

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Crucifer

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Lien-chung Chang, B.S., Associate Specialist

Pepper

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Chien-rong Ho, B.S., Research Assistant[a]
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Soybean

S. Shanmugasundaram, Ph.D., Plant Breeder
Miaw-rong Yan, B.S., Research Assistant

Tomato

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Allium

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Entomology

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Cheng-li Lee, M.S., Principal Research Assistant
Chih-hung Lin, M.S. Principal Research Assistant[b]

Plant Physiology

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Tyng-shyang Lai, M.S., Principal Research Assistant
Jinq-chyi Chang, M.S., Principal Research Assistant (project)
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Pi-er Huang, B.S., Research Assistant[a] (project)

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Jia-chain Shieh, B.S., Research Assistant
Ching-huan Chang, B.S., Research Assistant

Production Systems Program

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Crop Management

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Hsioh-chung Lu, Consultant

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African Regional Program, SADCC-AVRDC-CONVERDS, Arusha, Tanzania

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Remi Nono-Womdim, Ph.D., Associate Plant Pathologist

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Shih-chen Chang, M.S., Principal Research Assistant

Statistics and Computer Services

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Yuh-ling Chen, B.S., Computer Assistant

Farm Operations

Teng-sheng Tu, B.S., Farm Superintendent

[a] Left during 1996
[b] Arrived during 1996
[c] On study leave
[d] Transferred from another unit
[e] On contract

Meteorological Information, 1996

Meteorological data (monthly mean) collected at AVRDC weather station, 1996

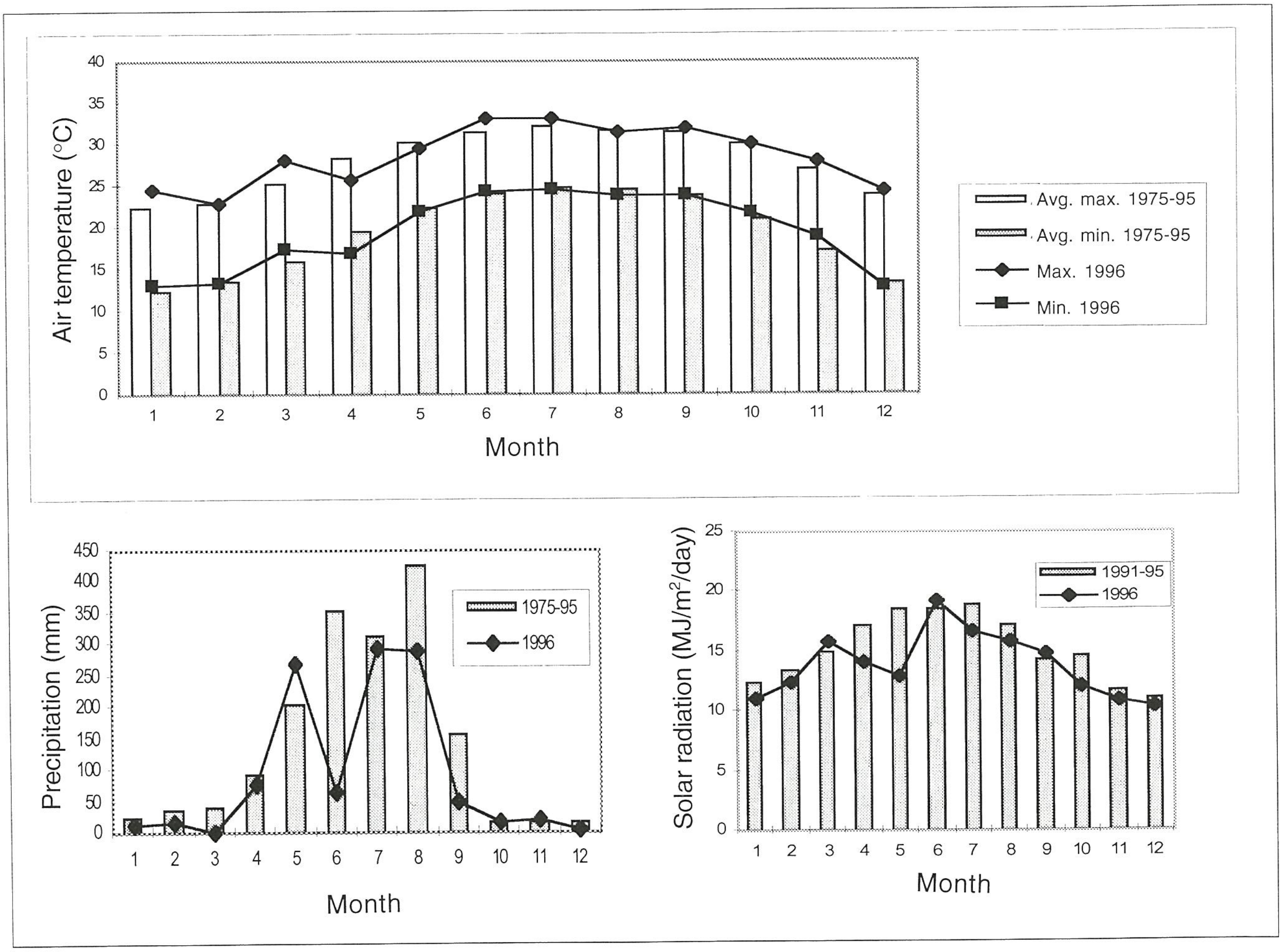
		January	February	March	April	May	June	July	August	September	October	November	December
Humidity (%)	Daily avg.	76.2	81.1	78.8	84.3	83.2	80.8	80.8	83.9	80.6	82.0	81.0	75.1
Air temperature (°C)	Daily max.	24.5	22.9	28.2	25.7	29.5	33.0	33.1	31.4	32.0	30.0	27.9	24.3
	Daily min.	13.0	13.4	17.3	17.0	22.0	24.4	24.5	23.9	23.9	21.6	18.7	12.9
Soil temperature 10 cm (°C)	Daily max.	22.0	22.1	26.3	26.0	28.3	31.1	32.5	32.2	32.1	29.1	26.7	23.6
	Daily min.	19.5	19.4	22.7	22.4	25.5	28.3	29.1	27.9	28.1	26.3	24.3	20.6
Soil temperature 30 cm (°C)	Daily max.	21.7	21.7	24.6	24.6	26.9	29.4	30.6	29.9	30.1	28.3	26.5	23.4
	Daily min.	21.0	20.9	23.6	23.6	26.1	28.6	29.6	28.7	29.0	27.2	25.5	22.4
Wind velocity (m/s)	Daily avg.	2.86	3.24	2.70	2.56	1.96	2.30	2.86	2.54	2.28	1.81	2.22	2.43
Solar radiation ($MJ/m^2/day$)	Daily avg.	11.0	12.4	15.9	14.1	13.0	19.3	16.7	15.9	14.8	12.0	10.8	10.3
Precipitation (mm)	Monthly	12.0	15.0	1.0	75.0	271.0	65.0	292.5	288.0	48.5	17.0	21.0	3.0
Evaporation (mm)	Daily avg.	3.3	3.9	5.5	3.9	5.0	6.9	7.4	5.2	5.5	3.4	3.7	3.6

Crop Environment

Climate in 1996 was rather hot in early spring and summer compared with an ordinary year. Daily maximum air temperature was 28.2°C in March (3°C higher than average) and more than 33°C in June and July, which exceeded an ordinary year by 0.9–1.6°C. However, temperature cooled down in late spring (25.7°C in April, 2.7°C lower than an ordinary year).

Total precipitation of 1110 mm was almost two-thirds of the average rainfall of 1700 mm for the last 21 years. Precipitation was less especially in June. It was only 65 mm, which comprised only 20% of that of a normal year (353 mm).

Solar radiation was higher in March and in June than in a normal year; the rest of months showed slightly lower values. Solar radiation was significantly lower in April and May due to a long spell of rainy days.



Financial Statements

Audited financial statements for the year are available from the Office of the Director General, AVRDC.

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF ASSETS, LIABILITIES AND FUNDS
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	December 31	
ASSETS	1996	1995
CASH	$3,432,128	$3,788,575
ADVANCES AND REFUNDABLE DEPOSITS (Note 3)	181,966	385,057
PREPAYMENTS	7,171	39,117
TOTAL ASSETS	$3,621,265	$4,212,749
LIABILITIES AND FUND BALANCES		
RECEIPTS FOR CUSTODY (Note 4)	$ 278,878	$ 303,895
RESERVES FOR EMPLOYEE BENEFITS (Note 5)	1,188,575	1,194,741
FUNDS		
Core fund	221,880	1,169,584
Working capital fund (Note 7)	900,000	900,000
Restricted core fund	(63,618)	(193,592)
Special projects fund	893,597	687,948
Self-sustaining operation fund	201,953	150,173
Total Funds	2,153,812	2,714,113
TOTAL LIABILITIES AND FUNDS	$3,621,265	$4,212,749

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1997)

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	
	1996	1995
ADDITIONS		
Contributions		
Republic of China	$4,177,912	$5,544,741
Japan	1,033,000	1,033,000
Federal Republic of Germany (Note 6)	542,173	956,104
United States of America (Note 6)	600,000	300,000
Thailand	204,993	424,312
Republic of Korea	150,000	-
Australia	148,658	148,478
Philippines	100,000	50,000
France	-	270,692
Total contributions	6,956,736	8,727,327
Grants from Japan International Cooperation Agency	12,990	90,603
Taiwan Kagome Co., Ltd.	1,822	1,835
Non-Tai Seeds Co.	1,822	-
Translation adjustment (Note 2)	(3,218)	(185,756)
Other (Note 6)	679,958	706,414
Total Additions	7,650,110	9,340,423
DEDUCTIONS		
Capital expenditures (Notes 2 and 6)	130,060	599,475
Operating expenditures (Note 6)	8,412,332	8,531,228
Total Deductions	8,542,392	9,130,703
NET INCREASE (DECREASE) IN FUND	(892,282)	209,720
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	1,169,584	934,898
Translation adjustment (Note 2)	(55,422)	24,966
As restated	1,114,162	959,864
FUND BALANCE, END OF YEAR	$ 221,880	$1,169,584

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1997)

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	
	1996	1995
ADDITIONS		
From German Agency for Technical Cooperation	$ 758,084	$ 608,621
From U.S. Agency for International Development	300,000	-
Total Additions	1,058,084	608,621
DEDUCTIONS		
Transfers to Core Fund		
-Federal Republic of Germany	542,173	956,104
-United States of America	400,000	-
Total Deductions	942,173	956,104
NET INCREASE (DECREASE) IN FUND	115,911	(347,483)
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	(193,592)	142,328
Translation adjustment (Note 2)	14,063	11,563
As restated	(179,529)	153,891
FUND BALANCE, END OF YEAR	($ 63,618)	($ 193,592)

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1997)

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, 1995					Year Ended December 31, 1996			
Sponsors	Balance, Beginning of Year	Translation Adjustment	Additions	Deductions	Balance, End of Year	Translation Adjustment	Additions	Deductions	Balance, End of Year
Japan	$ 171,198	$ -	$ 310,000	$ 232,890	$ 248,308	$ -	$ 340,000	$ 240,151	$ 348,157
Asian Development Bank	(213,772)	-	370,968	198,391	(41,195)	-	463,420	304,719	117,506
Federal Republic of Germany	50,759	-	321,296	343,875	28,180	-	326,416	239,774	114,822
Council of Agriculture/ROC	108,315	(3,657)	1,035,450	926,216	213,892	(1,480)	682,762	790,248	104,926
U.S. AID	5,342	-	433,407	302,393	136,356	-	245,814	285,708	96,462
Rural Development Administration/Korea	24,104	-	-	17,349	6,755	-	19,980	8,398	18,337
National Science Council/ROC	20,737	(700)	46,059	43,059	23,037	(160)	16,071	31,997	6,951
International Development Research Center	3,276	-	-	-	3,276	-	30,096	33,372	-
Others	50,617	(439)	181,757	162,596	69,339	(112)	257,034	239,825	86,436
	$ 220,576	($ 4,796)	$2,698,937	$2,226,769	$ 687,948	($ 1,752)	$2,381,593	$2,174,192	$ 893,597

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 6, 1997)