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Abbreviations and Acronyms

ACIAR — Australian Centre for International Agricultural Research
ACP-EC — African, Caribbean and Pacific-European Community
ADB — Asian Development Bank
ADRC — Agricultural Development Research Center (Northeast Thailand)
a.i. — active ingredient
AID — Agency for International Development (USA)
AIT — American Institute in Taiwan
AMV — alfalfa mosaic virus
ANOVA — analysis of variance
ARTT — advanced soybean rust tolerance trials
ASET — AVRDC Soybean Evaluation Trials
ATI — Agricultural Training Institute (Philippines)
AVNET — Collaborative Vegetable Research Program for Southeast Asia
AVRDC — Asian Vegetable Research and Development Center
AYT — advanced yield trial
BARC — Bangladesh Agricultural Research Council
BARI — Bangladesh Agricultural Research Institute
BAW — beet armyworm
BePMV — bell pepper mottle virus
BER — blossom end rot
BfDW — Bread for the World
BINA — Bangladesh Institute of Nuclear Agriculture
BMZ — German Ministry for Economic Cooperation
BP — bacterial pustule
BPI-LBNCRDC — Bureau of Plant Industry—Los Baños National Crop Research and Development Center (Philippines)
BSU — Benguet State University (Philippines)
BW — bacterial wilt
CARDI — Caribbean Agricultural Research and Development Institute
CATIE — Centro Agronómico Tropical de Investigación y Enseñanza
cfu — colony-forming units
CGIAR — Consultative Group on International Agricultural Research
CGN — Centre for Genetic Resources (the Netherlands)
CGR — crop growth rate
CHT — cherry tomato
CIAPAN — Centro de Investigaciones Agricolas del Pacifico Norte (Mexico)
CIAT — Centro Internacional de Agricultura Tropical (CGIAR)
CIDSE — Cooperation internationale pour le developpement socioeconomique
CIMMYT — Centro Internacional de la Papa (CGIAR)
CINDE — Coalicion Costarricense de Iniciativas de Desarrollo (Costa Rica)
CIP — Centro Internacional de la Papa (CGIAR)
CLS — Cercospora leaf spot
CMS — cytoplasmic male sterility
CMV — cucumber mosaic virus
COA — Council of Agriculture (Taiwan)
CONVERDS — Collaborative Network for Vegetable Research and Development in Southern Africa
CPA — para-chlorophenoxy acetic acid
CSIRO — Commonwealth Scientific Industrial Research Organization (Australia)
CTA — Technical Center for Agricultural and Rural Cooperation (EC)
cv. — cultivar
CVMV — chili veinal mottle virus
DAE — days after emergence
DAIS — District Agricultural Improvement Station (Taiwan)
DAS — days after sowing
DAS ELISA — double antibody sandwich
DAT — days after transplanting
DBM — diamondback moth
DM — downy mildew
DMRT — Duncan's multiple range test
DNA — deoxyribonucleic acid
DOAE — Department of Agricultural Extension (Thailand)
DWB — dry weight basis
EC — European Community
EDTA — ethylenediaminetetraacetic acid
ELISA — enzyme-linked immunosorbent assay
ENEA — Comitato Nazionale per la Ricerca per lo Sviluppo dell' Energia Nucleare e delle Energie Alternative (Italy)
FAO — Food and Agriculture Organization of the United Nations
FIRDI — Food Industry Research and Development Institute
FMTT — fresh market tropical tomato
FMV — feathery mottle virus
GRSU — Genetic Resources and Seed Unit
GTZ — German Agency for Technical Cooperation (Fed. Rep. of Germany)
GYT — general yield trial
HPLC — high performance liquid chromatography
HS — heat-sensitive
HT — heat-tolerant

IARC — International agricultural research center
IARI — Indian Agricultural Research Institute
IBPGR — International Board for Plant Genetic Resources (CGIAR)
IBSRAM — International Board for Soil Research and Management (IARC)
ICARDA — International Center for Agricultural Research in the Dry Areas (CGIAR)
ICIMOD — International Centre for Integrated Mountain Development (IARC)
ICIPE — International Centre of Insect Physiology and Ecology (IARC)
ICLARM — International Center for Living Aquatic Resources Management (IARC)
ICRAF — International Council for Research in Agroforestry (IARC)
ICRISAT — International Crops Research Institute for the Semi-Arid Tropics (CGIAR)
ICW — imported cabbageworm
IDIAP — Instituto de Investigación Agropecuaria de Panamá
IDRC — International Development Research Centre (Canada)
IFDC — International Fertilizer Development Center (IARC)
IFPRI — International Food Policy Research Institute (CGIAR)
IIMI — International Irrigation Management Institute (IARC)
IITA — International Institute for Tropical Agriculture (CGIAR)
ILCA — International Livestock Center for Africa (CGIAR)
ILRAD — International Laboratory for Research on Animal Diseases (CGIAR)
IMN — International Mungbean Nursery (AVRDC)
INA — Instituto Nacional Agrario (Honduras)
INIREB — Instituto Nacional de Investigaciones Sobre Recursos Bioticos (Mexico)
INRA — Institut national de la recherche agronomique (France)
INTHOPE — International Hot Pepper Trial Network
IPB — Institute of Plant Breeding (UPLB)
IPDR — Institut pratique de developpement rural (Niger)
IPM — Integrated pest management
IRRI — International Rice Research Institute (CGIAR)
ISNAR — International Service for National Agricultural Research (CGIAR)
IYT — intermediate yield trial
LAD — leaf area duration
LAI — leaf area index
LAR — leaf area ratio
LEHRI — Lembang Horticulture Research Institute (Indonesia)
MAFF — Ministry of Agriculture, Forestry and Fisheries (Japan)
MARDI — Malaysian Agricultural Research and Development Institute
MARIF — Malang Research Institute for Food Crops (Indonesia)
MYMV — mungbean yellow mosaic virus
NAR — net assimilation rate
NARS — national agricultural research systems
NBPGR — National Board for Plant Genetic Resources (India)
NIRS — near infrared reflectance spectroscopy
OPC — Office of Publications and Communications
PCARRD — Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PDA — potato dextrose agar
PE — polyethylene
PeMV — pepper mottle virus
PMMV — pepper mild mottle virus
POP — Philippines Outreach Program (AVRDC)
ppm — parts per million
PVMV — pepper veinal mottle virus
PVX — potato virus X
PVY — potato virus Y
PYT — preliminary yield trial
RDA — Rural Development Administration (Rep of Korea)
RGR — relative growth rate
ROI — return of investment
RYT — regional yield trial
SAVERNET — South Asia Vegetable Research Network
SDP — selective dissemination of publications
SEP — standard error of prediction
SPLCV — sweet potato leaf curl virus
SPLV — sweet potato latent virus
SPV II — sweet potato virus II
SPYDV — sweet potato yellow dwarf virus
TA — technology adaptation
TARC — Tropical Agricultural Research Center
TARI — Taiwan Agricultural Research Institute
TEV — tobacco etch virus
TFW — tomato fruitworm
TLCV — tobacco leaf curl virus
TMGMV — tobacco mild green mosaic virus
TMV — tobacco mosaic virus
ToMV — tomato mosaic virus
TOP — Thailand Outreach Program (AVRDC)
TSWV — tomato spotted wilt virus
TuMV — turnip mosaic virus
TVDF — Tropical Vegetable Data File (AVRDC)
TVMV — tobacco vein mosaic virus
UCNCT — upland crop national cooperation trial
UNDP — United Nations Development Programme
UPLB — University of the Philippines at Los Baños
USDA — United States Department of Agriculture
WARDA — West Africa Rice Development Association (CGIAR)
WAT — weeks after transplanting
YDV — yellow dwarf virus

Crop Improvement Program

Chinese Cabbage Breeding

Improving the Uniformity of Open-pollinated Chinese Cabbage Populations Through Maternal Line Selection

Summary

Two of AVRDC's heat-tolerant open-pollinated populations with undesirably long harvest duration were subjected to maternal line selection to determine if they could be improved for the trait without unduly depressing other important traits. After six MLS cycles, only population (M3)-27 responded favorably with a six day reduction in maturity duration and a slight but significant increase in yield. Maternal line selection did not significantly affect the maturity and harvest rate of this population. The reduction in duration of harvest makes the MLS6 derivative of population (M3)-27 as uniform-maturing as the hybrid check, ASVEG No. 1. Plots of both were completely harvested, on the average, by about the 10th day after the first harvest. However, ASVEG No. 1 was earlier by about 4 days and yielded nearly 5 t more than the MLS derivative. It is therefore concluded that maternal line selection is a useful breeding tool to concentrate the maturity of normally diverse open-pollinated populations of Chinese cabbage.

Introduction

Experience in growing Chinese cabbage during the hot and humid season at the Center had shown that the early maturing varieties with short harvest duration (from first to last harvest), such as ASVEG No. 1 and many early-maturing tropical cultivars, could frequently avoid the devastation wrought by soft rot disease, especially following the heavy rains. The longer the time of exposure of cultivars to diseases and unfavorable weather elements in the fields, the higher the losses due to these adverse factors.

AVRDC has developed a number of promising open-pollinated populations of Chinese cabbage, which is otherwise notorious for its long maturity duration. This trait limits the crop's use during periods of adverse weather. In countries where they could be grown during the dry months, the promising populations developed by the Center have been reported to perform as well as the tropical hybrids.

Maternal line selection was reported to be effective in improving open-pollinated Chinese cabbage cultivars (Shinohara and Suyano 1958)[1]. To increase the utility of the heat-tolerant, open-pollinated cultivars, a recurring cycle of maternal line selection (MLS) was applied on them. The general objective of this breeding technique is to compress the maturity duration of the populations. By 1990, five MLS cycles have been accomplished in two populations. Intervening MLS cycles were compared initially and indications are that MLS was indeed compressing the maturity duration of the populations. A 6th MLS cycle was practiced thereafter to develop the final populations for distribution to interested national partners.

Since improved uniformity is being enforced on normally heterogeneous populations, some form of inbreeding, mild they may be, could be imposed through maternal selection. Ideally, a significant compression of maturity duration, with uniform maturation without unfavorable effects on yield and other important traits, should be achieved. The original populations (referred to here as MLS0) were therefore compared with the final cycle (MLS6) for a number of important horticultural attributes during the hot season to determine if the above-mentioned ideal results have been attained.

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[1]Shinohara, S. and M. Suyano. 1958. Effect of maternal line selection method on improvement of cruciferous crops. 1. On case of Shonai No. 1 Chinese cabbage. Shizuoka Pref. Agr. Expt. Sta. Rpt. 3: 85–93.

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Materials and Methods

The two open-pollinated populations that were subjected to MLS were 77(M3)-27 and 77(M3)-35. Both populations are high-yielding, heat-tolerant and resistant to downy mildew. However, their maturity durations in the hot season could be as long as 3 weeks whereas hybrid varieties, e.g. ASVEG No. 1, could be completely harvested in about a week or so.

The S0 and S6 MLS-derived populations of these two cultivars were compared in a split-plot experiment, with populations {(M3)-27 vs. (M3)-35} as the main plot and the generations (S0 vs. S6) as the subplots. Check cultivar ASVEG No. 1 was included in each subplot for purposes of comparison. A first experiment planted in the early summer 1991 was destroyed by heavy rains. This experiment was resown on 5 August 1991 and transplanted to the field on 26 August.

Unit plots consisted of four rows in two double-row beds, each 6 m long and spaced 1.5 m between center to center of the beds. Spacing between rows within each bed was 50 cm and plants within rows, 40 cm. Total dimension of each unit plot was 18 m². The experiment was replicated four times. The major traits that were collected in the experiment were: days to maturity, duration from first to last harvest, yield and harvest rate.

Results and Discussion

Comparisons across populations between MLS6 derivative and the original population for various horticultural attributes are presented in Table 1. It is evident that maternal line selection was effective in significantly compressing the maturity duration by about 4 days. Cycle 6, however, was significantly later than the original population by 2 days. No apparent reduction in yield or harvest rate occurred following the practice of MLS on the populations.

Table 1. Comparative means (averaged across populations) for yield and other important horticultural traits of MLS0 vs. MLS6 derivatives from maternal line selection.

Population/generation	Duration (days)	Maturity (DAT)	Marketable yield (t/ha)	Harvest rate (%)
Original (MLS0)	16.1 B	41 A	24 3 A	97 A
Cycle 6 (MLS6)	12.8 A	43 B	24.4 A	96 A

When comparisons were confined within each cross, only population (M3)-27 pared significantly positive to maternal line selection (Table 2). A reduction of 6 days in maturity duration is positively combined with a slight but significant increase in yield. The increase in yield might have arisen from a higher harvest rate although this was not apparently recorded as a significant change. MLS6 matured a day later but this was not indicated as a significant delay.

In contrast to population (M3)-27's, maturity duration, the nearly 3-day reduction in maturity duration in MLS6 in population (M3)-35 was not significant. Furthermore, the maturity of MLS6 was delayed by nearly 5 days and harvest rate decreased by about nearly 5% relative to the original population. No significant change in yields occurred following maternal line selection.

When MLS6 generations of each population were compared to the hybrid check, ASVEG No. 1, only the derivative from population (M3)-27 compared well in terms of maturity duration of 9.8 days for the hybrid vs. 9.5 days for the MLS derivative of population (M3)-27. However, ASVEG No. 1 matured 4 days earlier and yielded about 5 t more than the MLS derivative.

Table 2. Comparisons for major horticultural traits between MLS0 and MLS6 derivatives from specific populations.

Population/generation	Duration (days)	Maturity (DAT)	Marketable yield (t/ha)	Harvest rate (%)
(M3)-27/MLS0	13.5	39.8	25 7	97 0
(M3)-27/MLS6	9.5	40.8	27 8	99 5
Single contrast test	*	NS	*	NS
(M3)-35/MLS0	18.8	41.3	22.8	96 5
(M3)-35/MLS6	16.0	46.0	21.1	91.8
Single contrast test	NS	**	NS	**

Development of Cytoplasmic Male-Sterile (CMS) Lines

Summary

All CMS populations produced from selections during cool season 1989–90 were planted for further selections in cool season 1990–91. Selections from families planted during cool season 1990–91 were planted in summer 1991 for further selection of heat tolerance and other horticultural traits. Final selections were made by combining data on seedling traits (vigor and degree of chlorosis), seed yield potential and heat tolerance.

Eight final selections with better horticultural traits and/or higher seed yield potential than the normal check line, CT1-27, were taken from Batch I CMS in cool season 1990–91. From these, 11 selections with better vigor and/or compact heads were derived following summer 1991 planting. These selections had radish as donor of cytoplasm.

From derivatives of mustard CMS, 12 selections with high seed yield potential and good horticultural characteristics in cool season 1990-91 planting, and 20 early maturing, heat-tolerant selections in summer 1991 planting were taken from 89W33, the best family from a previous generation of Batch II CMS. In Batch III, 10 final selections with good horticultural traits in cool season 1990–91 planting, and 14 selections with early maturity and compact heads in summer 1991 planting were taken. More good families and thus more selections were taken from Batch IV than from CMS compared to the other batches. Selections in this batch were generally better than in the other batches in terms of vigor, heat tolerance, and seed yield. The potential to isolate heat-tolerant CMS lines with good horticultural traits and high seed yield appears to be promising.

Introduction

The development of cytoplasmic male-sterility (CMS) as an alternative to self-incompatibility mechanism for hybrid seed production was continued. In the past, this program has been hampered by a high proportion of chlorotic plants in the male-sterile families, small pod size, poor seed set and generally poor horticultural characters. In 1990–91, various CMS families selected for good horticultural characters and seed set potential were examined. The best selections were then screened for heat tolerance in summer 1991 to obtain the final selections for further genetic manipulations.

Materials and Methods

Four batches of backcross-derived CMS materials from radish and mustard sources were planted in the field during cool season 1990-91 for further observation, selection and seed production. Prior to field-planting, initial selections were made in the seedling nursery for important traits such as normal green foliage color, good vigor, etc. Further details about the different materials are given below.

Sources of CMS	Batch	Generation	Sown/planted	No of families	Total plants	No. of selections
R. sativus	I	BC_6F_4	10/22 - 11/21/90	8	480	28
B. juncea	II	BC_8F_2	10/22 - 11/22/90	6	1440	50
B. juncea	III	BC_7F_3	10/22 - 11/22/90	8	960	38
B. juncea	IV	*	10/22 - 11/23/90	14	840	53

*Families originated from intercrosses with a normal, male-fertile derivative which was discovered from one of the backcross families, following the cross, each family has been open-pollinated three times by the original recurrent parents, CT1-32 and CT1-56

To evaluate the seed production potential of selections, CMS families were randomly arranged in the seed production field. Planting was carefully designed to ensure that each CMS progeny was always surrounded in the field by four male-fertile pollen plants (normally, the common recurrent parents of the families being tested). In this manner, the seed production potential of each CMS progeny could be fairly evaluated and used as an objective selection criterion. Additional beehives were located strategically in the field to add to the natural bee population. It was assumed that there were sufficient honeybees in the field

to avoid the nonrandom pollination of test plants. Final selection of CMS progenies followed this scheme: first, the CMS plants were selected for important horticultural characteristics such as early maturity, compact head, normal green foliage color, freedom from excessive axillary bud growth, etc; then, the plants were selected for apparent pod and seed production ability in the field; finally, data on seed yield, seed size, seed vigor, etc. were taken from a five-branch sample of each field-selected CMS plant for use in the final selection of progenies for further breeding.

Progenies of selections from cool season 1990–91 planting were grown in the field during summer 1991 to be observed for heat tolerance, selection and subsequently, seed production. Prior to the field-planting, initial selections were made in the seedling nursery for important traits such as normal green foliage color, good vigor, freedom from *Sclerotinia* infection, etc. Further details about the summer planting are given below.

Sources of CMS	Batch	Generation	Sown/planted	No of families	Total plants	No of selections
R. sativus	I	BC_6F_5	6/26 - 8/7/91	23	252	11
B. juncea	II	BC_8F_3	6/26 - 8/7/91	50	600	26
B. juncea	III	BC_7F_4	6/26 - 8/7/91	36	431	144
B. juncea	IV	*	6/26 - 8/7/91	52	622	30

*Families originated from intercrosses with a normal, male fertile derivative which was discovered from one of the backcross families; following the cross, each family has been open pollinated four times by the original recurrent parents, CT1-32 and CT1-56

The CMS families with their respective recurrent parents as checks were planted to the field in 4.8 m long single row plots within double-row beds. Two adjacent beds were 150 cm apart from center to center. Rows were spaced 50 cm apart and plants within the row 40 cm apart.

Results and Discussion

The selections from Batch I CMS materials (derived from radish) are shown in Table 3. Most of the final selections had better seed yield potential than the check line, CT1-27, with the exception of those from 90W17 and 90W18 which showed good horticultural traits but had comparatively poorer seed yield potential. Compared to the other batches derived from mustard, this batch is more uniform, less chlorotic, but of poor vigor and with lower heat tolerance. Only 6 selected plants produced compact but relatively small heads during summer.

Table 3. Pod and seed characteristics of selections from Batch I CMS materials in winter 1990–91 and summer 1991 plantings.

Family	1990–91 selections	Pod number	Seed number	Seed weight (g)	1000-seed weight (g)	Seed yield (g/plant)	1991 summer selections
90W1.	2	125	962	1.2	1.3	6.8	5
90W14	2	170	1314	3.1	2.4	11.0	1
90W15	1	190	1253	2.4	1.9	17.0	3
90W16	1	113	1836	3.0	1.6	9.6	0
90W17	1	93	374	0.6	1.5	1.7	2
90W18	1	41	282	0.4	1.3	1.5	0
CT1-27 (ck)		92	611	0.7	1.2	1.6	

The summary of selections from Batch II CMS materials are given in Table 4. The final selections had better seed yield potential than the check line, CT1-32, with the exception of 90W21 family which was considered more for its good horticultural traits and heat tolerance than seed yield potential. Seed yields of 90W23 and 90W25 families were very high since both included selections with excellent seed yields. Families 90W23, 90W24, 90W25, 90W26, which came from the best family of the previous generation (89W33), all had good seed yield potential in 1990–91 cool season. More importantly, 20 selections with early maturity and compact heads during summer 1991 planting were derived from these families.

Table 4. Pod and seed characteristics of selections from Batch II CMS materials in cool season 1990–91 and summer 1991.

Family	1990–91 selections	Pod number	Seed number	Seed weight (g)	1000-seed weight (g)	Seed yield (g/plant)	1991 summer selections
90W21	4	135	922	1.1	1.2	3 6	6
90W23	4	191	2813	4 6	1.6	22.2	5
90W24	2	154	1642	3 2	1.9	10.5	2
90W25	3	258	2585	5.4	2.1	21 4	5
90W26	3	164	1794	3.6	1.9	13.2	8
CT1-32 (ck)		164	1767	2 7	1.6	9.2	

Most final selections from Batch III CMS materials had lower seed yield potential than the check line, CT1-32, since the criteria for selection emphasized good horticultural traits and summer performance more than seed yield potential (Table 5). Only Family 90W37 gave generally high seed yield than the check since it included a selection with excellent seed yield potential.

All selected families from Batch IV CMS materials were comparable to either or both checks in seed yield potential (Table 6). Family 90W46 has extremely high seed yield since the single final selection had excellent seed yield. Generally, Batch IV progenies had better vigor, higher levels of heat tolerance, with longer cylindrical heads, and with higher seed yield potential than the other batches.

Table 5. Pod and seed characteristics of selections from Batch III CMS materials in cool season 1990–91 and summer 1991.

Family	1990–91 selections	Pod number	Seed number	Seed weight (g)	1000-seed weight (g)	Seed yield (g/plant)	1991 summer selections
90W33	2	83	839	1.1	1.3	2.2	2
90W36	1	189	1435	2.2	1.5	7.6	6
90W37	4	184	1999	3.3	1.7	16 8	2
90W38	3	147	1242	2.5	2 0	8.0	4
CT1-32 (ck)		164	1767	2.7	1.6	9.2	

Table 6. Pod and seed characteristics of selections from Batch IV CMS materials in cool season 1990–91 and summer 1991.

Family	1990–91 selections	Pod number	Seed number	Seed weight (g)	1000-seed weight (g)	Seed yield (g/plant)	1991 summer selections
90W41	3	173	1145	2.4	2.1	8.1	4
90W42	1	193	2015	2.9	1.4	8.3	3
90W46	1	211	2916	6.4	2.2	42.8	1
90W47	3	148	2178	4.7	2.15	13.3	6
90W48	1	178	2100	4.0	1.9	14 7	5
90W49	3	117	1062	2.3	2.1	6.8	4
90W50	1	112	1473	3.7	2.5	10.3	2
90W53	3	123	1472	2.3	1.7	8.3	5
CT1-32 (ck)		164	1767	2.7	1.6	9.2	
CT1-56 (ck)		176	1305	1.9	1.4	6.3	

Plants selected from the summer 1991 plantings were transplanted to 20-cm pots for hand backcrossing with respective recurrent male-fertile parents in 1991–92 cool season.

Development of Heat-Tolerant Populations with Cylindrical Head Type

Summary

Selections with the desired long and dense head conformation were taken from nine segregating families. Most of the selections were medium-early to medium-late maturing with compact, medium-long to long head. Some selections from F_3 group were medium-maturing with very long heads which were typically "bamboo-type", tight at the bottom and middle parts but loose at the top In general, the segregating materials deviated significantly from the "bamboo-type" head conformation of B61. Selections with the longest head types were taken for intra-family intercrossing with the aim of recapturing in the subsequent generation the head conformation of B61 and the tropical parents.

Introduction

The program on developing heat-tolerant populations with the cylindrical head conformation that is preferred by most of AVRDC's partners was continued. In 1991, several populations developed from crosses made in 1990 were planted for further selection.

Material and Methods

Two batches of segregating populations were planted. One consists of four F_3 populations from intercrosses between promising, cylindrical-headed inbred lines from the backcross program. One family originated from brush mass pollination and comprised of 200 plants. The other came from hand self-pollination and comprised of 88 plants each or less depending on available seeds. Included in the planting were 40 plants each of two heat-tolerant recurrent parents, E-9, and B152, and the donor parent for elongated head shape, B61. Forty plants of ASVEG 1 were also planted as a general check for heat tolerance.

The other batch consisted of F_2 populations of triple crosses between promising, cylindrical-headed inbred lines with heat-tolerant inbred lines. A total of five segregating families comprised this batch. A total of 200 plants were planted to each family. In addition, 40 plants each of the five heat-tolerant parent inbreds, B61, the original parent stock for elongated head shape, B152 and E-9, the original heat-tolerant parents, were planted as checks. Forty plants of ASVEG I were also planted as a general check for heat tolerance.

Seeds were sown on 15 August and seedlings were transplanted to the field on 4 September 1991. Selection of progenies emphasized the combination of compact head formation with elongated head shape.

Results and Discussion

The general characteristics of the selections from segregating families possessing the desired combination of cylindrical head shape and dense head formation (indicative of heat tolerance) are presented in Table 7. The first four families belong to the F_3 group. The rest were selections from the F_2 populations from triple crosses. Most selections tended to be medium-early to medium-late maturing with compact, medium-long to long heads. Some selections from F_3 group were medium-maturing with very long heads typical of the "bamboo-type" heads of B61. These selections produced heads that were very tight at the bottom and middle parts but partly loose at the top.

In general, the segregating materials deviated appreciably from the "bamboo-type" head conformation of B61. Segregants with the longest head types were taken for intra-family intercrossing with the aim of recapturing in the subsequent generation the head conformation of B61 and the heat tolerance of the tropical parents.

Table 7. Summary of selection for heat-tolerant plants with elongated head shape from various segregating families; 1991 late summer season.

Family	No. of selections	General maturity[a]	Head size[b]	Plant vigor[c]	Disease[c]	General uniformity[c]
91271	14	E-L	M-L	6-8	1-2	4
91272	5	E L	M-L	6-7	1-2	5
91273	8	E-ML	M-LL	7-8	1-2	6
91274	5	E-L	M-LL	7-8	1	6
91282	4	ME-ML	M-L	6-7	2	4
91284	21	ME-ML	M-ML	7-8	1-2	6
91286	12	ME-L	M-LL	8-9	2	5
91288	8	ME-L	M-LL	8-9	2	5
91290	8	E-ML	M-ML	7-8	2	4
B61 (ck)		L-VL	L-LL	5-8	2	5
ASVEG 1 (ck)		VE	M	8	4	9

[a]E = early; ME = medium early; M = medium, ML = medium late, L = late; VE = very early; VL = very late.
[b]M = medium; ML = medium large; L = large; LL = long & large
[c]Rating scale 1 = low, 10 = high

International Cooperation

Seed distribution

In 1991, 427 seed packets of Chinese cabbage were distributed to 57 cooperators in 36 countries. Most consisted of open-pollinated and F_1 hybrid cultivars, together with local checks and AVRDC's standard heat-sensitive check, B40, for testing. A limited shipment to national programs of elite inbreds or parental lines of F_1 hybrids for in-country seed production experiments was also provided. These were as follows:

Brazil. Mr. Nei Peixoto of Estaca Experimental de Anapolis/EMGOPA, was interested in AVRDC international trials of Chinese cabbage to evaluate both head and seed production in Anapolis. Seeds and information about the duration and temperature requirements of heat-tolerant Chinese cabbage were provided for vernalization and seed production purposes.

China. Dr. Charles Y. Yang, Director of AVRDC's Regional Program in Thailand requested 50 g each of the parental stocks of Hybrid #62 for seed multiplication in China. Some 4.5 kg of this hybrid were provided for further demonstration trials there. Two-hundred kilograms of Hybrid #62 seeds was imported from Taiwan through seed dealers for urgent distribution at the Yangtze River region following serious flooding in summer 1990. In November 1991, Nanjing requested 100 g of inbred N4-1 for use in 1991 hybrid seed production. According to the report, Hybrids 62 and 58 were grown in 4000 ha in South China and along Yangtze River. It was estimated that this area will increase to about 7000 ha in 10 provinces in 1992, and to cope with the expected demand for the hybrid seeds, 10 t of seeds (7.5 t for Hybrid 62 and 2.5 t for Hybrid 58) will be produced in spring 1992.

Indonesia. Dr. Anggoro Hadi of the Horticultural Research Institute, Lembang, received six parental lines of tropical lowland Chinese cabbage, such as Hybrids #58, #62, #82-46, in the previous years. He requested more inbred lines with good self-incompatibility. Six elite heat-tolerant inbreds were sent for further research.

India. Prof. M.M. Khan of the University of Agricultural Science at Bangalore grew AVRDC Hybrid 82-156 during the Kharif season (July) and obtained a yield of 15 t/ha. The crop stand was rated very good and its performance was considered excellent and comparable to the average performance of lettuce.

Philippines. Ms. Rizalina C. Guibao, researcher of the Vegetable Section of Bohol Agricultural Promotion Center conducted a dry season trial at Tubigon, Bohol, to evaluate two open-pollinated and six

hybrid entries from AVRDC vs. the standard heat-sensitive check B40. Performance of the AVRDC heat-tolerant cultivars was clearly better than that of the heat-sensitive check in all respects. Two hybrids, #85202 and #83-20, compared well with the standard heat-tolerant check, Hybrid #62. All three entries produced 37–38 t/ha of marketable heads, with mean head weights of over 1 kg per head, soft rot rating of 1% and less, harvest rate of 99% or more, and matured about 40 days after transplanting. In contrast, the heat-sensitive check B40 yielded less compact heads (13 t/ha), has a soft rot infection rate of 11%, head weight of 563 g and harvest rate of 71%.

Thailand. Dr. Chanai Yodpetch of the Institute of Technology and Vocational Education at Sirracha, Chonburi, completed the yield trial of summer Chinese cabbage using two open-pollinated and five hybrid cultivars from AVRDC. In general, these AVRDC-improved varieties produced compact, medium to small marketable heads with very high harvest rate. Hybrid #85202 produced the highest yield of 11 t/ha. Hybrid 62, a released cultivar in Thailand, yielded 10.4 t/ha.

Uganda. Messrs J.D. Mugerwa and W.T.H. Peregrine of the Food and Agriculture Organization of the United Nations, carried out an on-farm trial, with a progressive farmer near Namulonge. The farm was basically of mixed vegetables, with clay loam soil and was situated in swamp land. The farmer was instructed to grow on broad beds, which obviated flooding during heavy rains. The trial was planted using an improved cultural regime including planting on broad beds, given poultry manure mixed with coffee husks and mulched. Two open-pollinated and six hybrid cultivars from AVRDC vs. the standard heat-sensitive check B40 and a local check were included in this trial without replicates owing to land shortage. Varietal differences were clear-cut and showed particularly between the local check and improved materials. Yield of Hybrid 82156, the highest yielder, was up to 3.4 times that of the local cultivar (52 vs. 15 t/ha for the local check). Based on the calculation of the above researchers, the farmer expects to gross US$18,428/ha as opposed to US$5428 for the local cultivar. The researchers further reported that the farmer has adopted the improved cultural techniques and is now teaching his neighbors the technology.

Chinese Cabbage Entomology

Demonstration of IPM of Diamondback Moth on Farmers' Fields in the Lowlands

Summary

An integrated pest management (IPM) technique that utilizes the use of two larval parasites, sprays of microbial insecticide *Bacillus thuringiensis* Berliner and use of sex pheromone was tested to control diamondback moth, *Plutella xylostella* (L.), a destructive pest of crucifers on farmers' fields in the lowlands of Taiwan. A practically identical experiment was conducted twice during the traditional crucifer-growing season from October 1990 to April 1991. In both experiments, the diamondback moth population on cauliflower and broccoli was significantly less in the IPM fields than in neighboring check fields where farmers continued to use insecticides. Despite inundative releases, parasitism of diamondback moth by a larval parasite *Cotesia plutellae* Kurdjumov in the IPM field did not differ from that in the check fields. Parasitism by *Diadegma semiclausum* Hellén was insignificant despite repeated releases of this larval parasite. A major factor in DBM mortality was *B. thuringiensis* and other natural causes. *B. thuringiensis* infected the DBM larvae upon which *C. plutellae* parasitized. The DBM larvae were killed along with *C. plutellae* larvae feeding within them. Because of this, no *C. plutellae* pupae emerged and became adults. This infection of *C. plutellae* larvae by *B. thuringiensis* appeared to have reduced the parasitism of DBM by *C. plutellae* in the IFM field. The sex pheromone baited traps trapped a large number of diamondback moth adults. It was not possible to measure the contribution of sex pheromone in reducing diamondback moth damage.

Introduction

Diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is the most destructive pest of crucifers practically throughout the world. It is especially serious in Southeast Asia because crucifers are grown there throughout the year. The larva of this insect feeds on the foliage and other edible plant parts, adversely affecting quality and quantity of the produce. Farmers in Southeast Asia use large quantities of chemical insecticides, often indiscriminately, to combat this pest. As a consequence of excessive insecticide use, this pest has become resistant to practically all insecticides being used for its control. Since no practical alternate control measures are yet available, farmers continue to use even higher dosages of chemicals, often mixtures of several of them, and applying them ever more frequently. This has increased the cost of production, exacerbated the resistance problem and increased environmental pollution.

To combat the situation AVRDC has developed an integrated pest management (IPM) program based on the use of an egg parasite *Trichogrammatoidea bactrae* Nagaraja, two larval parasites *Cotesia plutellae* Kurdjumov and *Diadegma semiclausum* Hellén, and on the use of the biological insecticide *Bacillus thuringiensis* Berliner. This package was tested in the highlands and the lowlands in 1989–90. The results were satisfactory in the highlands but further improvement in the package was necessary to make it more effective in the lowlands. In 1990–91, therefore, the Center confined its research on the IPM package to the lowlands.

Materials and Methods

This experiment was done on farmers' fields in Luchu township (elevation 10 m) in Kaohsiung county. DBM is endemic in the area and causes considerable damage to cauliflower and broccoli which are grown

traditionally during cool and dry autumn and winter months. The experiment was done twice; once in the beginning—September to December—and once towards the end—November to February—of the traditional crucifer-growing season.

First experiment. A 0.5-ha field owned and cultivated by one farmer and which was located in the midst of other fields planted either to cauliflower or broccoli was contracted for the experiment. Half of the field was planted to cauliflower and the other half to broccoli. The owner was allowed to choose cauliflower and broccoli cultivars and all cultural practices typical to the region but was not allowed to use any insecticides. *Bacillus thuringiensis* was provided for use whenever the farmer, based on his past experience, felt it necessary to spray. All such sprayings were supervised. A total of 31 sticky paper traps, baited with 10 µg DBM sex pheromone, were set up uniformly throughout the field. The pheromone bait in each trap was replaced once a month and the sticky surface of the trap renewed whenever it was completely covered with DBM adults or dust particles.

Two parasite release stations, consisting of perforated wooden boxes mounted on a 1-m high pole, were erected in the experimental area and cocoons of *C. plutellae* or *D. semiclausum* were placed inside the stations at irregular intervals. Upon emergence from the pupae the parasite adults could fly away through the holes in wooden boxes and search for the host. *Trichogrammatoidea bactrae* reared on the indicated eggs of *Corcyra cephalonica* were also released twice during the season to infest DBM eggs. A total of 240,000 pupae of this egg parasite were released.

Starting 4 weeks after transplanting, and once a week thereafter until just before the harvest, 30 plants each of cauliflower and broccoli were selected for observation and the number of DBM larvae and pupae per plant recorded. Fifty 4th instar DBM larvae from each crop were collected and raised in the laboratory until pupation. The number of larvae pupating into *C. plutellae*, *D. semiclausum* or DBM pupae was recorded. From these data, percentage of DBM larvae parasitized by each parasite species was calculated. These observations were performed in the demonstration field as well as in the neighboring fields where none of these treatments was used. Instead, farmers continued to use their own control practices. These fields were considered as check fields.

Second experiment. The second field was smaller (0.2 ha), and planted to broccoli only in November 1990. As in the first experiment, the farmer was allowed to choose a broccoli cultivar of his choice and to use cultural practices typical for the region. A total of 15 sex pheromone traps were set up in the field. Pheromone bait was replaced once a month, when the sticky surface of the trap was saturated with dead moths or soiled by dust. *Cotesia plutellae* and *D. semiclausum* were released several times at irregular intervals throughout the field. A small number of pupal parasites, *Diadromus collaris*, was also released. The parasitism of DBM larvae and pupae was recorded once a week for 6 weeks starting 3 weeks after broccoli transplanting. The sampling and evaluation methods were similar to the first experiment. The population of DBM larvae in the experimental fields and neighboring fields was also recorded using a procedure similar to that used in the first experiment.

Results and Discussion

First experiment. The results of the monitoring of DBM larval population on broccoli and cauliflower in the IPM field and check fields are summarized in Figure 1. In the initial two or three observations when plants were small and DBM population was low, there was no difference in the DBM larval population on broccoli and cauliflower in the IPM and check field. However, as the season progressed and the DBM population started increasing, large differences were observed in larval population between the check fields and the IPM field. In check fields where farmers continued to use chemicals, the DBM population increased almost exponentially as the season progressed. However, in the IPM field, the insect population remained practically unchanged at a very low level. During the season the IPM farmer made only six weekly *B. thuringiensis* applications whereas the check farmers continued to apply traditional insecticide which involved spraying chemicals, often mixtures of several chemicals, at least once a week and often twice. Since the check farmers had no obligations to the Center's project exact information on spraying frequency and the chemicals used were not obtained. The cost of *B. thuringiensis* used by the IPM farmer is definitely less than the cost of chemical insecticides and *B. thuringiensis* that most farmers often use as mixtures.

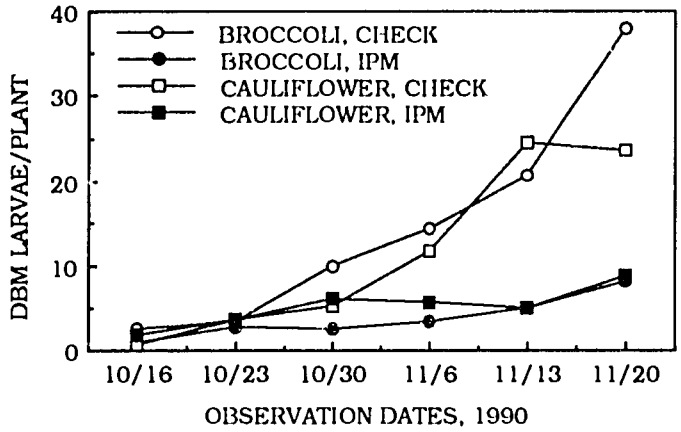

Fig. 1. Population of DBM larvae feeding on cauliflower or broccoli in IPM and check fields. Transplanting date: 26 September 1990.

The data on DBM mortality due to parasitism by *C. plutellae* and *D. semiclausum* and other natural factors, including *B. thuringiensis*-induced mortality have been recorded. *Diadegma semiclausum* parasitism was insignificant in the IPM field in both crops. This parasite was not found in the check fields which were located in the vicinity of the IPM fields. *C. plutellae* contributed significantly to DBM mortality in the IPM field as well as in the check fields. Despite almost equal contributions of parasites in both IPM and check fields, the DBM population was much higher in the check fields than in the IPM field. The major factor contributing to suppression of DBM in the IPM field appeared to be *B. thuringiensis*. Most of the natural mortality came from *B. thuringiensis* as the larvae collected from the field for rearing in the laboratory showed symptoms of *B. thuringiensis* infection. The farmers in the check fields also used *B. thuringiensis*; however, they always mixed it with a variety of insecticide 'cocktail' mixtures. It is quite possible that *B. thuringiensis* was inactivated in the spray solution tank before it was sprayed on cabbage. Whether or not tank mixture of *B. thuringiensis* with chemical insecticides destroys the activity of *B. thuringiensis* needs further investigation. Since none of the presently used chemical insecticides are effective on DBM, this insect remained uncontrolled in the check fields. High parasitism of *C. plutellae* in the check fields indicated that this parasite has developed resistance to insecticides. The lower than expected level of parasitism of DBM by *C. plutellae* in the IPM field is probably due to the use of *B. thuringiensis*, which is not toxic to *C. plutellae* adults but probably killed most of the DBM larvae and along with them, the larvae of *C. plutellae* feeding inside the DBM larvae. *B. thuringiensis*-infected DBM larvae died before *C. plutellae* larvae feeding inside DBM larvae could become pupae.

Parasitism of *D. semiclausum* was probably negatively affected by high temperatures that prevailed during the experimental period. The maximum temperatures remained 30°C practically throughout the period when observations were taken. This temperature is not suitable for parasitism of DBM by *D. semiclausum*. This parasite, therefore, is unsuitable for Luchu or other areas where the temperature approaches 30°C.

None of the DBM eggs were parasitized by *T. bactrae*. A total of 5787 DBM adults were trapped in the sex pheromone traps throughout the season.

Second experiment. Results of the monitoring of DBM on broccoli in the second experiment are presented in Figure 2. The DBM population was always lower in the IPM field than in the check fields. Although towards the end of the season the DBM population in the IPM plot increased, most of the insects were on the leaves and the curd was already ready for harvest. Early in the season when plants are in vegetative stage, DBM population in IPM plot was much lower than in the check plot.

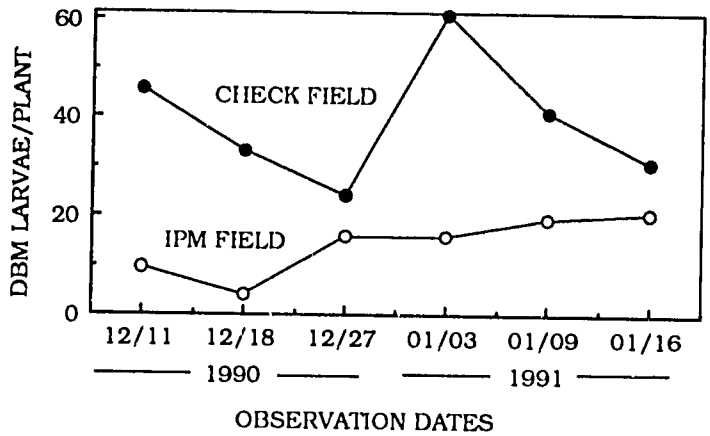

Fig. 2. Population of DBM larvae on broccoli in IPM field and check field. Planting date: 19 November 1990.

Contributions of various biological factors to the mortality of DBM in both IPM and check fields in the second experiment are summarized in Figure 3. In all observations DBM mortality in the IPM field was higher than in the check field. *Diadegma semiclausum*, which was released in the IPM field, was found parasitizing DBM but the level of parasitism was too low and its contribution to DBM mortality was virtually insignificant. During the first four observations, *C. plutellae* parasitism of DBM was consistently higher in the IPM field than in the check fields. However, there was little difference in the results of the final two observations. Natural mortality, which was mostly caused by *B. thuringiensis*, was always higher in the IPM field than in the check fields. Infection due to *B. thuringiensis* probably also killed the *C. plutellae* inside the host larvae which reduced the role of this parasite in the total mortality of DBM.

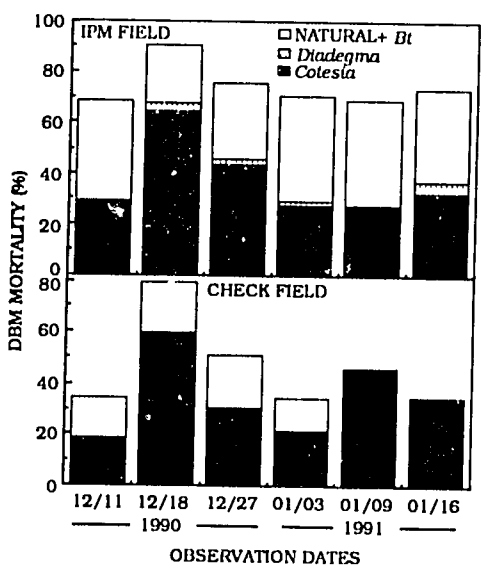

Fig. 3. Contribution of various biological factors to the mortality of DBM in IPM and check fields. Broccoli, planting date: 19 November 1990.

A total of 10,835 DBM adults were trapped in 15 sex pheromone traps set up in the field throughout the season.

Conclusions

Diadegma semiclausum is not suitable for the lowlands of Taiwan even in winter. *Cotesia plutellae* is already established in the lowlands of Taiwan and its inundative release does not seem to increase its parasitism, especially when *B. thuringiensis* is used. *B. thuringiensis* seems to become less effective if mixed with chemical insecticide 'coctails' commonly practiced by farmers in Taiwan. An economical and practical IPM technology is now available; however, the farmers' habit of using chemical insecticides makes it difficult to fully utilize this technology.

Study of Parasitism of Diamondback Moth by Larval Parasites in Various Seasons in Taiwan

Summary

A three-season field experiment was conducted to determine the extent of parasitism of diamondback moth [*Plutella xylostella* (L.)] by two larval parasites, *Diadegma semiclausum* Hellén and *Cotesia plutellae* Kurdjumov. Cabbage planted in the open field plot and in the enclosed field plot (nylon net cage) and intentionally infested with diamondback moth were exposed to the parasites throughout the season. Parasitism was recorded once a week throughout the season. Both parasites attacked diamondback moth larvae from October to February but not from March to May. No plausible explanation could be found for the absence of parasitism during the latter period. *Cotesia plutellae* parasitism was high at the beginning of the season and declined as the crop grew older. The opposite was true with the parasitism by *D. eucerophaga*.

Introduction

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is a major pest of crucifers in tropical to subtropical Asia. This pest attacks economically important crucifers both in hot and cool seasons. AVRDC is working on a simple and inexpensive integrated pest management package to control this pest. Part of the work involves exploring the use of parasites. Laboratory and field studies have shown that the larval parasite *Cotesia plutellae* Kurdjumov can survive and attack DBM larvae at temperatures over 30°C. Parasitism by another larval parasite *Diadegma semiclausum* Hellén is higher at 20–25°C and drops sharply at temperatures approaching 30°C. *Diadegma semiclausum* is an effective parasite of DBM; however, its requirement for lower temperatures makes it unsuitable in the tropical to subtropical conditions except in the highlands. If it can be adapted to slightly higher temperatures, it could play a significant role in combating DBM in the lowlands where the destruction of crucifers by DBM is especially serious. The purpose of this experiment was to find out whether, given the high population density of the host (DBM larvae) *D. semiclausum* would adopt and parasitize DBM at temperatures approaching 30°C. *Cotesia plutellae* was also included in this comparative test.

Materials and Methods

This experiment was done both in the open field and in large screen cages constructed in the field. Open field and enclosed field experiments were located in the two farthest corners of AVRDC's 100-ha experimental farm.

For both experiments, land was rototilled and worked into 1.5-m wide beds. In the enclosed field, four adjacent 13.5 × 13.5-m plots were planted to cabbage whereas in the open field, only one 13.5 × 13.5-m plot was planted. One-month old cabbage seedlings (cv. KY Cross) were transplanted in two parallel rows on the top of 1.5-m wide beds. Soon after transplanting, all four plots in the enclosed field experiment were covered with 2-m high fine mesh nylon net on all sides and the top. Starting 2 weeks after transplanting, an equal number of DBM pupae was released in each room and in the open field. This was done at irregular

intervals whenever the DBM population seemed to go down. These releases usually ranged from 100 to 300 insects per room and in the open field.

About 10 days after the release of DBM, *D. semiclausum* was released in the first room. *C. plutellae* in second, *D. semiclausum* + *C. plutellae* in the third, and no parasite was released in the fourth room. In the open field both parasites were released. At each release date, equal numbers of insects were released in each room and in the open field. The number of both DBM and parasites released varied among the four seasons but ranged between 700 and 800 per plot.

Starting 1 week after the release of parasites, 20–30 cabbage plants were observed at random in each plot and the number of DBM larvae were recorded for each of them. At this time, 30–50 4th instar larvae were collected from each plot and reared in the laboratory on cabbage leaves until they all pupated. The number of DBM larvae that pupated in *C. plutellae*, *D. semiclausum* or DBM was recorded. From these data percentage parasitism of each parasite species was calculated.

Results and Discussion

In the first planting in late September, parasitism of DBM larvae by *C. plutellae* in both open and enclosed fields was high (60%) at the beginning of the season but declined gradually as the season progressed. It ceased completely when the crop was ready for harvest 3 months after transplanting. A similar trend was observed in the open field in the second season (planting, beginning of December). In the enclosed field, however, parasitism by *C. plutellae* was very low (3–18%), although DBM larval population in both open fields in the enclosed area was similar throughout the season. High temperatures inside cages were suspected to be the cause. However, the temperature data for the caged area was not maintained. In the third season (planting date, early March), despite repeated releases of DBM and *C. plutellae* in both enclosed area and open field, no DBM larvae was parasitized by *C. plutellae*. The DBM population was low but was comparable with that in the open field in the first season when *C. plutellae* parasitism was substantial. No plausible reason can be found for this phenomenon.

Parasitism of DBM by *D. semiclausum* was very low at the beginning of each of the first two seasons but it rose gradually as the season progressed. In the first season, parasitism was generally higher in the open field than in the enclosed one, whereas in the second season, the opposite was true. This was not related to the population of DBM which generally increased from planting to harvest, or air temperature which remained practically unchanged throughout the first two seasons. The absence of parasitism in the third season is puzzling. Although the DBM population during this season was low, it was similar to the DBM population in the open field during the first season when parasitism by both parasites was substantial. This experiment will be continued in 1992.

Effect of Insecticides on the Parasitism of Diamondback Moth by Two Larval Parasites

Summary

In a field experiment the extent at which farmers' intensive use of chemical insecticides affect the parasitism of diamondback moth, *Plutella xylostella* (L.), by two larval parasites *Diadegma semiclausum* Hellén and *Cotesia plutellae* Kurdjumov was studied. A set of four cabbage plots were treated in rotation with mevinphos (0.5 kg AI/ha), methamidophos (0.5 kg AI/ha) and permethrin (0.05 kg AI/ha) once a week. A second set was treated with the same insecticides in rotation twice per week and the third set was maintained as an untreated check. *Diadegma semiclausum* and *C. plutellae* were released frequently and the population of diamondback moth larvae and pupae and parasitism of diamondback moth by both parasites was recorded. There was no significant difference in diamondback moth population in the check field and in insecticide-treated field. Parasitism of diamondback moth by *D. semiclausum*, which was low, decreased more significantly in the insecticide-treated plots than in the check plots. Insecticide treatment did not affect parasitism of diamondback moth by *C. plutellae*. It appears that like diamondback moth, *C. plutellae* also has developed resistance to these chemical insecticides.

Introduction

Diamondback moth (DBM), *Plutella xylostella* (L.), is the most destructive pest of all crucifers in Asia and the Pacific. To combat this pest farmers use only insecticides. As a result of continuous and indiscriminate use of insecticides, DBM has now become resistant to most chemical insecticides. As a result, farmers are now using stronger mixtures of insecticides and spraying them more often than in the past. AVRDC's research on DBM control emphasizes the introduction of exotic natural enemies of DBM to control this pest on a sustainable basis. AVRDC introduced *Diadegma semiclausum* Hellén to combat this pest in Taiwan and elsewhere in Southeast Asia. Another parasite, *Cotesia plutellae* Kurdjumov which was supposedly introduced in Taiwan in the early 1960s has now been established throughout Taiwan. *Diadegma semiclausum*, introduced in 1985, has become established in the highlands but, not in the lowland despite repeated releases. Inundative releases of *D. semiclausum* gave adequate control of DBM on experimental fields at AVRDC but not in the farmers' fields. The 1989–90 results show that heavy spraying of noncruciferous crops in the immediate vicinity of crucifers does not affect parasitism of DBM by *D. semiclausum* or *C. plutellae* on crucifers. Despite the establishment of *D. semiclausum* in the highlands and *C. plutellae* in the lowlands, farmers continue to spray insecticides. The extent to which the farmers' practice of spraying crucifers with insecticides affects parasitism of DBM by *D. semiclausum* and *C. plutellae* was studied.

Materials and Methods

A parcel of land was rototilled and worked into 1.5-m wide beds. The beds were further divided into twelve 15 × 15 m plots with a distance of 3 m between adjacent plots. One-month old cabbage seedlings (cv. KY cross) were transplanted in two parallel rows set 40 cm apart on the top of each bed.

Starting 2 weeks after transplanting, in four randomly selected plots, mevi phos 25.3EC (0.5 kg AI/ha), methamidophos 50 EC (0.5 kg AI/ha) or permethrin 10 EC (50 g AI/ha) was sprayed on a rotational basis once a week. In another four selected plots the same chemicals were sprayed on a similar rotation basis twice every week. The remaining four plots were maintained as checks where no insecticide was applied.

Two weeks after transplanting, researchers released a large number of DBM adults in the field to initiate DBM infestation. One week after the DBM release four parasite release stations were established in the field in the empty areas between plots. These stations consisted of a 30 × 20 × 20 cm wooden box mounted on a 1-m high pole. The box had on one side a door that can be easily opened and closed and several 2-cm diameter holes on all sides. *D. semiclausum* and *C. plutellae* cocoons were placed in each box. The parasite adults could easily fly out through the holes in the side walls and disperse in search of DBM larvae for oviposition.

DBM larval population in each plot and parasitism of DBM larvae by both parasites were monitored at weekly or biweekly intervals starting 10 days after parasite release. Twenty cabbage plants were selected randomly and the number of DBM for use on each of them was recorded. Some 50 4th instar DBM larvae were collected from each plot and reared on cabbage foliage until pupation. The number of individuals pupating into *D. semiclausum* and *C. plutellae* on DBM pupae was recorded. The percentage parasitism by individual parasite species was computed. Both DBM larvae for plant and percentage parasitism data for three treatments were compared by test of least significant difference (LSD).

Results and Discussion

The results of monitoring DBM larval population are presented in Table 1. In only one out of six observations did insecticide application reduce the DBM larval population. In the remaining five observations there was no significant difference between check and insecticide treatments even when the chemicals were applied twice a week. The three chemicals used in this test are the most frequently used ones for DBM control in Taiwan. Their continued use by farmers is obviously a waste.

The parasitism of DBM larvae by *D. semiclausum* and *C. plutellae* in three treatments is summarized in Table 2. Except for the initial observation, all insecticide treatments reduced parasitism of DBM by *D. semiclausum*. The parasitism of DBM by D. *semiclausum* was low even in the control. In most insecticide treatments, however, there was no parasitism at all. The insecticides do not control DBM but they prevent the parasitism of DBM by *D. semiclausum*, obviously by their toxic effect on parasite adults. The low level

Table 1. Population of DBM larvae on cabbage plants in insecticide treatment and check plots.

Observation dates	DBM larvae/plant (mean ± SD) insecticide spray frequency			LSD	
	Check	1/week	2/week	0.05	0.01
20 Dec.'90	4.3 ± 1 2	3 4 ± 0.7	3 3 ± 0 7	1.6	2.4
3 Jan. '91	9.5 ± 1 2	10.3 ± 1.5	7.4 ± 1 9	3.0	4.6
10 Jan.	8.3 ± 1 6	8.0 ± 0 8	7.2 ± 0.9	1 3	2.0
17 Jan.	9.9 ± 2 7	6.3 ± 1.2	7.1 ± 1.1	1.9	2.9
24 Jan.	4 3 ± 1.1	4.3 ± 1 2	3.7 ± 0.5	1.2	1.9
31 Jan	1.9 ± 0 4	2 4 ± 0 4	2 0 ± 0.4	0 5	0.7

Planting date. 28 November 1990 Plot size. 15 × 15 m. Data are means of four replicates Design. RCBD

of parasitism in the check plot was probably due to high temperatures in most days approaching 30°C during the season. Past studies have shown that at 30°C the parasitism of DBM by *D. semiclausum* is drastically reduced.

None of the insecticides affected the parasitism of DBM by *C. plutellae*. The overall parasitism of DBM by *C. plutellae* is considerably higher than that by *D. semiclausum*. *Cotesia plutellae* has long been established in Taiwan and despite intensive insecticide use, it still survives. This implies that it has developed resistance to all chemicals used in the control of DBM. However, this parasite alone cannot control DBM and there is need for introduction of additional high temperature–tolerant parasite species to achieve adequate control of DBM.

Table 2. Effect of insecticide sprays to control DBM on the parasitization of DBM by two larval parasites.

Observation dates	DBM parasitism (%) by *D. semiclausum*					*C. plutellae*				
	Insecticide spray frequency			LSD		Insecticide spray frequency			LSD	
	None	1/week	2/week	0.05	0.01	None	1/week	2/week	0.05	0.01
20 Dec. '90	7.1 ±10.1	9.4 ±13.3	0.0 ± 0.0	50.4	116 3	55.0 ± 3 0	56.8 ± 14.0	58 3 ± 11 8	25.1	57.9
3 Jan. '91	3 3 ± 0.1	1.7 ± 2.4	0.0 ± 0.0	5.8	13.3	45 9 ± 3.6	50 7 ± 1.0	66.0 ± 7.7	14.5	33.5
10 Jan.	2.0 ± 2.8	0.0 ± 0.0	0.0 ± 0.0	7.0	16.2	25 2 ± 7.4	55.4 ± 10 7	43.4 ± 17.2	60 9	140.4
17 Jan.	1.8 ± 2.5	0.0 ± 0.0	0.0 ± 0.0	6.3	14 5	19.2 ± 8 3	38.9 ± 2 6	46 3 ± 7 9	26.5	61.2
24 Jan.	9.2 ± 6.6	0.0 ± 0.0	0.0 ± 0.0	6.6	9.9	37.4 ± 14.0	19.2 ± 6.9	33 4 ± 10.1	17.8	27.0
31 Jan.	11.0 ± 4.2	3.5 ± 2.4	1.1 ± 2.3	3.0	4.5	37.5 ± 3.2	32.2 ± 6.1	33.3 ± 23 0	26 0	39 4

Planting date: 28 November 1990. Plot size: 15 m × 15 m. Data are means (±standard deviation) of four replicates Design: RCBD.

Mungbean Breeding

Evaluation of New Germplasm

Summary

Seventeen MYMV-resistant lines from India and Pakistan were evaluated in the field. Five entries were highly resistant to CLS but most had undesirable traits such as small seed size and photoperiod sensitivity. NM 92 performed very well except in CLS resistance. Two mungbean and four blackgram lines reported to be bruchid-resistant were also evaluated. The erect plant growth habit of eight early-maturing blackgram accessions from Pakistan changed to clinging (viny) or semi-erect when grown at AVRDC.

Introduction

New mungbean accessions are routinely evaluated for yield potential, resistance to diseases and insects, and other important characters. The most promising new germplasm are then utilized in the AVRDC breeding program and also distributed to interested scientists. In 1991, a number of new accessions were received and evaluated.

Materials and Methods

Six lines from India and 11 from Pakistan, which were reported to have resistance to mungbean yellow mosaic virus (MYMV), were planted in the field on 3 July 1991 to observe the following traits: days from planting to 50% flowering (DF), days to maturity (DM), plant height at flowering (PHF) and maturity (PHM), pods per plant, seeds per pod, 1000-seed weight and resistance to Cercospora leaf spot (CLS).

Four blackgrams and two bruchid-resistant mungbean mutants were received from Dr. V. Muralidharan, Tamil Nadu Agricultural University, India. Eight early maturing blackgram accessions were also received from Dr. B.A. Malik, National Agricultural Research Center, Pakistan. These materials were planted in the field on 19 September 1990, 7 March and 3 July 1991. They were observed on plant type, days to 50% flowering and maturity, number of pods per plant and number of seeds per pod.

Results and Discussion

NM 92, developed from a three-way cross (6601 × VC 1973A) × VC 2768B, had the largest seed size (53 g), shortest stature (58 cm) and earliest maturity (55 days). However, it is only moderately resistant to CLS (Table 1). Most lines had small seeds. Varieties Pusa 101, Pusa 9171, Part M 3, NCM 91 and NCM 206 were highly resistant to CLS.

All the NARC-ME entries which were reported to be short and erect in Pakistan were viny or semi-erect when grown at AVRDC (Table 2). The most promising bruchid-resistant (BR) mungbean entries will be used in the breeding program once their resistance to bruchids has been confirmed by the entomologists.

Table 1. Evaluation of MYMV-resistant accessions in summer 1991.

Germplasm[a]	PHD[b]	PHM[c]	Pod/ plant	Seed/ plant	DF[d]	DM[e]	1000[f] SDWT	CLS[g]
Pusa 101	76.2	114.0	12 0	11.4	54	67	28	1
Pusa 105	69.4	107.4	9 3	10.5	50	67	30	2
Pusa 9171	65 4	89.4	18 0	10.5	47	62	27	1
Pusa 9173	65.0	74 4	13.9	9 8	42	59	35	2
Pant M 3	61.8	88 6	16.5	11 2	49	67	26	1
L 24-2	-	112.0	-	8.7	67	-	21	3
NCM 91	66.8	80.4	17.8	9.8	46	63	31	1
NCM 205	62.0	82 6	19.2	10 2	49	64	30	2
NCM 206	64.8	76.6	21.8	11.1	46	62	33	1
NCM 209	65.0	76 2	22 3	10.5	45	62	32	3
6601	59.0	105 2	13 9	12.0	51	69	30	3
E 321	59 0	84.4	12 3	11.9	48	65	30	3
NM 121-25	56.6	73 8	15.8	10 6	45	63	31	3
NM 13-1	63.8	82 0	16.2	11.1	45	62	34	3
NM 20-21	58 8	69 8	15 6	12.1	45	63	32	3
NM 19-19	56.8	69.6	17 8	10.6	45	63	35	3
NM 92	57.8	58 4	8.9	9.7	39	55	53	3

[a]1-6 from India; 7-17 from Pakistan.
[b]PHF: Plant height at 50% flowering.
[c]PHM: Plant height at 50% maturity.
[d]DF: Days to 50% flowering.
[e]DM. Days to 50% maturity.
[f]1000-SDWT: 1000 seed weight.
[g]CLS: Cercospora leaf spot resistance score. 1 = highly resistant, 2 = resistant, 3 = moderately resistant

Table 2. Evaluation of newly introduced mungbean and blackgram accessions in fall 1990, and spring and summer 1991.

Germplasm	Plant type	90 Fall		91 Spring		91 Summer		Pod/[c] plant	Seed/[c] pod
		DF[a]	DM[b]	DF	DM	DF	DM		
BR.1	Erect	40	78	43	68	56	68	19 2	5.5
BR 2	Semi-erect	39	77	50	71	61	73	19.2	5.9
BR.3	Semi-erect	39	77	44	67	61	73	25 2	6.7
BR 4*	Erect	39	69	49	70	60	73	7.0	1[illegible].4
BR 5*	Erect	40	68	45	62	49	67	18.4	10.7
BR.6	Semi-erect	38	76	43	65	61	73	25.2	6.2
NARC-ME 9001	Viny	37	71	37	58	34	55	26.2	5.8
NARC-ME 9002	Viny	37	71	37	58	34	55	31.6	5 0
NARC-ME 9008	Viny	37	71	37	58	34	56	17.2	5.9
NARC-ME 9015	Viny	37	72	37	58	35	57	26.0	6.1
NARC-ME 9018	Semi-erect	37	77	41	60	47	65	24.4	5.7
NARC-ME 9020	Semi-erect	37	76	38	60	43	63	26.8	6.5
NARC-ME 9025	Viny	37	71	37	58	33	54	28.0	4.7
NARC-ME 9026	Viny	37	71	37	58	33	54	20.6	5.9

[a]DF: Days to 50% flowering;
[b]DM. Days to 50% maturity.
[c]Data from spring, 1991;
*Mungbean; others are blackgram

Breeding for Disease and Insect Resistance

Summary

Bruchids (*Callosobruchus chinensis*) are serious storage pests of mungbean. Two *Vigna radiata* var. *sublobata* accessions (TC 1965 and TC 1966) and two *V. radiata* accessions (V 2709 and V 2802) that were identified earlier as resistant to bruchids were used as donor parents in a backcross breeding program. Three

backcross generations have been completed, enabling the recovery of most characteristics of the recurrent parents.

Breeding line, V 2839-70, was moderately resistant to beanfly and highly resistant to powdery mildew. Since selection for beanfly resistance is difficult to do in Taiwan, a shuttle breeding program has been started in cooperation with the Chai Nat Field Crop Research Center in Thailand.

Mungbean yellow mosaic virus (MYMV) is one of the major constraints of mungbean production in the Indian subcontinent. An expert consultation meeting was held in July in Bangkok to address the important problems posed by this virus. The participants agreed to form an MYMV-working group and developed a number of recommendations.

Bruchid Resistance

Introduction

Bruchids (*Callosobruchus chinensis*) are serious insect pests of mungbean during storage. Hitherto, no resistant cultivar has been developed even though two wild mungbean (*Vigna radiata* var. *sublobata*) accessions, TC 1965 and TC 1966, and two mungbean accessions, V 2709 and V 2802, were shown to be immune or highly resistant in previous studies. In addition, many mungbean and blackgram accessions were identified as moderately resistant to bruchids.

The objectives of the present experiment were to study the genetic mechanism of bruchid resistance and to incorporate the resistant gene(s) into advanced breeding lines using the backcross breeding method.

Materials and Methods

Three backcross generations were completed using TC 1965, TC 1966, V 2709 and V 2802 as donor parents for bruchid resistance, and breeding lines V 1178A, VC 1973A, VC 2778A, VC 3890A and V 3476 as recurrent parents. Following each backcross, the seeds were screened for bruchid resistance and only resistant seeds were planted. Of these resistant progenies, only those possessing desirable traits in the field were selected for further backcross.

The four resistant lines above and two susceptible lines, VC 1973A and VC 3890A, were used as parents to develop the segregating populations for the genetic experiment.

Results and Discussion

General observation of the BC_3 breeding progenies in the field indicated that they already had similar plant types as the recurrent parents. After another backcross in fall 1991, they will undergo a selfing series to select agronomically desirable bruchid-resistant breeding lines. The best lines will undergo intensive agronomic evaluations afterwards.

Bruchid resistance in TC 1965, TC 1966, V 2709 and V 2802 was shown from preliminary evaluations to be controlled by dominant gene(s). About 20% of V 2802 seeds were susceptible to bruchid indicating that this resistant parent is not homozygous for the resistance gene(s). The mode of inheritance and allelic relationship between resistant genes will be fully determined in 1992 using the parents, F_1, F_2 and the backcross families.

Beanfly Resistance

Introduction

Beanfly (BF) damage is serious during the seedling stage of mungbean and other legumes in tropical and subtropical Asia. Past resistance breeding efforts at AVRDC led to the selection of line VC 2839-70 from the cross between V 4281, a moderately BF-resistant accession, and V 2184. This breeding line is high yielding and resistant to BF and powdery mildew (PM).

In the last decade, further progress in BF resistance breeding has been constrained by the fact that the natural BF population in Taiwan is high only in October and November when mungbean does not grow very well. In order to resolve this difficulty, a shuttle breeding program was established jointly between AVRDC and the Chai Nat Field Crops Research Center (FCRC) in Thailand. In this set-up, genetic materials are to be screened for BF resistance in Thailand where the BF population is always high.

Current status of shuttle breeding

F_2 populations from crosses between BF-resistant line (VC 2839-70) and 16 AVRDC breeding lines were sent to Chai Nat FCRC. These were planted in June in Chiang Mai where beanfly population is always high. Healthy plants with desirable traits were selected and F_3 seeds were sent back to AVRDC. After selection for PM resistance, F_4 seeds will be sent back to Thailand for further selection.

The same F_2 seeds were planted at AVRDC and selections were backcrossed to the recurrent parents (BF-susceptible breeding lines). The resulting backcross seeds were planted again at AVRDC on 3 October for selection of PM resistance. Only PM-resistant progenies will be used in further backcrosses. The second generation backcross seeds will be selected for BF resistance in Thailand.

MYMV Resistance

Mungbean yellow mosaic virus (MYMV) is one of the most important constraints of mungbean production in the Indian subcontinent. In the past, very little work was done at AVRDC because MYMV is not endemic in Taiwan. In the early 1980s, crosses between MYMV-resistant lines and AVRDC breeding lines were made and F_2 seeds were sent to the mungbean breeders in India and Pakistan. Two cultivars, NM 51 and NM 54, selected from the above populations by Dr. Ilyas A. Malik of the Nuclear Institute of Agriculture and Biology in Faisalabad, Pakistan, were officially released to mungbean growers in Pakistan.

At AVRDC's 1990 planning and review workshop, MYMV research and development was considered as high priority. An MYMV expert consultation meeting was held in July, 1991 in Bangkok where participants agreed to form an MYMV working group and publish a biannual newsletter for information exchange. Sixty-eight MYMV-resistant lines that were collected earlier from India and Pakistan were presented in a demonstration planting to the participants. The participants formulated the following recommendations:

- Establish a multilocational international MYMV field nursery to screen materials with reported resistance.
- Collect MYMV isolates from different geographic locations within each country to challenge the MYMV-resistant materials under controlled conditions.
- Develop sensitive diagnostic probes to identify MYMV.
- Standardize the screening protocol and rating method for MYMV reaction.
- Study the genetics of MYMV resistance and combine the best resistance genes with improved agronomic traits.
- Determine the relationship of MYMV from the Indian subcontinent with the geminivirus causing yellow mosaic elsewhere, and with geminiviruses affecting other legume crops.
- Investigate the geographic distribution of legume geminiviruses in South and Southeast Asia using sensitive and specific diagnostic probes.
- Investigate the possible role of vector biotypes and virus strains in the recent upsurge of MYMV epidemics.
- Evaluate strategies for virus-derived resistance, e.g., coat protein gene, ribozymes, anti-sense RNA and interference schemes aimed at virus replication.

The entries of the first international MYMV nursery will consist of five lines originating from Pakistan and nine from India. One susceptible and six resistant lines were used for the inheritance study. Numerous crosses were made between the best AVRDC breeding lines and the MYMV-resistant lines. Their F_2 seeds will be distributed to the national programs in the Indian subcontinent to select for MYMV resistance and improved agronomic characters.

Development and Application of a Saturated Genetic Map

Gene tagging with closely linked RFLP (restriction fragment length polymorphism) and isozyme markers will improve efficiency of selection for traits that are difficult to select through conventional breeding methods. Dr. Nevin Young of the University of Minnesota is constructing a saturated genetic map

of mungbean using RFLP markers in collaboration with AVRDC through a grant provided by the Rockfeller Foundation. An RFLP mapping population was made by crossing mungbean (VC 3890A) with its wild progenitor, *Vigna radiata* ssp. *sublobata* (TC 1966). Three-hundred genomic clones from soybean, cowpea and mungbean were analyzed and 153 were probed against F_2 blots of the mapping population for segregation analysis. Based on these probes, an initial RFLP linkage map was constructed (Fig. 1) More probes will be analyzed in the future to situate more markers in the map.

F_2 and F_3 seeds from each F_2 individual of the mapping population were planted and evaluated at AVRDC. RFLP markers linked to genes for powdery mildew resistance, bruchid resistance, seed size, pod length and days to maturity were identified. The RFLP markers that are closely linked to various traits are as follows: bruchid resistance (pA882); powdery mildew resistance (pA450, pA7, pA64, pK385, pM247, pP157, pA112, pA77 and pA841); and seed size (pM185, pM228, pA124, pM182, pA487, pA509, pA286, pK472a, pM307). One-hundred twenty recombinant inbred lines from the F_2 population that were used for mapping is also being developed. This population will provide a permanent mapping resource that can be distributed worldwide to map markers in a single genetic population. These lines are currently in the F_4 generation. F_7 lines will be ready for RFLP analysis in 1992.

Another population was developed to focus on other important traits viz. Cercospora leaf spot resistance and mungbean yellow mosaic virus resistance. Other techniques such as non-radioactive probing for RFLP and RAPD mapping are now being developed at the University of Minnesota.

Complementary to the RFLP mapping, Dr. Desiree M. Hautea of the University of the Philippines at Los Baños is constructing a morphological and isozyme marker map in collaboration with AVRDC. Eighteen polymorphic morphological markers and 14 polymorphic isozyme markers were identified from the cross between mungbean and black gram. Five polymorphic isozyme markers were also found between VC 3890A and TC 1966. More markers are now being identified. Eventually, they will be mapped with RFLP markers to construct a dense genetic map.

Yield Trials

Summary

A series of yield trials were conducted. Fifteen entries for advanced yield trials (AYT), 13 for elite yield trials (EYT) and 20 for international mungbean nursery (IMN) were evaluated in spring and summer. All entries were moderately resistant to Cercospora leaf spot but highly susceptible to powdery mildew.

In the AYT, seven entries outyielded the check VC 3890A but not significantly. VC 4386-B-1-2B, a CLS-resistant line, had the largest seed. VC 4453-3B and VC 4152-B-1-3B were the most uniformly maturing lines, producing high first harvest grain yields relative to total yields. In the EYT, six entries yielded significantly higher than the check in spring or summer. VC 4503A had the largest seed size. In the 18th IMN, seven entries yielded significantly higher than the check in spring. VC 4059A yielded high in all seasons and had the largest seed size.

Introduction

The most important objective of the mungbean breeding program at AVRDC is to develop widely adaptable, high and stable-yielding lines with uniform maturity, resistance to lodging, disease and insect resistance and good seed quality. Promising breeding lines were evaluated in various yield trial stages in 1991 spring and summer.

Materials and Methods

In 1991 spring and summer, the 18th international mungbean nursery (IMN) yield trials, elite yield trials (EYT) and advanced yield trials (AYT) were conducted. Details about these trials are given in Table 3. AVRDC's suggested cultural practices were followed in conducting these trials. The name and parentage of entries in the aforementioned trials are given in Table 4.

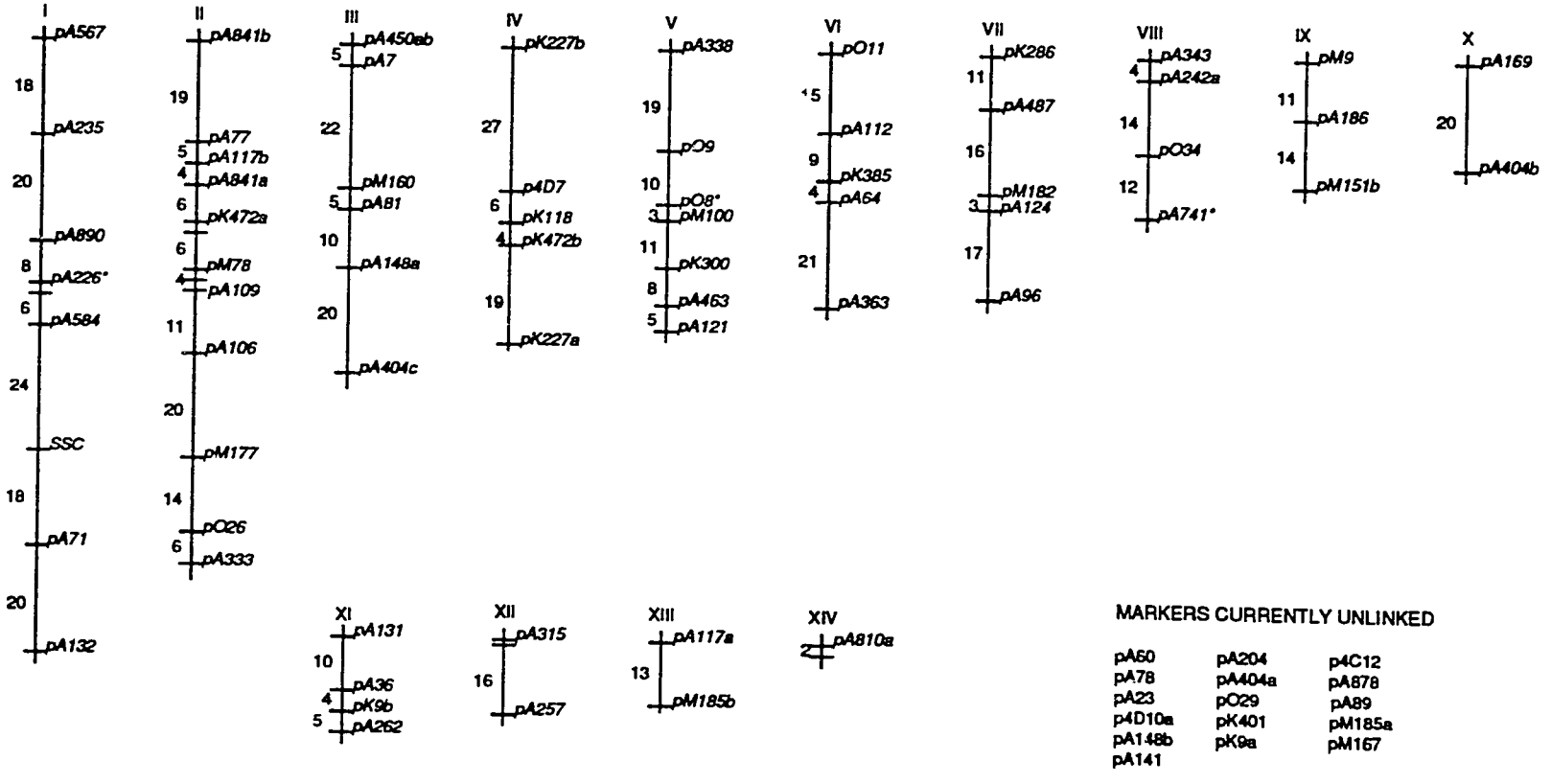

Fig. 1. Mungbean RFLP linkage map—2/91

Table 3. Planting dates and experimental design used for yield trials in spring and summer, 1991.

Type of trial	No. of entries	Planting date	Plot size (m^2)	Expt. design	No. of reps.
Spring 1991					
AYT	15 (2)	13 Mar.	5 m × 2 m	RCBD[a]	4
EYT	13 (2)	14 Mar.	5 m × 2 m	RCBD	4
IMN	20	14 Mar.	5 m × 2 m	RCBD	4
Summer 1991					
AYT	15 (2)	02 July	5 m × 2 m	RCBD	4
EYT	13 (2)	02 July	5 m × 2 m	RCBD	4
IMN	20	01 July	5 m × 2 m	RCBD	4

[a]RCBD = Randomized Complete Block Design

Table 4. Name and parentage of entries in various yield trials in spring and summer, 1991.

Entry name	Parents	Entry name	Parents
Advanced Yield Trial			
VC 4533-1-2B	VC 4446 × VC 4466	VC 3920A	VC 2778A × VC 2764B
VC 4540-1-2B	VC 4520 × VC 4469	VC 4184A	VC 2802A × VC 1178A
VC 4541-1-2B	VC 4531 × VC 4471	VC 4355A	VC 3510-B-2-1-2B × VC 2771A
VC 4386-B-1-2B	VC 2778C × VC 3543	VC 3828A	VC 2778A × VC 3754
VC 4314-B-9-2B	VC 2985A × VC 3303	VC 3890A	VC 2750A × VC 2768A
VC 4426-B-2-2B	VC 3663 × VC 3724	International Mungbean Nursery	
VC 4437-B-4-2B	VC 3724 × VC 3513	V 2773	ML-3
VC 4453-3B	VC 1131B × VC 2768A	VC 1089A	ML-3 × Ph. Coll. 1
VC 4482-3B	VC 1163D × VC 3178A	VC 1137A	VC 1025A × VC 1000A
VC 4510-3B	V 1388 × VC 2802A	VC 1160B	CES 55 × ML-3
VC 4227-4B	VC 1628A × VC 1000D	VC 1163D	EG-MG-16 × ML-6
VC 4234-3-B-1-3B	VC 2768A × VC 1000D	VC 1168B	CES 59 × ML-5
VC 4250-4-1-3B	VC 3061A × VC 2778A	VC 1560D	BPI. glab. 3 × VC 1301
VC 4152-B-1-3B	VC 1973A × VC 3061A	VC 1973A	CES1D-21 × EG-MG-16
VC 4146-2-1-1-3B	VC 1560D × VC 3031A	VC 2763A	VC 1481A × VC 1560A
VC 3890A	VC 2750A × VC 2768A	VC 2768A	VC 1482A × VC 1628A
Local variety	Shin Gang	VC 3300A	VC 1168B × VC 1973B
Elite Yield Trial		VC 3746A	VC 1482C × V 3726
VC 4133A	VC 1000A × VC 2778A	VC 3890A	VC 2750A × VC 2768A
VC 4192A	VC 3031A × VC 2720A	VC 3902A	VC 2768A × VC 2755A
VC 4304A	VC 3012B × VC 3061A	VC 3945A	VC 1000C × VC 1647B
VC 4433A	VC 3710-1-3-B-1-B × VC 3303-B-1-2-1-2B	VC 4059A	VC 1973A × VC 2768A
VC 4442A	VC 2750A × VC 3012A	VC 4066A	VC 2527A × VC 3974
VC 4443A	VC 2750A × VC 3301A	VC 4143A	VC 1482E × VC 3061A
VC 4503A	V 1388 × VC 2768A	VC 4152A	VC 1973A × VC 3061A
VC 4541A	VC 4531 × VC 4471	VC 4176A	VC 2768A × VC 1000C
VC 3901A	VC 2764A × VC 3836		

Entries in the different trials were observed on total yield (adjusted to 12% moisture), percent first harvest [(first harvest yield/total yield) × 100], days to 50% flowering and maturity, plant height, 1000-seed weight, number of seeds per pod, number of pods per plant, total number of plants, percent protein, and resistance to PM in spring and to CLS in summer.

Results and Discussion

Advanced Yield Trial (AYT)

No breeding line significantly outyielded the check VC 3890A in either spring or summer (Table 5). VC 4386-B-1-2B had the highest 1000-seed weight and was more resistant to CLS than VC 3890A. In

Table 5. High yielding entries from the advanced yield trials in spring and summer, 1991.

Entry	Yield (t/ha)			% First	1000-seed	Disease score[b]	
	spring	summer	mean	yield	wt[a] (g)	PM	CLS
VC 4533-1-2B	1.9	1 9	1 9	62	55	4.8	1.8
VC 4394-B-9-2B	1 8	1.8	1.8	73	59	4.8	1.5
VC 4386-B-1-2B	1.8	1.8	1.8	67	66	5.0	1.3
VC 4482-3B	1 7	2.1	1.9	74	53	5.0	1 3
VC 4152-B-1-3B	1 8	2.2	2.0	83	62	4.8	2.0
VC 4453-3B	1.8	2.3	2.0	82	58	4.5	2.3
VC 4227-4B	1.7	2 2	2 0	71	58	5.0	1.8
VC 3890A (ck)	1.7	2.2	2 0	77	60	4.8	2.0
Means of 17 entries	1.6	2.0	1.8	73	58	4 7	1.9
CV	11 4	6.1	8 7	8 6	3.9	8.10	22.42
LSD (0 05)	0 3	0.2	0 2	0 1	2 3	0.6	0.6

[a]Mean of spring and summer,
[b]PM: powdery mildew; CLS Cercospora leaf spot; 1 = highly resistant, 2 = resistant, 3 = moderately resistant, 4 = susceptible, 5 = highly susceptible

general, the AYT entries had low PM resistance. Even VC 4152-B-1-3B, which was moderately resistant to PM in the 1990 intermediate yield trial, was rated as highly susceptible in 1991. All entries showed good CLS resistance. VC 4453-3B and VC 4152-B-1-3B had significantly higher first harvest yields than the check, indicating that they are more uniform-maturing.

Elite Yield Trial (EYT)

Six entries yielded significantly higher than the check VC 3890A in spring and two of them also in summer (Table 6). They will be considered for inclusion in the 19th IMN next year. PM infection was very heavy in spring that even the moderately resistant check, VC 3890A, was rated as highly susceptible. VC 2839-70, a new source of high PM resistance, has been identified and will be further utilized in the breeding program.

Table 6. High yielding entries from the elite yield trials, 1991.

Entry	Yield (t/ha)			1000-seed	Disease score[b]	
	spring	summer	mean	wt[a] (g)	PM	CLS
VC 4442A	1.6	2.1	1.8	53	4.8	2.3
VC 4443A	1.6	2.0	1.8	52	4.3	1.8
VC 4503A	1.5	1.8	1.7	63	5.0	2.0
VC 4355A	1.5	2.1	1.8	50	4.3	2.0
VC 4541A	1.4	2.3	1.9	53	5.0	2.0
VC 3901A	1.3	2.3	1.8	60	4.8	1.8
VC 3890A (ck)	1.2	2.0	1.6	57	4.5	1.5
Means of 15 entries	1.3	2.0	1.6	56	4.7	2.1
C.V.	8.9	9.1	9.3	3.4	7.2	15.9
LSD (0.05)	0.2	0.3	0.2	1.9	0.5	0.5

[a]Mean of spring and summer;
[b]PM: powdery mildew; CLS: Cercospora leaf spot; 1 = highly resistant, 2 = resistant, 3 = moderately resistant, 4 = susceptible, 5 = highly susceptible.

International Mungbean Nursery (IMN) Trial

Of 19 AVRDC breeding lines and one accession tested in the 18th IMN trials, seven significantly outyielded the check VC 3890A in 1990 and 1991 spring (Table 7). Only VC 3300A yielded significantly higher than the check in 1990 summer. VC 4059A yielded consistently very high in all seasons and its 1000-seed weight was the highest among the entries.

Table 7. High yielding entries in the 18th IMN, 1991.

Entry	Yield (t/ha)				1000-seed wt[a] (g)	Disease score[b]	
	1990		1991			PM	CLS
	SP	SU	SP	SU			
VC 4059A	1.1	1.0	1.8	2.2	61	3.8	2.1
VC 4176A	1.2	0.8	1.5	2.2	52	3.5	2.4
VC 1168B	1.0	1.3	1.5	2.2	53	3.8	2.3
VC 3300A	1.0	1.4	1.4	2.2	58	4.1	2.1
VC 4066A	1.1	1.2	1.4	2.1	55	3.4	1.9
VC 4143A	1.0	1.5	1.3	2.2	52	3.6	2.0
VC 4152A	0.9	1.3	1.3	2.1	60	3.5	2.0
VC 3890A (ck)	0.7	1.1	1.3	2.2	55	3.4	2.0
Means of 20 entries	0 8	1.0	1.3	2.0	52	3.6	2.1
C.V.	13.1	26.1	12.0	9.5	3.4	19.7	15.6
LSD (0.05)	0 2	0.4	0.2	0.3	1.2	0 7	0.3

[a] Mean of four seasons;
[b] PM: Powdery mildew (means of spring 1990 and 1991); CLS: Cercospora leaf spot (means of summer 1990 and 1991); 1 = highly resistant, 2 = resistant, 3 = moderately resistant, 4 = susceptible, 5 = highly susceptible.

International Cooperation

Summary

A total of 894 seed packets were distributed to 35 cooperators in 20 countries. VC 2754A was officially released as 'Merpati' in Indonesia. As of November 1991, 52 cultivars have been officially released by the national programs of 19 countries using AVRDC's improved mungbean lines. Two MYMV-resistant cultivars were released in Pakistan using VC 1973A as a parent.

Seed Distribution

Distribution of germplasm and breeding lines to the national programs is one of the major goals of the mungbean program. A total of 14 IMN sets, 359 breeding lines, 178 accessions and 72 accessions of other species were distributed to 35 cooperators in 20 countries (Table 8).

Table 8. Distribution of mungbean breeding lines and accession to cooperators around the world.

Countries	IMN (set of 20 entries)	Breeding lines	Accessions	Other species
Bhutan	1		1	
Cook Islands	1			
France	1			
Germany		4	3	33
Haiti	1			
Hong Kong		1	1	
India	1	9	64	7
Indonesia	1			
Korea		25	37	5
Mauritius		10		
Nigeria		10		
Pakistan	1	16	2	
Philippines	2	25	22	5
Taiwan, ROC		18	1	1
Seychelles	1			
Sierra leone		5		
Sudan	1			
Thailand	2	222	25	18
U.S.A.	1	10	9	3
Vietnam		4	13	
Total: 20	14	359	178	72

Cultivar Releases

As of November 1991, 52 cultivars have been officially released by the NARS in 19 countries using AVRDC improved mungbean lines (Table 9). VC 2754A was officially released as 'Merpati' in Indonesia. VC 1628A was released as 'Chai Nat 36' in Thailand. VC 3016A and VC 3528A were released as 'V87-41' and 'DX-135' in Vietnam, respectively. Two MYMV-resistant cultivars (NM 54 and 51) derived from

Table 9. Mungbean varieties officially released by cooperating countries (November, 1991)

AVRDC ID	Name of cultivar	Release year	Country	Remarks[a]
V 1388	King	1982	Australia	HY, EM, PM, LD
VC 1560D	*	1982	Australia	PM, CLS, SS, (LD, GR, SQ)
V 2013	Satin	1987	Australia	HY, CL, DR
VC 1973A	Xu Yin No 1 (Zhong Lu No. 1)	1985	China	EM, HY, WA, GR, NS, (PM, CLS, LD)
VC2768A	Su-Luh No 1	1988	China	
VC2778A	Er Lu No 2	1989	China	
VC 1089A	ASVEG 78	1978	Costa Rica	HY
VC1163A	Boliche 451	1985	Ecuador	
VC 1163D	INIAP 451	1985	Ecuador	HY, EM, UM, LD
VC 1000D	Station 46	1982	Fiji	(CLS, PM), NS
VC 1007A	Station 25	1984	Fiji	HY
VC 1160B	Station 27	1984	Fiji	
V 3554	M 986	1981	India	
VC 1137A	Pusa 105	1983	India	HY, MYMV, CLS, PM
V 3484	Pusa 101	1983-1984	India	MYMV, HY, DR
V 2773	Nuri	1983	Indonesia	HY, (CLS), R
VC1089A	Manyar	1983	Indonesia	
VC 1160C	Gelatik	1986	Indonesia	HY, NS CLS, PM, UM
VC 1163A	Walet	1986	Indonesia	HY, PM, CLS
VC 2754A	Merpati	1991	Indonesia	HY, (UM, CLS, PM), SS
VC 2719A	Kbalkoh 2	1989	Kampuchea	SQ, LD, PM
VC2768A	Kbalkoh 1	1989	Kampuchea	
V 3476	Bangasa	1980	Korea, Rep of	HY, UM, LD
VC1973A	Seon Hwa Nogdu	1982	Korea, Rep of	
VC1168B	*	1988	Laos	(CLS, SQ)
VC1560D	*	1988	Laos	
VC 2750A	*	1988	Laos	HY, PM, UM, (CLS)
VC1163D	BPI Mg 2	1984	Philippines	
VC 2764B	BPI Mg 4	1986	Philippines	HY, (PM, CLS, UM)
VC 1973B	BPI Mg 7	1989	Philippines	SS
VC 2768B	BPI Mg 9			
VC2768B	(Taiwan Green)	1989	Philippines	HY, GR, (CLS, PM)
VC 4080A	SIROC (1)	1989	Solomon Is	(HY, CLS,.PM), UM, EM, SS
VC 1168B	Filsan	1987	Somalia	EM, NS, HY, GR, LD
VC 1131B	Type 77	1982	Sri Lanka	HY, MYMV
VC 1628A	Tainan Sel # 3	1981	Taiwan	EM, HY, GR, LD, SQ, (PM, CLS)
VC 3890A	Tainan Sel # 5	1989	Taiwan	EM, Um, Pm, (CLS)
V 1380	Imara	1983	Tanzania	R, HY
VC 2778A	KPS No. 2	1985	Thailand	(UM), SQ, (CLS), HY, PM
VC1973A	KPS No. 1	1985	Thailand	
VC 1178A	Chai Nat 60	1987	Thailand	EM, SS, (PM, CLS), UM
VC2768A	PSU 1	1988	Thailand	
VC1973A	Texsprout	1988	U.S.A.	
VC1560D	DX 91	1986	Vietnam	
VC 2763A	DX 113	1986	Vietnam	HY, PM, (CLS)
VC 2768A	DX 102A	1986	Vietnam	HY, LD, EM, WA, GR, (CLS, PM)
VC 3178A	V87-13	1989	Vietnam	HY, UM, (PM, CLS, LD), SQ, SS
VC 2770A	DX 103	*	Vietnam	HY, SS, LD, SQ, PM
Total: 34	52		19	

* Release name or year is unknown.

[a]CL = tolerant to cold; CLS = resistant to Cercospora leaf spot, CR; resistant to charcoal rot; DR = tolerant to drought; EM = early maturity; GR = good general rating; HY = high yields; LD = resistant to lodging; MYMV = resistant to mungbean yellow mosaic virus; PI = photoperiod insensitivity; PM = resistant to powdery mildew; R = resistant to rust; SS = large seeded; SQ = good seed quality; UM = uniform maturity; ( ) = moderately resistant/tolerant.

the cross using VC 1973A as one of the parents were officially released in Pakistan. These cultivars have the following desirable traits: larger seeds and higher yield potential than the local cultivars; early and uniform maturity; non-shattering pods; and resistance to both MYMV and CLS.

Country Reports

China. Seven AVRDC breeding lines were evaluated at the Jiangsu Academy of Agricultural Sciences in Nanjing (Cooperator, Yilu Ling). VC 3849A and VC 3737A were the earliest. VC 2917A and VC 3849A were promising for mechanical harvest. Mungbean acreage in 1991 was extended remarkably due to the flooding in July. VC 1973A, VC 2768A and VC 2917A were reported to have occupied more than half of the total mungbean area in the country.

Kampuchea. Variety trials have been done in Kbalkoh since 1986 (Cooperator: Brent Rowell). In general, the AVRDC lines were shorter, matured earlier, were more uniform maturing and more resistant to CLS and virus disease (unidentified) than the local varieties. Thus, their yields were also higher. VC 2768A and VC 2719A were the best performers. VC 3737A, VC 3746A, VC 3853A, and VC 3890A also performed well. VC 1973A had the highest yield (1 t/ha) in a trial under drought just after planting.

Lesotho. Of the six entries evaluated at the Agricultural Research Division (Cooperator: Michael H. Makhata) in Maseru, VC 3513A gave the highest average yield (2.2 t/ha).

Swaziland. Among 20 entries of the 16th IMN evaluated in the country, VC 1973A, VC 3738A and VC 3737A performed very well in Nhlangano and Lowveld Experiment Station, and VC 4066A and VC 3737A in Malkerns Research Station (Cooperator: Sebenzile Matsebuala).

Turkey. A 17th IMN trial was conducted in Tokat (Cooperator: Abdurahman Yazgan). VC 3945A and VC 4176A had the highest yields and matured early. However, their seed size was smaller than those of other entries.

U.S.A. A 17th IMN trial was conducted at the Oklahoma State University in Perkins (Cooperator: Lewis Edwards). VC 4152A had the highest yield (1.5 t/ha) and had a heavy 1000-seed weight (75 g).

Three 18th IMN trials were conducted at Texas A&M University (Cooperator: J.C. Miller). VC 1168B, VC 3300A and VC 3746A gave the highest yields.

Vietnam. Among the 12 entries evaluated in Longxuyen, Phutan and Cantho (Cooperators: M. Phung, B. Phu and D. Minh), the highest yielding lines were VC 2768B (1.5 t/ha), VC 2778B (1.4 t/ha) and VC 3541A (1.3 t/ha), respectively.

Zimbabwe. Of 11 AVRDC breeding lines evaluated at the Horticultural Research Center (Cooperator: Chigumira Fabeon) in Marondera, VC 3528A and VC 3580A performed the best.

Mungbean Entomology

Screening of Breeding Progenies for Resistance to *Callosobruchus chinensis*

Summary

AVRDC's research on the control of the bruchid *Callosobruchus chinensis* (L.), a destructive pest of stored mungbean seeds, aims to develop bruchid-resistant mungbean cultivars. In 1991, four sets of progenies derived from straight- or back-crosses between bruchid-resistant mungbean accessions, V2709 and V2802, or a *Vigna sublobata* accession TC1966, and elite breeding lines, were screened for resistance to *C. chinensis*. The infestation of the progenies ranged from no damage to 100% seed damage. The damage-free entries were selected for further improvement in agronomic characters.

Introduction

Three species of bruchids (*Callosobruchus chinensis* (L.), *C. maculatus* (F.) and *C. analis* (F.)) are important pests of mungbean seed in storage. Of the three, *C. chinensis* is the most widespread and occurs wherever mungbean is grown or consumed. *Callosobruchus maculatus* ranks close behind in geographic distribution and damage; *C. analis* is confined mainly to South Asia. In the primary infestation that takes place in the field, adult insects lay eggs on green pods and larvae bore through the pericarp into the developing seeds. These larvae turn to adults during seed storage and begin a secondary infestation that causes far greater damage than the primary infestation. Research is thus aimed at developing mungbean cultivars resistant to these pests. AVRDC has identified two mungbean accessions (V2709 and V2802) resistant to *C. chinensis* and has confirmed resistance of a *Vigna sublobata* accession, TC1966, to *C. chinensis*. These three accessions are being utilized in the Center's breeding work on bruchid resistance. In 1991 the entire entomological research on bruchids was aimed at screening progeny from crosses made by AVRDC's mungbean breeder for resistance to *C. chinensis* and assist the breeder to select insect-resistant progenies for further improvement.

Materials and Methods

All experiments were conducted in the laboratory. In brief, seeds received from the plant breeders were weighed and the number of seeds in each entry determined. The seeds were then transferred into 50 ml Erlenmeyer flasks and 30–50 bruchid adults were released in the flasks over the seed for oviposition. After 1 week of egg-laying, the adults were discarded and seeds were maintained at 30±2°C for 4 weeks. At the end of the 4th week, the number of adults that emerged and the number of bruchid-damaged and healthy seeds were recorded. The numbers of adults/g seed and percentage-damaged seed data were used to compare the susceptibility/resistance of individual entries in each screening test. Healthy seeds were returned to the mungbean breeder for further improvement. With this general procedure the following breeding materials were tested for resistance:

- F_3 seeds from reciprocal crosses between bruchid-resistant *V. sublobata* and susceptible mungbean. A total of 10 bulked entries including five with *V. sublobata* as female parent and remaining five with *V. sublobata* as male parent were screened.
- Ten BC_3 entries from crosses made by a Japanese breeder between bruchid-resistant *V. sublobata* (TC1966) and susceptible *V. radiata*.

- A group of 55 F_3 seed samples from a cross between VC3890A and TC1966 to gain insight into the genetics of bruchid resistance.
- A group of 31 progenies in various generations of backcrossing using two bruchid-resistant mungbean varieties (V2709 and V2802) and one bruchid-resistant *V. sublobata*, TC1966, accessions was screened.

Results and Discussion

Screening of F_3 populations from reciprocal crosses between bruchid-resistant *V. sublobata* and each of AVRDC elite bruchid-susceptible germplasm (V3476, VC1973A, VC1178A, VC3890A and VC2778A) gave the following results. All seeds of each susceptible parent were damaged. Less than 2% of the seeds of TC1966 were damaged. The damage to F_3 progeny (average of 35 entries from each cross) was in-between but tended to be on the lower side (less than 10% seeds). There was no difference in bruchid damage between TC1966 used as female or male parent. Among the five susceptible parents used, bruchid damage was less in VC2778A used as male and TC1966 as female parent and in VC3890 as female and TC1966 as male parent. Individual entries within each cross with no bruchid damage were sent to the mungbean breeder for further improvement.

None of the BC_3F_4 progenies from crosses between *V. sublobata* and *V. radiata* were damaged whereas susceptible *V. radiata* check (VC1973A) were considerably damaged (3.4 adults emerged per seed) and resistant *V. radiata* checks, V2709 and V2802 were partially damaged (0.3 and 0.6 adults/seed, respectively). TC1966 was not included. The BC_3F_4 seeds were as large as AVRDC's elite but bruchid-susceptible line VC1973A, with 1000-seed weight of 70.7 and 64.5 g, respectively. Bruchids laid considerably more eggs on the seeds of BC_3F_4 (7.2 eggs/seed) than on the seeds of VC1973A (4.9 eggs/seed). Despite this, BC_3F_4 seeds remained free of bruchid damage. This indicates that the BC_3F_4 progeny is truly resistant. These lines were turned over to the mungbean breeder for improvement and selection for superior agronomic characters.

Bruchid infestation on F_3 populations from a cross between VC3890A and TC1966 resulted in seed damage ranging from 0 to 100% as against 20% damaged seeds in TC1966 and 100% damaged seeds in VC3890A. Seven entries were free of bruchid damage and given to the breeders for backcrossing and further improvement.

Among 33 backcross progenies in various generations, three entries were free of bruchid damage and one had less than 7% seed infestation as against an average of 30% for all entries. The damage-free progenies are being processed for further improvement in yield and agronomic characters.

Screening of Selected Mungbean Germplasm for Resistance to *Callosobruchus maculatus*

Summary

Laboratory studies were conducted to determine whether the *Callosobruchus chinensis* (L.)-resistant *Vigna* accessions are also resistant to *C. maculatus* (F.), the second most important (second only to *C. chinensis*) pest of mungbean seed in storage. Two *C. chinensis* mungbean accessions V2709 and V2802 and one blackgram accession VM2164 were equally resistant to *C. maculatus*. The mechanism of resistance is being studied.

Introduction

A bruchid species *Callosobruchus maculatus* (F.) is an important pest of mungbean, whose distribution and economic importance is surpassed only by *C. chinensis* (L.), which infests mungbean wherever the crop is cultivated or utilized. In isolated areas *C. maculatus* is even more serious than *C. chinensis*. Until now AVRDC's research in developing bruchid-resistant mungbean cultivars was aimed at *C. chinensis*. Sources of resistance to *C. chinensis* are available and are being routinely used in breeding resistant cultivars. In 1991 *C. chinensis*-resistant accessions were tested for resistance to *C. maculatus*.

Material and Methods

Two *C. chinensis*-resistant mungbean accessions, V2709 and V2802, one *Vigna glabrescens* accession, V1160, which had shown a low level of resistance to *C. chinensis*, and one *V. mungo* accession, VM2164, which is highly resistant to *C. chinensis*, were included in this test. They, along with two susceptible mungbean checks, V2184 and VC1973A, were screened for resistance to *C. maculatus*. Five-gram seeds of each entry were placed in four individual 50 ml Erlenmeyer flasks, each flask being one replicate. Thirty *C. maculatus* adults were then released over the seeds for 1 week to allow insects to lay eggs. After 1 week the adults were discarded and the seeds with bruchid eggs were placed at 30±2°C for 1 month. At the end of this period, the number of the first generation *C. maculatus* adults that emerged and the number of damaged seeds were recorded. The number of adults per 5 g seeds and the percentage of damaged seeds were compared using Duncan's multiple range test.

Results and Discussion

Results of the infestation of various *Vigna* accessions by *C. maculatus* are summarized in Table 1. Two mungbean accessions V2709 and V2802 were significantly less damaged than the susceptible checks VC1973A and V2184. These accessions also showed similar levels of resistance to *C. chinensis*. VM2164 which was practically immune to *C. chinensis* was also immune to *C. maculatus*. V1160 which showed low to moderate levels of resistance to *C. chinensis* was susceptible to *C. maculatus*. The resistance profile of V2709, V2802 and VM2164 was similar to that of both *C. chinensis* and *C. maculatus*. The mechanism of resistance to *C. maculatus* in these accessions is being studied. If the resistance mechanism is found to be identical, it is possible that the *C. chinensis*-resistant cultivar that was planned to be developed could be resistant to *C. maculatus*. In that case there is no need to start a new breeding program for *C. maculatus* resistance.

Table 1. Infestation of selected *Vigna* accessions by *C. maculatus*.

Accession	No. adults emerged (mean ± SE)[c]	Damaged seeds (%) (mean ± SE)[c]
VC1973A	129.3 ± 13.2a	96.1 ± 1.5a
V1160[a]	127.5 ± 14.5a	80.8 ± 3.7b
V2184	116.3 ± 12.4a	96.7 ± 4.4a
V2802	71.5 ± 5.9b	43.2 ± 3.9c
V2709	63.0 ± 7.5b	33.4 ± 2.6c
VM2164[b]	0.0c	0.0d

[a] *Vigna glabrescens*
[b] *V. mungo*. The rest are *V. radiata* accessions.
[c] Data are means of four replicates. Means in each column followed by the same letter are not significantly different at 5% probability level by Duncan's multiple range test.

Effect of Tumbling Seeds on the Infestation of Mungbean by *Callosobruchus chinensis*

Summary

Tumbling of mungbean seeds for 5 min twice a day (morning and evening) drastically reduced infestation of *Callosobruchus chinensis* (L.), a destructive pest of mungbean seed in storage throughout the world.

Introduction

Callosobruchus chinensis (L.) is an important pest of mungbean seeds in storage wherever this crop is cultivated or consumed. The insect lays eggs on seed in storage and the larva feeds inside the seed. In

a recent letter to the editor of Nature (vol. 352, 1 August 1991) Spencer et al. of Michigan State University indicated that tumbling of common bean (*Phaseolus vulgaris* L.) seeds reduces infestation by a bruchid species *Acanthoscelides obtectus* (Say). Because *A. obtectus* and *C. chinensis* are both bruchids and the nature of their damage is similar, this tumbling procedure could also be effective in reducing damage of *C. chinensis* to mungbean seed.

Materials and Methods

One kilogram of mungbean seeds of VC1973A was confined in each of eight 1-liter volume plastic containers and 5 kg of seeds were confined in each of eight 5-liter volume plastic containers. One hundred *C. chinensis* adults were introduced in each 1-liter container and 200 adults in each of the 5-liter containers. Four containers of each size, one container being one replicate, were mounted on a shaker and the remaining containers were kept on a laboratory bench next to the shaker. After 2 days, the containers on the shakers were tumbled at a moderate speed for 5 min in the morning (8 AM) and 5 min in the afternoon. One week after the introduction of the adults on the seeds, all insects were removed and the seeds were returned in original position (tumbling and stationary) for another month. The number of the first generation bruchid adults that emerged in each container was recorded.

Results and Discussion

Results of the effect of tumbling of mungbean on the emergence of the first generation of *C. chinensis* adults are summarized in Table 2. Populations of *C. chinensis* in all tumbled containers were reduced drastically; by 80% in small containers and by 70% in large containers compared with stationary containers.

Table 2. Effect of tumbling of seeds on the infestation of mungbean by *C. chinensis*.

Container /treatment[a]	Condition	No. weevils introduced	No bruchid adults[c] emerged
1 liter plastic jar	tumbling[b]	100	22 50± 9 8**
1 kg seed	stationary	100	115.25± 29 5
5 liter plastic jar	tumbling[b]	200	188 75± 14 5**
5 kg seed	stationary	200	388.25± 48.5

[a]Insects were introduced on seeds on 18 August for oviposition. Tumbling treatment began on 20 August 1991. Observations taken 1 October 1991

[b]Containers were tumbled (rolled over) at moderate speed twice for 5 min every day.

[c]Reduction in bruchid infestation in tumbling treatment significant at 0 01% level according to student's t-test.

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Mungbean Pathology

Cercospora Leaf Spot and Powdery Mildew Resistance in Mungbeans

Summary

Two of the most important foliar diseases of mungbeans are Cercospora leaf spot and powdery mildew. Over the past 2 years, new sources and reconfirmation of already existing sources of resistance have been tested. Twenty-six out of 28 entries that had previously been rated resistant to Cercospora leaf spot were classified as moderately resistant and resistant. Some of these entries and others with different disease reactions were selected to study some of the components of partial resistance. The range of leaf area infected was 10 – 90% with lesion numbers ranging from 0.2 to 5.9 per percentage of leaf area infected. There was a significant correlation (r = 0.85) between leaf area infected and lesion number. To evaluate partial resistance, quantitative measurements such as infected leaf area or lesion numbers are useful for quantifying disease resistance. In an experiment to identify new sources of resistance to Cercospora leaf spot, eight lines from Indonesia and 13 AVRDC accessions were rated resistant. Three accessions, V 2139, V 4069, and V 4814, were highly resistant to powdery mildew in a reconfirmation screening test in the field. Most accessions that were found resistant to powdery mildew came from India.

Introduction

Cercospora leaf spot (CLS) of mungbean is an important disease especially during the rainy periods in the tropics and subtropics. *Cercospora canescens* is the primary pathogen, but other *Cercospora* species also causes CLS. Under field conditions, defoliation is common and in part is related to yield loss especially when plants are infected early in the growth season. Powdery mildew (PM) occurs when rainfall is light and temperatures are moderate. PM usually is severe late in the season and often causes the entire leaf surface of susceptible lines to turn gray to whitish.

To control these diseases, research at AVRDC has concentrated on finding and developing sources of host resistance. In trials conducted during the 1970s, most of the mungbean accessions were screened for resistance to these two diseases. The objectives of this study were to screen these original sources of resistance again and to check for new sources of resistance. These studies were done in cooperation with the mungbean breeding group.

Materials and Methods

Cercospora leaf spot

Field evaluation of existing resistant sources. Twenty-eight accessions/breeding lines and four check entries, V2773 (resistant), VC3890 (moderately resistant), VC2380A (moderately susceptible), and V2010 (susceptible), were planted on 3 July 1991. The experimental design was an RCBD with three replications. *C. canescens* was inoculated on 26 and 31 July, and on 9 and 13 August 1991. Disease was recorded on 3 and 16 September using the disease scale of 1 = no infection, 2 = slight, 3 = moderate, and 4 = heavy. This scale corresponded to the expected reaction of the four check entries mentioned previously.

Evaluation of partial resistance. Nine mungbean breeding lines, VC1137A, VC3543A, VC3689A, VC2754A, VC2768A, VC3737A, VC2380A, VC3000A, and VC3738A, were planted in 15-cm diameter clay pots on 10 July 1991. There were three replications per entry with two plants per pot. A conidial suspension of *C. canescens* at 2×10^3 conidia/ml was sprayed with a hand sprayer until runoff on 3 July 1991. Plants were covered with a plastic bag for 1 day and incubated in a growth room at 28±2°C

and 100% RH. On 9 August, trifoliate leaves 1–3 were removed, and the number of lesions and the leaf area were determined. The percentage of leaf area infected was estimated, and the lesion number per leaf area infected was calculated. Data were analyzed by ANOVA with means separated by the least significant difference test.

Evaluation of new sources. Twenty-two Indonesian lines and three checks, V2272 (resistant), V1560D (moderately resistant) and V2010 (susceptible), were planted in 20-cm clay pots (2 plants/pot) with three replications on 23 August 1991. All plants were cut prior to inoculation so that only two leaves were inoculated and evaluated. A conidial suspension of *C. canescens* at 1×10^4 conidia/ml was sprayed on plants until runoff on 13 September 1991. Plants were moved to a growth room at 28±2°C and 100% RH. Disease was evaluated 14 days later as described previously.

Powdery mildew

Field screening. Three check lines, VC 2839-70 (resistant), VC 3890 (moderately resistant), and VC 1628 A (susceptible), were planted along with 135 accessions on 7 March 1991. Each plot was 1 × 0.5m with two plants per hill and 20 hills per meter. The experimental design was randomized complete block with three replications.

Plants were inoculated by spraying a conidial suspension made from infested dried mungbean leaves on 22 and 25 April. The plots were furrow-irrigated after inoculation. Disease was assessed on 22 May and 3 June based on the following scale: 1 = no visible symptoms (highly resistant); 2 = slight infection (resistant, 1-10% of foliage infected and similar to VC 2389-70); 3 = moderately resistant; 4 = moderately susceptible; and 5 = susceptible (similar to VC 1628A).

Results and Discussion

Cercospora leaf spot

Field evaluation of existing resistant sources. Lines that were rescreened for resistance were all moderately resistant to resistant except for the two test lines and the two susceptible check lines (Table 1).

Table 1. Disease reaction of mungbean lines that [illegible] inoculated with *Cercospora canescens* under field conditions[a].

Accession	Reaction[b]	Accession	[illegible]	Accession	Reaction
V 1445	MR	V 5036	[illegible]	VC 2530B	R
V 1471	R	V 2773	[illegible]	VC 2565A	R
V 2272	MR	VC 3890A	[illegible]	VC 2566A	R
V 2273	MR	VC 2380A	[illegible]	VC 2762A	MR
V 2757	R	VC 2010	[illegible]	VC 2762B	MR
V 2773	R	VC 1089A	MS	VC 2985A	MR
V 4679	MR	VC 1089B	R	VC 3012B	R
V 4706	S	VC 1601A	MR	VC 3689A	R
V 4717	S	VC 1658A	R	VC 3741A	MR
V 4718	R	VC 1750B	R	VC 3746A	MR
V 5000	MR	VC 2530A	R		

[a]Average of three replications.
[b]R = resistant (V 2773), MR = moderately resistant (VC 3890A), MS = moderately susceptible (VC 2380A), and S = susceptible (VC 2010)

Evaluation of partial resistance. The lines that were evaluated for partial resistance ranged in severity from 10 to 90% and the lesion number per leaf area infected ranged from 0.2 to 5.9 (Table 2). There was a good correlation (r = 0.85) between these two disease parameters. These and other quantitative-type measurements are useful in defining partial resistance and will be used in future studies.

Evaluation of new sources. The check lines V2272, V15600, and V2010 were resistant, moderately resistant, and susceptible, respectively. Only one test line was susceptible while all other lines were resistant or moderately resistant (Table 3).

Table 2. The percent leaf area infected and the number of lesions per leaf area infected of nine mungbean breeding lines inoculated with *Cercospora canescens* under controlled conditions.

Breeding lines	Leaf area infected (%)	Lesion number/leaf area infected
VC 3543A	12.5[a]	1.7
VC 1137A	85 0	5.9
VC 2380A	58.3	0.5
VC 2754A	37.5	0.5
VC 3000A	90.0	2.1
VC 3737A	15.0	1.4
VC 3689A	25.0	0.2
VC 2768A	23.3	1.4
VC 3738A	10.0	1.0
Average	39.6	1.6
LSD ($P \leq 0.05$)	22.5	4.1

[a]Values represent three plants in each of three replications.

Table 3. Disease reaction of mungbean lines primarily from Indonesia that were inoculated with *Cercospora canescens* under controlled conditions.[a]

Entry	Reaction[b]	Entry	Reaction
Bakti	R	Manyer	R
Mlg 935	R	Mlg 70	S
Mlg 929	MR	Mlg 1	MR
Mlg 930	R	Mlg 234	R
Mlg 901	MR	Mlg 124	MR
Mlg 944	MS	Mlg 256	R
Mlg 911	MR	Mlg 235	MR
Mlg 917	MR	Walet	MR
Mlg 897	MR	Nuri	MR
Mlg 879	MR	V2272 (CK)	R
Mlg 960	R	V1560D (CK)	MR
Gelatik	R	V2010 (CK)	S
Parkit	MR		

[a]Average of two plants in each of three replications.
[b]R = resistant (V 2272), MR = moderately resistant (VC 1560D), and S = susceptible (VC 2010).

Powdery mildew

Field screening. Accession V2139, V4069, and V4814 were highly resistant (Tables 4–5). Nearly 50% of the accessions tested were susceptible even though many of these in the 1970s had been rated moderately resistant or resistant. Most of the resistant accessions except for V 2139 and V 2406, originated

Table 4. Disease reaction of 135 mungbean accessions that were evaluated for resistance to powdery mildew under field conditions[1].

Disease reaction	No. of entries (%)
Highly resistant (HR)[2]	3 (2)
Resistant (R)	30 (22)
Moderately resistant (MR)	37 (27)
Moderately susceptible (MS)	34 (25)
Susceptible (S)	31 (23)

[1]Average of three replications
[2]V 2139, V 4069, and V 4814.

Table 5. Disease reaction of mungbean lines that were inoculated with powdery mildew under field conditions.

Accession	Reaction[a]	Accession	Reaction	Accession	Reaction
V2139	HR	V2768	R	V4406	R
V4069	HR	V3017	R	V4508	R
V4814	HR	V3033	R	V4589	R
V1104	R	V3492	R	V4601	R
V1539	R	V3061	R	V4758	R
V1741	R	V4020	R	V4793	R
V2406	R	V4060	R	V4796	R
V2507	R	V4121	R	V4800	R
V2560	R	V4186	R	V4962	R
V2643	R	V4189	R	RUM-21 M	R

[a]HR = highly resistant, R = resistant.

from India. The shift of some lines from resistant to susceptible is new information that may indicate a change in virulence genes of the pathogen. Although this cannot be verified directly since the isolates from the 1970s were not preserved, it does show that a simple type of resistance to powdery mildew may not be durable, and therefore of less value than those lines that exhibit partial resistance to the pathogen.

Pepper Breeding

Observation and Evaluation Trials of *Capsicum* Germplasm

Summary

One cool season observation trial and one hot season trial were conducted to evaluate new hot pepper accessions primarily, *C. frutescens* accessions for adaptation and quality traits. Virus incidence was severe in both experiments. A number of entries in the cool season trial were very early in fruit setting, and had a very short crop duration. These included 'TAM Veracruz Jalapeño', 'YCb 76105', 'Hanbyal (F_1)', 'Jinpum (F_1)', 'Taeyangkun (F_1)', '*C. annuum* 29', 'YJ 81032' and 'Kingkun (F_1)', which began flowering between 56 and 68 days after sowing. Pungency values ranged from 0.4 to 8.2 mg capsaicin/g DM. The most pungent entries were PBC370, PBC372, 'Var. UL-2190', 'Var. U-Kimba', 'Taeyangkun (F_1)', and 'Var. UL-3878'. A few entries had exceptional field resistance to natural infection by cucumber mosaic virus (CMV) and chili veinal mottle virus (CVMV). These included 'Pant C-1', PBC370, PBC392, PBC473 and 'Rotan'. For the hot season trial, capsaicin values were very high for most of the entries of the Bird's Eye and Tabasco types (between 5 and 11 mg capsaicin/g DM). Entries C00847, C01664 (*C. annuum*) and 'Greenleaf Tabasco-1982' yielded the highest crude fat percentage.

Introduction

Trials to observe germplasm are necessary for their preliminary evaluation for highly heritable traits. Under field conditions at AVRDC virus incidence of CMV and CVMV is often high. Most of the observation trials aimed to observe for virus field resistance and adaptability to subtropical conditions, and to conduct preliminary screening for anthracnose resistance and quality traits (chemistry/nutrition).

Cool Season Observational Trial

Materials and Methods

Fifty-seven entries were transplanted into two-row beds without replication on 19 November 1990. There were 44 plants per bed at a spacing of 50 cm between rows and 45 cm within rows. Beds were 1.5 m apart. For some entries half-plots were caged for seed multiplication. Fruit samples were gathered for anthracnose and pungency screening. Yields were not recorded.

Results and Discussion

A number of entries were early in fruit setting, and had a short crop duration. These included 'TAM Veracruz Jalapeño', 'YCb 76105', 'Hanbyal (F_1)', 'Jinpum (F_1)', 'Taeyangkun (F_1)', '*C. annuum* 29', 'YJ 81032' and 'Kingkun (F_1)', which began flowering 56–68 days after sowing. The average flowering period for all entries was 99 days after sowing. Pungency values ranged from 0.4 to 8.2 mg capsaicin/g DM. The most pungent entries were PBC370, PBC372, 'Var. UL-2190', 'Var. U-Kimba', 'Taeyangkun (F_1)', and 'Var. UL-3878'. 'Var. UL-3878' is a *C. frutescens* line. Powdery mildew and virus incidence was high late in the season. A few entries had exceptional field resistance to natural infection by CMV and CVMV. These included 'Pant C-1', PBC370, PBC392, PBC473 and 'Rotan'. A complete list of entries and characterization information is available upon request.

Hot Season Observational Trial

Materials and Methods

The main objective of this experiment was to evaluate *C. frutescens* accessions for adaptability to the hot-humid season and to evaluate for variability in quality traits such as capsaicin, crude fat and color. Thirty-six and 23 accessions were transplanted on 5 and 11 July 1991, respectively, in two randomized complete block design experiments with two replications. Single row beds were spaced 1.5 m apart and transplants were placed 60 cm apart within each row. Each experimental unit contained two beds. Remnant plants from these experiments had been grown under net-house conditions for seed multiplication. Once fruits fully ripen, the chemical analysis will be compared with the results from the field samples. Means of the mean, maximum and minimum temperature were 28, 32 and 25°C, respectively, with an accumulation of 857 mm rainfall between 5 July and 30 October. Virus incidence was severe during the season.

Results and Discussion

Some accessions with a passport listing of *C. frutescens* were identified as other species. Previous recipients of *Capsicum frutescens* germplasm from AVRDC are encouraged to check the list in Table 1 for corrections in the species identification. Despite the close phylogenetic relationship between *C. frutescens* and *C. chinense*, the classification followed here designated those accessions with a strong calyx constriction as *C. chinense*. Because of severe virus incidence, very limited information was obtained from these experiments. By late September, average virus incidence among all lines was 67%. The ELISA assays indicated that CMV and CVMV were the predominant pathogens. Entries with the most virus tolerance were Tom Thumb, C01664 (*C. annuum*), Greenleaf Tabasco 1982, C00758 (*C. annuum*), MC-003, Tabasco L-167, and UL-3878. Some fruit samples were obtained for quality analysis, but the results should be viewed as preliminary only. Preliminary data from field-harvested fruits indicated that large variation for color value occurred within each entry. Sampling procedures for color determination may need to be refined and information regarding the effect of virus infection on fruit chemical traits should be obtained. Capsaicin values were high for most of the entries of the Bird's Eye and Tabasco types (between 5 and 11 mg capsaicin/g DM). Entries C00847, C01664 (*C. annuum*) and Greenleaf Tabasco-1982 yielded the highest crude fat percentage.

Table 1. Clarification of species for some *Capsicum* accessions.

Accession No.	Passport description	Correction
C00310	*C. frutescens*	*C. annuum*
C00312	*C. frutescens*	*C. annuum*
C00313	*C. frutescens*	*C. baccatum* var. *pendulum*
C00313-1	*C. frutescens*	*C. baccatum* var. *pendulum*
C00642	*C. annuum*	*C. frutescens*
C00758	*C. frutescens*	*C. annuum*
C00776	*C. frutescens*	*C. chinense*
C00967	*C. frutescens*	*C. chinense*
C01377	*C. frutescens*	*C. annuum*
C01379	*C. frutescens*	*C. chinense*
C001434	*C. frutescens*	*C. annuum*
C01664	*C. frutescens*	*C. annuum*
C01769	*C. frutescens*	*C. annuum*
C01771	*C. frutescens*	*C. annuum*
C02677	*C. annuum*	*C. chinense*

Pureline Selection of Szechuan Landraces

Summary

Pureline selection of 'Szechuan' landraces from Taiwan has been going on since 1987. This year, an advanced yield trial was conducted on 27 selections. Six check entries, including two hot pepper hybrids and four original populations of Szechuan 1, 8, 9 and 10 were included in the trial. The mean marketable fresh weight for early yield was 9.3 t/ha, and the sum marketable yield was 15.5 t/ha. Percentage of unmarketable fruits due to various causes averaged 21%, with a range of 16–26% culls. The marketable yield of the most productive selection was 19 t/ha compared to one hybrid with 23.8 t/ha and another hybrid with 17.6 t/ha. Only nine of the 27 selections had yields significantly lower than that of the two check hybrids. Average fruit length was significantly reduced by 2.0 cm from the 2nd to the 8th harvest period, with a 3 mm and 0.8 mm reduction in fruit width and wall thickness, respectively.

Introduction

Uniformity and quality of hot pepper seed stocks are often limited in the varieties grown by most farmers in the tropics. Farmers traditionally save their own seed from an existing crop, or purchase a seed mixture that has been produced locally. The semiallogamous nature of many *Capsicum* varieties has contributed to the heterogeneous composition of many locally adapted landraces. Selection for plant type, fruit morphology, disease tolerance and overall productivity within certain landraces should improve the quality of locally adapted germplasm. The long-term objective of these efforts is to make breeder's seed of improved hot pepper landraces available to the national agricultural research systems (NARS) for multiplication and distribution.

Materials and Methods

The first advanced yield trial of the Szechuan selections was sown on 26 November 1990 and transplanted on 21 January 1991. Twenty-seven selections and six check populations (two hybrid varieties and four original unselected populations) were planted in a randomized complete block design with three replications. A fourth set of plots was covered with cages for seed multiplication. The most advanced bulks were inbred S_3 and S_4 families. The others were OP_2S_2 and OP_3S_3 families (OP = open-pollinated; S = self-pollinated).

Each two-row plot consisted of 30 plants spaced at 45 by 50 cm on raised beds with 1.5 m between beds. Plots were managed with plastic mulch and a standard fertilizer with an amendment of organic fertilizer in the basal application. Plots were irrigated by furrow irrigation. Ten weekly harvests were conducted from 1 May to 3 July 1991. The means of the mean, maximum and minimum temperatures were 24, 28 and 19°C, respectively, with a total rainfall accumulation of 772 mm from transplanting until the last harvest. Samples were submitted to AVRDC's Plant Pathology and Chemistry departments for anthracnose and pungency screening, respectively.

Results and Discussion

Harvest data were divided into early yield (harvest periods 1 through 4) and the sum yield for the 10 harvests. The mean marketable fresh weight for early yield was 9.3 t/ha, and the sum marketable yield was 15.5 t/ha. Percentage of unmarketable fruit number due to various causes averaged 21%, with a range of 16–26% culls. The marketable yield of the most productive selection was 19 t/ha compared to one hybrid with 23.8 t/ha and another hybrid with 17.6 t/ha. In fact, only nine of the 27 selections had yields significantly lower than the two check hybrids. Four selections had early yields ranking higher than the hybrid 'Chain Fair' and 10 lines ranked higher than the hybrid 'Hot Beauty'. All entries had mild pungency levels. Simple t-test comparisons between the second harvest and the eighth harvest indicated that fruit shape characters were significantly different between the two harvest dates. Average fruit length was reduced by 2.0 cm by the eighth harvest with a reduction of 3 mm in fruit width. Fruit wall thickness was reduced by 0.8 mm.

Progeny of six of the best selections based on yield, market quality and anthracnose tolerance were entered in a regional yield trial in September 1991 in Taiwan. Ten selections were forwarded to the AVRDC Thailand Regional Training Program for an advanced yield trial. Another advanced trial of 15 selections was sown at AVRDC in November 1991. Release of advanced lines is expected in the fall of 1992.

International Trials: Collection, Evaluation, Multiplication and Distribution of Entries for the International Hot Pepper Trial Network (INTHOPE)

Summary

The first global seed distribution of INTHOPE #1 entries was sent to 44 cooperators representing 22 countries. The benefit of pruning plants below the main-stem branching was tested again in a cool season planting of the INTHOPE #1 trial. In contrast to the warm season when pruning had no significant effect on production, the pruning treatment had a significant adverse effect on the cool season production. Total fruit number and weight were, respectively, 18 and 12%, significantly (P=0.05) less on pruned plots than on unpruned plots. Similar differences occurred for marketable fruit yields. Considering the time and labor costs involved in pruning, this practice cannot be recommended for the cultivation of hot pepper under AVRDC conditions. Entries were quantified for capsaicin content and screened for reaction to the pathogens: CMV, CVMV, PVMV, PVY, TMV, ToMV, PMMV, *Xanthomonas campestris* pv. *vesicatoria*, *Phytophthora capsici*, *Colletotrichum capsici* and *C. gloeosporioides* under controlled conditions. The mean marketable fruit weight among all entries was 5.1 t/ha. Unmarketable fruits averaged 26% of the total fruit number among all entries. Entries Punjab Lal and Huey Sithon had the highest fruit dry matter content, near 30%, followed by Unknown 6, KKU Cluster, Huaruar and Keriting ($24\% \leq x \leq 27\%$). Three entries with the lowest fruit dry matter content (<13%) were Chain Fair (F_1), PSR 67085 (F_1) and Jalapa (F_1). Entries Huey Sithon, Huaruar, Punjab Lal, Atarodo, Unknown 6 and KKU Cluster were the most pungent with capsaicin levels from 5.7 to 4.0 mg/g DM. Mean capsaicin level for all entries was 2.8 mg/g DM. One rainy season evaluation had been completed for the INTHOPE #2 set of entries. Serious flooding resulted in the survival of only 11 out of 39 entries.

Introduction

The International Hot Pepper Trial Network (INTHOPE) was initiated in 1988 in response to the need to disseminate popular hot pepper landraces and elite germplasm and test them in different international environments. This was discussed at the International Symposium on Integrated Management Practices for Tomato and Pepper Production in the Tropics. The objective of the network is to facilitate the exchange and evaluation of hot pepper landraces and elite germplasm across international test environments. Entries with at least field tolerance to important diseases are prioritized. The coordination of the network is the responsibility of AVRDC, the principal role of which is to receive, evaluate, multiply and redistribute germplasm, from and to the network collaborators. Each participant is expected to evaluate at least one multilocational trial per year in their own country, and provide feedback on the performance and acceptance of the germplasm. Some cooperators have chosen to evaluate the set in their disease nurseries. At AVRDC, the INTHOPE evaluation trials are sown in April and September. In addition, a seed crop is sown in September to provide seed for distribution in February/March.

The long-term objectives of the network are to introduce adapted hot pepper landraces and elite germplasm from different countries into appropriate regions of production; to monitor the performance of different hot pepper populations in diverse environments and to gather information on the variability of pathogenic strains involved in *Capsicum* host-pathogen relationships.

All INTHOPE #1 entries were screened for reaction to the pathogens CMV, CVMV, PVMV, PVY, TMV, ToMV, PMMV, *Xanthomonas campestris* pv. *vesicatoria*, *Phytophthora capsici*, *Colletotrichum capsici* and *C. gloeosporioides* under controlled conditions, and results were forwarded to all INTHOPE participants. Future evaluations at AVRDC will include screening for broad mite (*Polyphagotarsonemus latus*) and bacterial wilt (*Pseudomonas solanacearum*) resistance. Routine screening for PVMV resistance

will be discontinued. The first global seed distribution of 30 INTHOPE #1 entries was sent to 44 cooperators representing 22 countries.

INTHOPE #1: Fall 1990

Materials and Methods

The experimental design for the 1990 dry-cool season INTHOPE #1 trial was a split-plot with 43 entries in the main plot treatment and two management practices (pruning vs. nonpruning) in the subplot treatment. Pruning was conducted on the lateral shoots below the first bifurcation of the main stem. Whole plot treatments were replicated in three randomized complete blocks with 28 plants per replication, spaced 1.5 m apart on two-row beds with 0.5 m between rows and 0.45 m between plants. Subplot treatments were randomized among plots in units of 14 plants. A pair of plants (pruned) served as the border between subplots. Plants were sown, transplanted and pruned on 1 September, 11 October and 26 November, respectively. Standard cultural practices as recommended for pepper experiments at AVRDC were employed with an amendment of organic fertilizer at basal application. Mulching was conducted twice with rice straw. Fourteen weekly harvests were conducted from 28 November 1990 to 27 February 1991. The means of the mean, maximum and minimum temperatures were 20, 25 and 15°C, respectively, with a total rainfall accumulation of 48 mm from transplanting until the last harvest. Furrow irrigation was applied seven times at approximately 4–7-week intervals depending on the plant growth stage.

Data recorded were days to flowering, plant height on the first and last harvest, total and marketable fruit number and fruit weight, and fruit shape dimensions. Days to flowering were recorded when 75% of the plants in a plot were flowering at the secondary-branch nodes. Fruit shape measurements were taken when an entry was harvested for the third time. Fresh mature fruit samples were sent to the Chemistry and Pathology units for capsaicin determination and anthracnose screening, respectively. Incidence of powdery mildew was moderately high although no ratings were recorded.

Results and Discussion

Analysis of variance for the split-plot experimental design indicated that the treatment effect of pruning was significant for most of the yield components that were evaluated. In contrast to the summer season evaluation where pruning had no significant effect on yield, the pruning treatment in the cool-dry season had an adverse effect on yield. Total fruit number and weight were, respectively, 18 and 12%, significantly (P=0.05) less on pruned plots than on unpruned plots. Similar differences occurred for marketable fruit yields. Considering the time and labor costs involved in pruning, this practice cannot be recommended for the cultivation of hot pepper under AVRDC conditions. Unmarketable fruits averaged 26% of the total fruit number among all entries. Means of marketable fruit yields are presented for the highest yielding (Table 2) and early maturing (Table 3) entries. Yields from this cool season evaluation compared to the hot season rankings indicated that many entries suitable for cool season production were not suitable for hot season production and vice versa (Table 2). Some varieties performed comparatively well in both seasons for early fruit set (Table 3).

During the fall screening for virus resistance, no lines were 100% resistant to any virus except for IAC Ubatuba Cambuci, Atarodo, Red Horn (F_1), Magic Scarlet (F_1), Hot Long (F_1), Champion (F_1), Olympiad (F_1) and PE49 (F_1), which were resistant to TMV and ToMV. Screening for CMV resistance during the cool season revealed more susceptible responses than occurred during the hot season inoculations, but many entries were still heterogeneous for resistance. Selected individuals were self-pollinated for further screening, and subsequent redistribution. Entries Punjab Lal and Huey Sithon had the highest fruit dry matter content, near 30%, followed by Unknown 6, KKU Cluster, Huaruar and Keriting (24%≤x≤27%). Three entries with the lowest fruit dry matter content (<13%) were Chain Fair (F_1), PSR 67085 (F_1) and Jalapa (F_1). Entries Huey Sithon, Huaruar, Punjab Lal, Atarodo, Unknown 6 and KKU Cluster were the most pungent with capsaicin levels from 5.7 to 4.0 mg/g DM. Mean capsaicin level for all entries was 2.8 mg/g DM.

A complete summary of the INTHOPE #1 evaluation for two seasons is available upon request.

Table 2. Marketable fruit yields for the 16 best entries in the 1990–91 cool season INTHOPE trial compared to their hot season ranking.[a]

Entry	t/ha	Rank	Entry	Fruits/ plant	Rank
Chain Fair (F_1)	10.6	27	Keriting	58 9	11
Passion (F_1)	9.2	3	Unknown 6	52.8	34
Long Chili (F_1)	8.9	11	Punjab Lal	45.7	1
IAC Ubatuba Cambuci	8.7	22	KKU Cluster	43.3	15
Hero (F_1)	8.2	21	Huey Sithon	40.8	24
Champion (F_1)	8.1	4	Huaruar	39.8	30
Chili	8.0	40	Jawahar 218	39 7	20
Long Fruit	7.5	25	Champion (F_1)	34 5	12
Lv. 2323 (Jatilaba)	7.3	18	Golden Heat (F_1)	33.4	6
Yangjiao	7.1	38	PE64 (F1)	31 0	3
Golden Heat (F_1)	7.0	10	Magic Scarlet (F_1)	25.6	4
Long Fruit (A)	7.0	19	Chain Fair (F_1)	25.4	35
Szechuan 1	6 8	na[b]	Lv. 1583	24 9	9
Lv 1583	6.6	9	Lv. 2323 (Jatilaba)	24.9	21
Cheongryong	6.6	30	Long Fruit	24.8	27
Lv. 2319 (Tit Super)	6.3	15	Szechuan 1	24.6	na
Mean (of all 43 entries)	5.4			24.2	
C.V	18.2%			26.6%	

[a]Yields are the means of three replications for the sum of 14 harvests for unpruned subplots.
[b]Not evaluated.

Table 3. Marketable fruit yields for 16 earliest maturing entries in the 1990–91 cool season INTHOPE trial compared to their hot season ranking.[a]

Entry	t/ha	Rank	Entry	Fruits/ plant	Rank
Twist Green (F_1)	0.65	2	Twist Green (F_1)	3.8	1
PE49 (F_1)	0.58	6	PE49 (F_1)	2.1	2
Champion (F_1)	0.51	8	Lv. 1092	2 0	16
Long Chili (F_1)	0.50	1	Champion (F_1)	2.0	6
Hot Long (F_1)	0.50	3	Cegledi 6 t.f.	1.9	4
Olympiad (F_1)	0.48	12	Ludhiana Long Selection	1 7	29
Cegledi 6 t f.	0.47	5	Long Chili (F_1)	1.3	5
Lv. 1092	0.44	19	Olympiad (F_1)	1.3	11
Red Horn (F_1)	0.43	10	Magic Scarlet (F_1)	1.2	10
Lv. 2319 (Tit Super)	0 41	20	Lv. 2319 (Tit Super)	1.2	20
Ludhiana Long Selection	0.34	32	Red Horn (F1)	1.2	9
PSR 67085	0.31	4	Hot Long (F_1)	1.1	3
Tit Paris	0.29	17	Golden Heat (F1)	0.9	8
Magic Scarlet (F_1)	0.20	15	PE64 (F_1)	0.9	27
Golden Heat (F_1)	0.19	9	Extra Long Selection	0.9	12
PE64 (F_1)	0.18	28	Tit Paris	0.9	14
Mean (of all 43 entries)	0.19			0.7	
C.V.	49.8%			47.2 %	

[a]Early yields are the means of three replications for the sum of the first four harvests for unpruned subplots.

INTHOPE #2: Summer 1991

Materials and Methods

The experimental design for the 1991 hot rainy season INTHOPE #2 trial was a randomized complete block with 39 entries and three replications. There were 30 plants per replication, spaced 1.5 m apart on two-row beds with 0.5 m between rows and 0.45 m between plants. Plants were sown on 21 April and transplanted on 21 May. Standard cultural practices as recommended for pepper experiments at AVRDC were applied with an amendment of organic fertilizer at basal application. Mulching was done twice with

rice straw. Eight weekly harvests were conducted from 21 August 1990 until 9 October 1991. The means of the mean, maximum and minimum temperatures were 28, 32 and 25°C, respectively, with a total rainfall accumulation of 1721 mm from transplanting until the last harvest.

Data recorded were those on days to flowering, plant height on the first and last harvest, total and marketable fruit number and fruit weight, and fruit shape dimensions. Days to flowering were recorded when 75% of the plants in a plot were flowering at the secondary-branch nodes. Fruit shape measurements were taken when an entry was harvested for the third time. Fresh mature fruit samples were sent to AVRDC's Analytical Laboratory for capsaicin, fiber, crude fat, lignin and color determination. The experiment was sown again on 9 July and transplanted on 20 August, for a late summer evaluation. All entries of INTHOPE #2 have been screened so far for resistance to CMV, CVMV, PVY, TMV, ToMV, PMMV, and Phytophthora blight [see Pepper Pathology]. Screening for CMV resistance was conducted in two separate batches. One batch was inoculated at the cotyledon stage and the other batch was inoculated at the 3–4 true leaf stage.

Results and Discussion

Serious flooding occurred for 7 days in June (675.5 mm) and 6 days in July (591.5 mm) that resulted in marked differences in the survival of entries. Of the 39 original entries, only 11 entries survived the flooding, and remained productive for more than one picking. Physiological wilting averaged 15% with a range of 0–60% among entries. Virus incidence was also quite high after mid-season. The surviving entries were Pangalengan-2, Unknown 41, Pant C-1, Cheong Yang, Salmon, KA-11, MI-2, Num, PBC199, PBC384, and PBC385. Average fresh-weight marketable yield, however, was only 1.1 t/ha. The highest capsaicin content was determined in the entry 'Unknown 41' (6.05 mg/g DM). Pant C-1, MI-2, and PBC199 had the next highest capsaicin values, which ranged between 3.8 and 4.9 mg/g DM. A large variation for color value occurred within each entry. Sampling procedures for color determination may need to be refined.

Of all entries, only six plants of PBC199 resisted infection by CMV. A number of entries were 100% resistant to PVY. These included TAM Mild Jalapeño-1, TAM Veracruz Jalapeño, DaChang Niujiao Jiao, MI-2, R7-26(17), Pangalengan-2, King Gum Go Chu, Cili Langkap, Hidalgo, C01511, PBC384 and PBC389. The following entries were heterogeneous for CVMV resistance: Num, MI-2, KA-2, Hidalgo, KA-11, C01511 and PBC199. None of the entries were resistant to PMMV, but some had hypersensitive localized resistance to ToMV such as Kun Ja, Slam Chili, DaChang Niujiao Jiao, *C. baccatum pendulum* 3-4, King Gum Go Chu, TAM Mild Chile-2, Var. PL-38475 and PBC389.

Stigma Position of Seventeen Pepper Varieties

Summary

Pepper belongs to the autogamous species; however, a considerable amount of cross-pollination occurs mainly through insects and to a lesser extent by wind. Providing isolation distance is often difficult where peppers are cultivated on adjacent farms as well as on seed production farms where land is limited. Flower traits that would facilitate self-pollination would be invaluable both in seed production and in breeding programs. Among pepper varieties there is noticeable heterostyly where flowers differ in the position of the stigma in relation to anthers. This preliminary study investigated the extent of varietal differences in style length under different environmental conditions.

Seventeen pepper varieties were planted in observational plots under three different environments. Ten flowers from each plant were measured for their stigma and stamen length and the mean values were calculated for stigma position for the 17 varieties. Daily maximum temperature at each location was recorded during the period of the experiment. Cultivars significantly varied in their stigma position. The variety 'P.I. 241650' and 'Long Fruit A' had the inserted stigma position whereas the others showed exserted stigmas. An analysis of covariance indicated that the mean maximum temperature for 1 week prior to anthesis did not show any significant effect on stigma position. However, both pistil and stamen lengths significantly varied with temperature. Some plants developed both homomorphic and heteromorphic flowers.

Introduction

Outcrossing may create undesirable genetic variability in a cultivar, underscoring the importance of controlling cross-pollination in purity maintenance of pepper cultivars. Providing isolation distance is often difficult where peppers are cultivated on adjacent farms as well as on seed production farms where there is limited land. Flower traits that would facilitate self-pollination would be invaluable both in seed production and in breeding programs. Two such traits are homostyly and cleistogamy. Among pepper varieties there is noticeable heterostyly where flowers differ in the position of the stigma in relation to anthers. Three kinds of flowers were identified; short styled, medium styled and long styled. The long styled flowers in which the stigma extends beyond the stamens should favor cross-pollination whereas a high degree of self-pollination is expected from the short-styled flowers. This preliminary study investigated the extent of varietal differences in style length under different environmental conditions.

Materials and Methods

Seventeen pepper varieties were planted in observational plots under three different environmental conditions, namely, the field and two different screenhouses. The number of plants tested in these locations were 10, 6 and 4, respectively. Ten flowers from each plant were measured for their stigma and stamen length. Lengths were determined at full anthesis by measuring up to the tip of the style and anthers from the base of the ovary. Daily maximum temperature at each location was recorded during the period of the experiment. Temperature varied between 29 and 33°C in the field and 35 and 42°C in the two screenhouses. Locations were treated as replications and an analysis of covariance was used to test the hypotheses of no differences among varieties and no temperature effect on heterostyly.

Results and Discussion

The mean values were calculated for stigma position for the 17 varieties. Negative values represented the inserted stigma position while positive values indicated an exserted stigma position. Cultivars significantly varied in their stigma position. The variety 'P.I. 241650' and 'Long Fruit A' had the inserted stigma position whereas the others showed exserted stigmas. Among these two major groups, eight significantly different discrete classes in stigma position were found based on a Fisher's Protected LSD means comparison test. Only two classes had overlapping values. The range in phenotypic expression suggested a quantitative expression for the character.

The covariate, mean maximum temperature for 1 week prior to anthesis, did not show any significant effect on stigma position. However, both the pistil and the stamen length significantly varied with temperature changes. Variety × temperature interactions for stigma position were significant for seven varieties only. These varieties were CH-6 Num 216, Gwangju, P.I. 102883, Jawahar 218, Ludhiana Long Selection, P.I. 125807 and CA 8. It was observed that all the varieties that had shown variety × temperature interaction had some plants with either exserted and inserted stigmas or with all three flower types. In the case of 'CA 8' and 'Punjab Lal', all the plants produced homomorphic and heteromorphic flowers, even at the same temperature. Other factors, either genetic or environmental, probably influenced stigma position of these varieties. The production of flowers with all three stigma positions may be characteristic of these two varieties.

Although most of the plants of 'Long Fruit A' had the inserted stigma position a few plants produced either flowers with exserted stigmas or flowers with all three stigma positions. Hence, variability for stigma position of this variety may be attributed to heterogeneity of the plants. The variety 'P.I. 241650', a *C. frutescens* accession, was quite stable for the inserted stigma position.

Pepper Entomology

Screening of Pepper Germplasm for Resistance to Mites and Aphids

Summary

Two hundred and seventy-three pepper accessions were screened for resistance to mites [mostly *Tetranychus cinnabarinus* (Boisduval)] and aphids (mostly *Myzus persicae* (Sulzer)] in insecticide-free fields and weekly decamethrin-treated fields. The following 13 accessions had the least mite damage: C00003, C00014-1, C00296, C00186-1, C00326, C00468, C00469, C00475, C00477, C00523, C00527-A, C00536-A and C00577. The seven least aphid-damaged accessions were: C00010, C00012, C00044, C00067, C00358, C00373 and C00545-B. None of the apparently mite-resistant accessions was also resistant to aphids. Application of the synthetic pyrethroid decamethrin causes resurgence in both mite and aphid populations. This chemical will be used in future screenings to increase pest populations and to do reliable screening of the germplasm.

Introduction

Pepper or chili is an economically important vegetable in Asia and elsewhere. The survey on insect pests of this crop revealed that species of thrips, mites and to some extent aphids and tomato fruitworm (*Helicoverpa armigera* Hübner) are important in Asia. Tomato fruitworm damage to pepper, especially hot pepper, is minimal in Taiwan. Aphids are more important in transmitting virus diseases. Their physical damage to plants is not always significant. Thrips and mites are the key pests, both of which seem to be more serious when chemical insecticides are used. AVRDC's research is aimed at developing environmentally sound integrated pest management programs. Host-plant resistance is an important component of IPM. AVRDC possesses a large pepper germplasm collection with a wide genetic base. It is, therefore, possible to find a pest-resistant source in the collection. In 1991 screening was initiated to find sources of resistance, initially to mites, mainly *Tetranychus cinnabarinus* (Boisduval). Since aphids, mainly *Myzus persicae* (Sulzer), also attacked the pepper plant, their germplasm was screened for resistance to this pest as well.

Materials and Methods

Seeds of 267 pepper (mostly hot pepper) accessions were planted in seedling flats. Plants were maintained in greenhouses for 5 weeks after germination. A 0.8 ha parcel of land was rototilled and after basal fertilizer application, worked into 1-m wide beds. These beds were further divided into 5-m long single bed plots. The field was divided into two halves. Five-week old seedlings of each accession (20 seedlings/accession) were planted in two plots, one plot per half of the field. The crop was raised by standard cultural practices. One-half of the field containing one plot of each accession was sprayed weekly with decamethrin at 50 g AI/ha. The crop was raised using standard cultural practices such as irrigation, weeding, fertilizer application, etc., to ensure good growth and harvest.

At 12, 14 and 16 weeks after transplanting, 10 randomly selected plants from each plot were observed and the number of mites and aphids per plant was recorded. Each plant in a sample was classified as having 0, 1–100, 101–1000 and >1000 mites or aphids/plant. For judging the resistance, a weighted average was calculated as follows: Plant number in '0' pest category was multiplied by 0, in "1–100" category by 50, in "101–1000" category by 500 and in ">1000" category by 5000. The sum total of the number was divided by 10 to arrive at the number of mites or aphids per plant. The accessions having the lowest number of insects and mites were selected for further studies.

Results and Discussion

The numbers of mites (mainly *T. cinnabarinus*) per plant during each of the three observations are summarized in Figure 1. The mite population was very low in the first observation but increased gradually as the season progressed. Insecticide application did not affect mite population in the first two observations but in the third, the mite population increased considerably (Fig. 1). While selecting the least damaged germplasm this style of observation was emphasized and selected 13 least-infested accessions: C00003, C00014-1, C00186-1, C00296, C00326, C00468, C00469, C00475, C00477, C00523, C00527-A, C00536-A, and C00577. Accessions C00017-2, C00375 and C00593, which had the highest number of mites in all three observations, were also selected as susceptible checks for further studies.

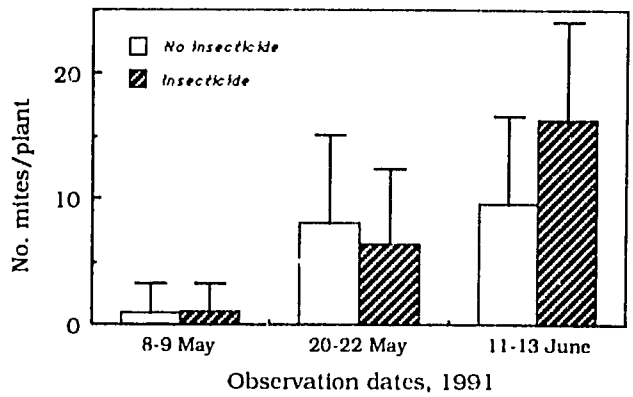


Fig. 1. Infestation of pepper germplasm by mites (*T. cinnabarinus*) in insecticide-treated and insecticide-free fields. Data are means of 267 accessions.

In insecticide-free plots, the aphid population increased considerably from the time of first observation to the second but decreased in the third (Fig. 2). However, in insecticide-treated plots the aphid population remained high throughout the season; it was significantly higher in the third observation. In selecting least aphid-damaged pepper accessions, the third observation taken in insecticide-treated plots was emphasized. The following seven least-damaged accessions were selected: C00010, C00012, C00044, C00067, C00358, C00373 and C00545-B. C00105, C00476 and C00526, which were heavily damaged by aphids in all three observations were also selected as susceptible checks.

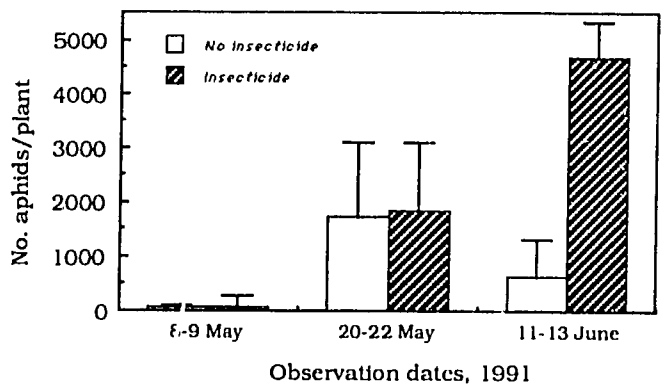


Fig. 2. Infestation of pepper germplasm by aphids (*M. persicae*) in insecticide-treated and insecticide-free fields. Data are means of 267 accessions.

None of the accessions resistant to aphids was also resistant to mites. Similarly, none of the accessions that were highly susceptible to aphids were also highly susceptible to mites.

The evaluation for resistance was based on a single experiment. Different accessions obviously had different growth habits; some grew vigorously and produced excessive foliage, others were less vigorous and produced only a moderate amount of foliage. This physical factor, i.e. production of different amounts of growth, which in turn offers different amounts of food and shelter for the arthropod pests, rather than genetic factors could be responsible for the observed differences in mite or aphid populations in different accessions. These aspects will be evaluated in multireplicate tests with selected least-damaged accessions in autumn 1991, and the results will be included in the 1992 Progress Report.

Insecticide application increased the populations of both mites and aphids. Neither the mites nor aphids are specific pests of pepper. Both are polyphagous. Farmers in Southeast Asia use large amounts of various chemicals to control insects to reduce virus infestation and other pests such as armyworm and fruitworm which are of minor importance. These user farmers are likely to increase the incidence of mites and aphids unless they use specific chemicals. Synthetic pyrethroids, often used to control armyworms and fruit borers, are likely to exacerbate the mite and aphid problem.

Pepper Pathology

Evaluation of Peppers for Resistance to *Colletotrichum* species, *Phytophthora capsici*, *Pseudomonas solanacearum*, and *Xanthomonas campestris* pv. *vesicatoria*

Summary

Anthracnose and Phytophthora blight are important fungal diseases of pepper, whereas bacterial spot and wilt are important bacterial diseases. To improve peppers for the tropical environments, the control of these diseases is crucial, and since 1986, efforts at AVRDC have concentrated on using host plant resistance. This study reports on the evaluation of peppers for resistance to anthracnose, Phytophthora blight, bacterial spot, and bacterial wilt. Lines Cegledi 6 t.f., Cipanas, Chain Fair (F_1), Jalapa (F_1), Lv. 2319, PSR 67085, IAC Ubatuba Cambuci, and Tit Paris, had low anthracnose indices in one or two of the sample dates. Several new sources of resistance to anthracnose were identified in an observation trial. Most Szechuan selections were susceptible to anthracnose and 70% of the fruits averaged over all lines were field-infected at harvest. Phytophthora blight resistance was identified from many of the lines in the International Hot Pepper Trial I (INTHOPE I), but only two lines from Nigeria were considered resistant among the lines in the INTHOPE II. Some of the Szechuan selections, previously selected for resistance to Phytophthora blight, were confirmed as resistant in progeny tests. In the field, bacterial spot was recorded over time on hot and sweet peppers. Many of the hot peppers had low ratings for bacterial spot severity, whereas only one sweet pepper line homozygous for Bs1-Bs3 genes had significantly less disease than the other lines. Under greenhouse conditions, soil drench and toothpick stabbing into stems were effective in inducing bacterial wilt. Lines CA-8, CAB, Hong San Ho (F1), MC4, MC5, and Sinagtala had 0% wilt in one or both methods of inoculation.

Introduction

Peppers are infected by several different genera of bacteria and fungi. Under some conditions these pathogens are known to cause significant yield reductions. The main thrust at AVRDC to control some of the most important diseases has been to find sources of resistance.

Anthracnose is caused by several species of the fungus *Colletotrichum*. Infection occurs on most plant parts, and symptoms are most obvious on fruits as sunken lesions. The disease is most prevalent under conditions of high humidity and abundant rainfall. Past research has identified more than a dozen resistant sources, but not all of these have suitable horticultural characteristics. The current studies were done to evaluate resistance represented in more horticulturally accepted lines in the INTHOPE trial.

Phytophthora capsici causes collar rot of the main stem and blight on branches of pepper. The fungus is soilborne and may drastically reduce the population of plants in the field. Resistant sources have been identified and are used in most breeding programs. An evaluation of resistance of lines in two INTHOPE trials and on selections from Szechuan landraces are reported here.

Bacterial spot, caused by *Xanthomonas campestris* pv. *vesicatoria*, usually occurs when peppers are grown in hot, humid regions. There are several races of the pathogen, and factors relating to partial resistance are often complex. Most of the AVRDC accessions and breeding lines have not been tested for resistance to bacterial spot. In this study we report on field experiments designed to evaluate resistance in hot and sweet peppers.

Bacterial wilt, caused by *Pseudomonas solanacearum*, is an important pathogen on most solanaceous crops. Its geographic distribution and occurrence on peppers is not well documented like that of tomatoes. A survey conducted by AVRDC showed that it ranked fourth in importance among pepper diseases in tropical Asia. Some initial screening techniques and the evaluation of a few lines for resistance are presented.

The overall objectives of these studies were to assess host plant resistance to anthracnose, Phytophthora blight, bacterial spot, and bacterial wilt. Most of these experiments were done in conjunction with the pepper breeding group.

Materials and Methods

Anthracnose

INTHOPE I. Seedlings of 43 entries representing INTHOPE I were transplanted to the field on 11 October 1990 in a randomized complete block design with three replications. Each experimental unit was 1.5 × 6.75 m with 15 plants in each of two rows. The plots were not sprayed with fungicides.

Twenty marketable fruits per plot were selected randomly from each entry on 23 January 1991 for the first sample and on 21 February for the second sample. Fruits were washed, blotted dry, and punctured once with a five-needle pen. The 20 fruits were divided in two groups and 10 were inoculated with *C. capsici* and 10 with *C. gloeosporioides* by dropping a 3×10^6 conidia/ml suspension directly on the punctured portion of the fruit. Fruits were placed inside containers and incubated for 14 days at room temperature. Lesion diameter on fruits was assessed using the following scale: 1 = no lesion, 2 ≤ 0.5 mm, 3 = 0.5–1 cm, 4 = 1–2 cm, and 5 ≥ 2 cm; and also evaluated based on field infection (latent infection). Data on incidence of anthracnose were converted to percentages. Data from each assessment date were analyzed by ANOVA and means were separated by least significant difference (LSD).

Observation trial. Seeds of 57 entries were transplanted to the field on 19 November 1990 in a nonreplicated trial. Ten healthy fruits per entry were incubated without inoculation on 17 April as described previously. Incidence of anthracnose was recorded on post-incubated fruits on 2 May. An additional 10 fruits each were inoculated with either *C. capsici* or *C. gloeosporioides* on 17 April 1991. Fruits were inoculated, incubated, and assessed as described previously. The standard deviation (SD) and mean were used to select entries with smaller lesion diameters.

Szechuan selections. Plants for this trial were transplanted on 21 January 1991 in a randomized complete block design with three replications. On 23 May, 30 fruits of 31 Szechuan selections, Chain Fair (F_1) and Hot Beauty (F_1) were divided into three lots and subjected to the following treatments: inoculated with *C. capsici*, inoculated with *C. gloeosporioides* or not inoculated. Fruit incubation, inoculation, disease assessments, and statistical analysis were done as previously described.

Phytophthora blight

INTHOPE I. Seeds of 43 pepper entries were planted in a sterile soil mix in flats on 9 September 1990. There were eight entries per flat and 10 plants per accession in three replications. PI 201234, Szechuan 10, and Blue Star (F_1) were included as highly resistant, moderately susceptible, and highly susceptible checks. Inoculum of *P. capsici* was prepared as described in the 1990 AVRDC Progress Report. Plants were inoculated on 10 October and assessed on 30 October by counting the number of surviving plants. Based on these results 15 entries were retested along with Blue Star (F_1). These entries were planted 27 February 1991, inoculated 30 days later, and evaluated by counting the number of surviving plants.

INTHOPE II. Seeds of 39 pepper entries and a susceptible check Queen Star (F_1), were planted on 9 September 1991 and evaluated on 29 October 1991. The planting, inoculations, and evaluation were done as described previously.

Szechuan selections. Based on previous experiments, lines that had a higher percentage of survival were progeny-tested along with six entries from Korea that were multiplied at AVRDC to obtain enough seeds for this experiment. These were planted on 26 July 1991, inoculated 30 days later, and evaluated on 17 October. Procedures used for the experiment were like those previously described for INTHOPE I.

Bacteral spot

Field test. Two trials, for evaluating hot and sweet pepper, separately, were conducted under field conditions. Pepper plants were transplanted to the field on 10 August 1991 in a randomized complete block design with five replications. Plants were inoculated by atomizing with strain XCV14 several times from 10 September to 14 November with inoculum of 10^6–10^7 cfu/ml. Disease was assessed weekly from 12 September to 17 October by rating 10 plants per plot or by rating the whole plot for percent leaf area infected. The area under the disease progress curve (AUDPC) was calculated using the data of leaf area infected over time and these values were used in ANOVA with means compared by an LSD test.

Bacterial wilt

Inoculation techniques. Seeds of Giant Bell (F_1) were sown in 10-cm pots in a pipehouse on 12 September 1991. Two strains (Ps4 and Ps41) of *P. solanacearum* were inoculated on pepper by toothpick stabbing, and drenching soil with and without root wounding. Half of the number of plants were inoculated at 20 days after emergence (DAE) and the other half at 30 DAE. Toothpick ends were rubbed in bacterial colonies and inserted into the stem at the axil of the second or third expanded leaf. For soil drenching, roots were injured with a knife by cutting the soil 1.5 cm away from the stem and a 30-ml bacterial suspension (10^7 cells/ml) poured into each pot. Plants were evaluated for wilt daily for the first 2 weeks after inoculation and at 2-day intervals thereafter. Plants were rated as dead if all the leaves had wilted.

Evaluation of lines. Seeds of 16 lines were planted in flats and 9-cm diameter pots. When plants were 25 days old those in pots were inoculated by stabbing an infected toothpick into the leaf axil; those in flats were inoculated by soil drenching after cutting roots. There were four replications for each line and each inoculation method. Plants were assessed 10 days after inoculation by rating wilt as previously described. Data were converted to percentages before ANOVA.

Results and Discussion

Anthracnose

INTHOPE I. The incidence of *Colletotrichum* spp. on noninoculated field-infected fruits averaged over all entries over two sampling dates was 8.2% (Table 1). On the first sampling date, there were significant differences between entries, for example, Huaruar, KKU Cluster, and Jalapa had no fruits while Cegledi 6 t.f and Lv. 1092 had 29 and 23% infected fruits, respectively. There was no significant difference between the lines in the second sampling date, but several lines, Golden Heat (F_1) and Lv. 2319, had no fruit infection while entry Long Fruit had 15% fruit infection.

The disease index for fruit inoculated with *C. capsici* and *C. gloeosporioides* averaged 3.5 and 3.4 for sample one and 3.9 and 3.1 for sample two, respectively. There were significant differences between the lines (Table 1). In sample one, the lines that had fruit with the lowest rating when inoculated with *C. capsici* was IAC Ubatuba Cambuci and Tit Paris; while lines Cegledi 6 t.f., Cipanas, and IAC Ubatuba Cambuci had the lowest disease indices when fruits were inoculated with *C. gloeosporioides*. For sample two, fruit of PSR 67085 had the lowest disease indices when inoculated with either species. Disease ratings for fruits of Chain Fair (F_1), Cipanas, IAC Ubatuba Cambuci, Jalapa (F_1), and Lv. 2319 were not significantly different from PSR 67085 when inoculated with *C. capsici*. Fruit ratings of Lv. 1092 were not significantly different from those of PSR 67085 when inoculated with *C. gloeosporioides*. Data from field-infected fruits were not significantly correlated to the disease indices; however, there was a significant positive correlation ($r = 0.5$) between disease indices from sample one and two.

Observation trial. The average incidence of anthracnose on noninoculated fruit (latent infection) was 47%. Five lines had means less than 1 SD below the overall mean. Entries Taeyangkun (F_1) and Jinpum (F_1) had 0% fruit infection.

The disease indices for *C. capsici* and *C. gloeosporioides* was 3.1 [standard deviation (SD = 0.9)] and 3.7 (SD = 1.0), respectively. There was a significant positive correlation ($r = 0.36$) between disease indices on fruits inoculated with the two species. Entries that had 1 SD below the mean in one or both inoculations were PBC076 (Szechuan 10), PBC397A (Shata Balady), PBC402 (P. Sakaraho), PBC426 (DaChang Wiu Jiao Jino), PBC453 (Cayenne Cajun 2A), and PBC474 (Rotan).

Table 1. Disease indices of anthracnose on fruit inoculated with *Colletotrichum capsici* (Cc) and *C. gloeosporioides* (Cg), and the incidence of anthracnose on noninoculated fruit of 42 field-grown pepper lines at two sampling times.

	Sample one			Sample two		
	Disease Index[a]		Field	Disease Index		Field-
Entry	Cc	Cg	infected (%)[b]	Cc	Cg	infected (%)
Atarodo	3.2	2.4	3 8	3 6	2 7	1.7
Cegledi 6 t.f.	2 6	2 1	28.8	-	-	-
Chain Fair (F_1)	2.9	3.6	18.3	2 8	3 8	5.1
Champion (F_1)	2.6	3.7	5.9	3 8	2.5	3.3
Cheongryong	3.9	4 0	11 8	4 3	3.0	1.9
Chili	3.5	3.5	8.8	4.4	2.3	1.9
Cipanas	2.6	2.1	8.2	3 0	2 2	4.8
Extra Long Selection	4.6	4 3	1.6	3.6	5 3	4 4
Golden Heat (F_1)	3 3	3.8	4.5	2 8	0 0	3.9
Hero (F_1)	4.0	3.9	16.8	4 1	3.6	3.3
Hot Long (F_1)	3.2	3 2	9 5	3 9	2.9	10.0
Huaruar	4.4	4 4	0 0	4 6	3.4	3.7
Huey Sithon	4.5	3.8	4 4	4.3	3.2	1.7
IAC Ubatuba Cambuci	2.1	2.1	2 8	3.1	2.9	7.0
Jalapa (F_1)	3.5	3.1	0.0	3 0	2.5	7.0
Jawahar 218	4.2	4 2	9.8	4 2	3.3	4.1
KKU CLuster	4.8	-	0.0	4 5	3 1	3.3
Keriting	3 0	3.0	10.0	3 6	3.5	10.0
Long Chili (F_1)	4 1	3.1	14.5	3 7	3 6	5.2
Long Fruit	3.7	4.2	7.2	4 2	3.3	15.2
Long Fruit (A)	4.2	4.3	12.4	4 3	4.6	15.4
Ludhiana Long Selection	4.2	3.9	5 2	3.5	3 5	4.8
Lv. 1092	2.9	2 8	22 8	3.8	1.8	3.3
Lv. 1583	3.8	2.7	12.0	3 6	2.6	1.7
Lv. 2319	2.7	2.2	14.2	3.1	2 4	0.0
Lv. 2323	4.1	4 5	1.7	3 9	3 7	9.0
MC 4	3.3	3.5	6.3	3.7	2 9	5.0
MC 5	4 0	4 2	12.8	4.7	3 6	1.7
Magic Scarlet (F_1)	3.0	2.7	9.1	3.4	2.7	5.0
New Comer (F_1)	3.0	3.4	7.0	3 8	3 3	11.0
Olympiad (F_1)	3.8	3 4	1.8	4 4	3.5	3.3
PE49 (F_1)	4.6	4.3	4.0	4.5	3.7	5.6
PE64 (F_1)	3.8	3.8	5.3	4.4	3.5	3.3
PSR 67085	3.3	2.9	5.3	2.0	1.4	6.0
Passion (F_1)	3.8	4.1	16.7	4.3	3.2	6.9
Punjab Lal	3.7	3.8	3.3	4 5	3.1	1.9
Red Horn (F_1)	4.1	3.7	5.7	4.2	3 2	8.7
Szechuan 1	3.3	2.9	12 7	4.2	3.9	5.4
Szechuan 10	2.4	3.0	19.5	4.3	3.6	10.7
Tit Paris	2.3	2.1	4.4	3 2	2.3	3.5
Twist Green (F_1)	3.0	2.6	10.8	3.7	2 5	8.3
Unknown 6	4.2	3.4	5.0	3.9	2.7	1.7
Yangjiao	2 6	2.7	3.5	3 8	2.8	6.9
Average	3 5	3 4	8.3	3 9	3.1	8.1
LSD (5%)[c]	0.8	0.9	12.8	1.1	0.7	N.S.

[a]Ten fruits were inoculated per species with three replications.
[b]Twenty fruits from those inoculated were also observed for latent infection.
[c]Least significant difference.

Szechuan selections. There were significant differences in anthracnose ratings between the lines when inoculated with *C. gloeosporioides*, but not with *C. capsici*. There was a high incidence of field infection in most of the lines which ranged from 37 to 87%. Some lines that had lower disease scores are being used in further selections.

These studies on the occurrence of anthracnose on field-infected fruits and lesion diameter on inoculated fruits showed that there were significant host differences with regard to infection. However, more research is needed to obtain information on the genetics of resistance and epidemiology of the disease. Differences in disease reaction may also be related to fruit size, chemical composition, wall thickness, or waxiness. A complete understanding of the host-pathogen relationship is necessary.

Phytophthora blight

INTHOPE I. Many lines with a high percentage of plant survival were not significantly different from the resistant check PI 201234. The average survival over all lines was 70% (Table 2). Entries Hero (F_1), Lv. 1092, PE 49 (F_1), PE 64 (F_1), and Tit Paris all had over 90% surviving plants. In a repeated experiment with selected lines, all had similar ratings to the first trial except for Chain Fair (F_1) which had fewer surviving plants than in the first test.

INTHOPE II. The average survival over all lines was 14%, and only two lines from Nigeria, var. P. Sakaraho and var. U-Kimba, had significantly higher survival rates than other lines. Most of the lines from this trial seemed to have inadequate resistance to Phytophthora blight

Szechuan lines. The mean survival was 49%. Entries, Szechuan 1-3-1-Bk-Bk, Szechuan 8-18-1-Bk-1, Szechuan 8-18-1-Bk-2, and Szechuan 10-9-9-2-Bk-7 had over 80% survival. Entries from Korea did very poorly because the plants tested were from the seed of hybrids that have been reported to have good levels of resistance in Korea, and were therefore segregating.

Sources of resistance to *Phytophthora* appeared to be adequate and a number of hybrids that were tested in INTHOPE I had high levels of resistance. Few entries in INTHOPE II had resistance, but no earlier information on their resistance is known.

Bacterial spot

Field trial. In hot peppers, the average AUDPC value was 565. There was a significant difference between lines (Table 3). The lines with the lowest three values were CNPH 703, Jawahar 218, and Lv. 1092. Tit Paris had the highest rating. In sweet pepper, the AUDPC value averaged 1008 (Table 3). The disease severity at each rating in sweet peppers was much higher than that of hot peppers. One sweet pepper line, 34-6-7-1-1-Bk, had a significantly lower value than the other lines. This line is homozygous for the Bs1-Bs3 genes for resistance. Other lines that had considerably less disease were PI 322719, XVR 3-25, and Line 16-3. These either have one or more of the BS genes or have been identified previously as having partial resistance to bacterial spot.

From field observations, it was obvious that hot peppers had higher levels of resistance to bacterial spot compared to sweet peppers. In general, although there was disease, the bacterial spot epidemic did not continue in hot peppers and the increase in disease severity, if there was any, was the result of continuous inoculations and not of secondary spread. Most of the sweet pepper plants from susceptible lines were distorted, defoliated, and generally lacked vigor due to the disease. Those sweet pepper lines that had less disease either had single genes for resistance or were partially resistant. Bacterial spot symptoms on line 34-6-7-1-1-Bk having the three resistance genes were somewhat atypical with restricted lesions, although the bacterium was easily isolated from its leaves several weeks after inoculation.

Bacterial wilt

Inoculation techniques. The differences in the percentage of plants that were wilted was not significantly due to isolate or plant age, but the method of inoculation was highly significant. Toothpick stabbing and soil drenching with root wounding caused about 80% wilt whereas soil drenching without wounding caused only 35% wilt. From these results, it appears that wounding either roots or stem by toothpick is necessary to obtain levels of wilt that can be utilized in screening host entries for resistance.

Table 2. Percentage survival of pepper in INTHOPE I, and a selected repeat of INTHOPE I, and in INTHOPE II 30 days after inoculation with *Phytophthora capsici*.

	INTHOPE I		INTHOPE II	
Entry	Survival (%)	Survival (%)	Entry	Survival (%)
Atarodo	0 0[a]	0 0	*C. baccatum*	2.1
Blue Star (F_1)	3.3	0 0	C01511	0.0
Cegledi 6 t f.	1.1	-[b]	C01621	3.3
Chain Fair (F_1)	83.3	28 1	C01647	0.0
Champion (F_1)	36 6	-	Cheong Yang	5.4
Cheongryong	11.1	-	Cili Langkap	0.0
Chili	35 5	-	DaChang Niujiao	23.3
Cipanas	85 8	87.5	Gwangju	3.3
Extra Long Selection	36 6	-	Hidalgo	0.0
Golden Heat (F_1)	82 2	-	KA-11	26.7
Huay Sithon	53 3	-	KA-2 (tb)	6.7
Hero (F_1)	93.3	78.1	King Gum Go Chu	20.0
Hot Long (F_1)	31 1	-	Lv. 1583	50.0
Huaruar	45 5	31.3	MI-2	8.3
IAC Ubatuba Cambuci	0.0	0 0	Num	1.7
Jawahar 218	43.3	-	Orias Kossarvu	0.0
KKU Cluster	33.3	-	PBC199	41.7
Keriting	50.0	-	PBC384	0.0
Long Chili (F_1)	41 1	-	PBC385	6.7
Long Fruit	35.5	-	PBC389	0.0
Long Fruit (A)	30.0	-	PI 215743	0.0
Ludhiana Long Selection	60.0	-	Pangalengan-2	0.0
Lv 1092	90.4	91.7	Pant C-1	41.7
Lv. 1583	86.6	75.0	Queen Star	0.0
Lv. 23 i9	90.0	69.1	R7-26(17)	6.7
Lv 2323	74 4	-	Salmon	1.7
MC 4	10.0	0 0	Slam Chili	0.0
MC 5	6.6	0.0	Szechuan 8	8.3
Magic Scarlet (F_1)	85.5	96.4	TAM Mild Chile-2	0.0
New Comer (F_1)	27.7	-	TAM Mild Jalapen	35.0
Olympiad (F_1)	13.3	-	TAM Veracruz Jal	0.0
PE49 (F_1)	93.3	100	Unknown 41	3.3
PE64 (F_1)	97.7	87.4	Var. P. Sakaraho	73.3
PI 201234	100.0	-	Var. P1-2190	11.7
PSR 67085 (F_1)	65.5	-	Var. PL-2289	30.0
Passion (F_1)	60.0	-	Var PL-38475	18.3
Punjab Lal	1.1	-	Var. U-Kashinbur	0.0
Red Horn (F_1)	21.1	-	Var. U-Kimba	90.0
Szechuan	85.5	-	Var. UL-2190	26.7
Szechuan 10	74.4	-		
Tit Paris	95.5	92.9		
Twist Green (F_1)	51.1	-		
Yangjiao	26.6	-		
Average	69.7	16.8		14.0
LSD (5%)	25.7			19.0

[a]Values represent 10 plants in each of three replications.
[b]Not tested

Evaluation of lines. Ten days after inoculation the percentage of wilted plants differed significantly by line (Table 4). Several lines, including CA-8, Hong San Ho, MC4, MC5, and Sinagtala had no wilted plants with either one or both of the inoculation techniques. Other lines, like California Wonder and Giant Bell (F_1) had over 90% wilted plants when inoculated with either method. The percentage wilt between the

Table 3. Values for the area under the disease progress curve (AUDPC) for hot and sweet pepper entries inoculated in the field with *Xanthomonas campestris* pv. *vesicatoria*.

Hot Peppers	AUDPC	Sweet Peppers	AUDPC
Cipanas	587	AG	1374
CNPH 703	109	All Season	1015
Jawahar 218	188	AR 89	1410
Keriting	391	LAB 469	1076
Lv. 1092	231	Line 16-3	785
Lv. 1583	567	Morgold	990
Lv. 2323	444	PI 322719	537
Punjab Lal	284	Redlands Sweet Sue	1109
Tit Paris	858	ROC 29	1164
Unknown 6 (COO551)	308	Sinagtala	1091
YJ 81032	2246	XVR 3-25	626
Yolo Wonder B	1603		
34-6-7-1-1-Bk	368		
75-3-4-4-1-Bk	934		
Average	565		1008
LSD (5%)	186		176

Table 4. Percentage wilt of 16 pepper entries 10 days after inoculation with *Pseudomonas solanacearum* by soil drenching or toothpick stabbing.

Entry	Toothpick (%)	Soil drench (%)
All season	30	10
Antibois	58	55
CA-8	0	0
CAB	10	0
California Wonder	95	90
Cubanelle	95	70
Douxd E'spagne	100	85
Giant Bell (F1)	95	95
Hong San Ho (F1)	25	0
Hungarian Wax	75	80
MC4	0	0
MC5	0	0
Pant C1	75	30
Sinagtala	25	0
Sweet Banana	25	20
Yolo Wonder B	65	55
Average	48	37
LSD (5%)	29	34

two inoculation methods among lines was significantly positively correlated (r = 0.74). Although only a few lines were tested in this experiment, it does indicate that there are sources of resistance to bacterial wilt in peppers.

Foliar and Stem Blight of Peppers and Tomatoes Caused by *Phytophthora capsici*

Summary

Phytophthora capsici is an important disease of peppers. The pathogen also attacks other plants including many vegetables. Isolates of *P. capsici* from pepper stems and tomato foliage were inoculated on black nightshade, cabbage, cucumber, pepper, potato, tobacco, and tomato by atomizing foliage or drenching soil with a suspension of zoospores. Foliar and stem blight symptoms were observed on black nightshade, pepper, and tomato. Isolates varied in their virulence on these hosts. An isolate obtained from tomato was generally more virulent than other isolates. When pepper and tomato plants were foliar-inoculated, isolates varied from causing no symptoms to complete blighting and death of the plants. When pepper and tomato plants were drench-inoculated, blight was observed on all ages of pepper plants, but not on 28-day or older tomato plants. Eleven lines of tomato that were foliar-inoculated were all susceptible with over 50% of the foliage infected. Pedicel and sporangia sizes of 10 *P. capsici* isolates did not differ significantly among the isolates.

Introduction

Phytophthora capsici causes blight, root and crown rot, and other symptoms on many hosts including such vegetables as cucumber, eggplant, melon, pepper, and tomato. The fungus is soilborne, and is difficult to control partly because of its broad host range and its ability to survive in the soil. On peppers, the fungus infects roots and lower portions of stems causing cankers and death of plants. The fungus has also been reported to cause foliar blight and fruit rot on pepper. On tomato, the fungus has been reported to occur on roots, lower stems, and fruits. In a recent report, the fungus was isolated from field-blighted tomato leaves, and isolates from pepper and tomato were shown to be highly virulent on pepper and tomato when either foliar- or drench-inoculated. As early as 1972, isolates of *P. capsici* were shown to be variable in pathogenicity. Intraspecific variation in pathogenicity is known to occur among isolates from cucurbits and pepper. In prior studies isolates have been shown to differ in their virulence on pepper and tomato.

P. capsici has been identified by using morphological characteristics. Because of the variation in morphology reported in the literature, a revised species description was published in 1988. To work within this species concept, it is important to properly identify isolates before conducting research on the host-pathogen interaction. The objective of this study was to characterize *P. capsici* in terms of its morphology, growth, pathogenicity, and host range.

Materials and Methods

P. capsici was isolated from diseased pepper stems, tomato leaves, soil, and obtained in pure culture from National Chung Hsing University and from Academia Sinica in Taiwan. The fungus was isolated from diseased tissue by surface-sterilizing 1–2-mm pieces of tissue with NaOCl (1%) and plating them on water agar. Cultures of the fungus were maintained on PDA (potato dextrose agar) at room temperature and in sterilized water at 18°C.

Fungal morphology. Ten isolates from different locations in Taiwan (Table 5) were cultured on V-8 agar at 28°C for 7 days in the dark. Cultures were cut into 1–2-cm pieces, rinsed twice with sterile distilled water, and incubated at room temperature for 2–3 days. Agar pieces were rinsed and the length and width of 20 sporangia and length of 20 pedicels were measured for each isolate. The L:B (length:breadth) ratio of sporangia was calculated.

Host range. One-month old seedlings of cabbage, cucumber, pepper, tobacco, and tomato planted in 9.5-cm diameter pots were inoculated by atomizing foliage until runoff and by drenching soil with a 50-ml suspension of 1×10^4 zoospores/ml. There were five replications each for isolate (Pc4 and Pc9) and inoculation method. After inoculation, plants were incubated in a growth room at 28°C, 98±2% RH, and 49.3 $\mu E/m^2/sec$ of light for 12 hours/day. Plants were evaluated based on whether basal stem or foliar blight

symptoms occurred (+) or no symptoms were observed (-) at 5 days after inoculation. In a second trial, black nightshade (*Solanum nigrum* L.), eggplant (Farmers Long and Pingtung Long), pepper (Blue Star), potato, and tomato (PT4121) were inoculated as described above with the two isolates, two inoculation methods, and five replications. Plants in both experiments were arranged in a completely random design.

Plant age. Pepper (Blue Star) and tomato (Line 1501) seedlings were inoculated 7, 14, 21, and 28 days after emergence with isolates Pc5 and Pc9. Seedlings were grown in 9.5-cm diameter clay pots with four plants (per replication) per isolate and age. A suspension of 50 ml of 1 x 10^4 zoospores/ml was poured into each pot. Plants were incubated at 25–28°C in a growth room with humidity, light, and temperature conditions as previously described. The experiment was a split plot in a randomized complete block design with the age of plants as main plots and isolates as subplots. Disease was assessed 10 days after inoculation by rating plants as either dead (+) or having no symptoms (-).

Virulence of isolates. Seeds of tomato (AVRDC, L3975) and pepper (Blue Star) were planted in 9.5-cm clay pots. When plants were 30 days old, a suspension of 1 × 10^3 zoospores/ml of five isolates, Pc1, Pc2, Pc3, Pc5, and Pc9 were either soil-drenched (50 ml of suspension) or foliar-sprayed until runoff. There were 10 plants (per replication) for each host, isolate, and inoculation method. Plants were rated for disease daily for 7 days and again at 14 days after inoculation by using the following scale: 0 = no symptoms; 1 = 1–10% of leaf area infected (LAI); 2 = 11–20% LAI; 3 = 21–40% LAI or 1–10% of stem area infected (SAI); 4 = 41–70% LAI or 11–50% = SAI; 5 = 71–90% LAI or 51–100% SAI; and 6 = 91–100% LAI or plant dead.

Inoculation of tomato lines. Thirty-day old seedlings of 11 tomato lines were atomized with a suspension of 1 × 10^3 zoospores/ml of isolate Pc9 and covered with polyethylene bags for 24 hours inside a growth room at 25–28°C. After removing bags, plants were overhead-misted twice per hour for 40 sec each time. There were 10 plants/line (per replication) arranged in a randomized complete block design. Disease was assessed 5 days after inoculation using the scale previously described.

Results and Discussion

Fungal morphology. The range of the mean length of sporangia was 43.1–65.8 and 30.0–50.4 µm in width (Table 5). The mean L:B ratio ranged from 1.23 to 1.54. The mean pedicel size ranged from 33.5 to 98.9 µm. Isolates that were not obtained from pepper did not appear different in mycelial growth or in morphologic sizes than those from pepper. The morphological characteristics of our isolates were within the range of the revised description of the fungus.

Table 5. Mean length and width of sporangia, calculated length: breadth ratio (L:B), and pedicel length of 10 isolates of *Phytophthora capsici*.

Isolate	Source	Sporangia Length (µm)	Sporangia Breadth (µm)	Sporangia L:B	Pedicel length (µm)
Pc1	Pepper stems	57.9[a]	45 2	1.28	42.7
Pc2	Pepper stems	58.3	47.5	1.23	71.4
Pc3	Pepper stems	65.8	50.4	1.31	98.9
Pc4	Pepper stems	43.1	32.5	1.33	60.7
Pc5	Pepper stems	52 3	41.0	1.29	79.5
Pc9	Tomato leaves	53 5	37.6	1.43	83.9
Pc10[b]	Eggplant	49.1	38.7	1.27	68.8
Pc12[c]	Pepper	46.0	30.0	1.54	76.6
Pc13a	Soil	56.6	42.0	1.36	51.5
Pc13b	Soil	53.5	40.0	1 34	33.5

[a]Values represent the mean of 20 measurements.
[b]From Dr. Chang, Academic Sinica, Taipei, Taiwan.
[c]From Dr. Hsieh, National Chung Hsing Unversity, Taichung, Taiwan

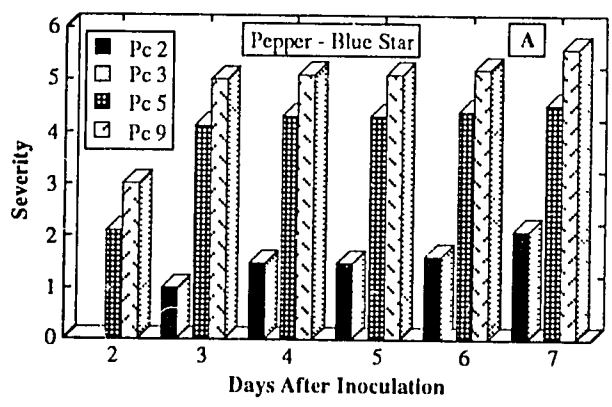
Host range. No symptoms were recorded on cabbage, cucumber, eggplant, and tobacco when either foliar- or drench-inoculated. Foliar-applied inoculum caused symptoms on pepper and tomato leaves while

drench-applied inoculum caused symptoms only on pepper plants. When foliage of black nightshade was inoculated, isolate Pc4 caused all plants to die while isolate Pc9 caused some stem blight but did not kill the plants. Both isolates caused two of the five plants of black nightshade to have stem blight when drench-inoculated. Symptoms on potato only occurred when foliar-inoculated and atypical symptoms were observed as eruptions of the leaf laminar without any necrosis.

The isolates did show host preferences as only black nightshade, pepper, and tomato were susceptible, while other reported hosts such as cucumber and eggplant were not infected using the inoculation method. Symptoms on tomato occurred when foliar-inoculated but not when drench-inoculated. Black nightshade was more susceptible when roots were inoculated. The data indicate that there are differences in susceptibility between foliage and roots of some hosts.

Plant age. At 10 days after inoculation, all pepper plants died regardless of plant age or isolate. Tomato plants inoculated 1 and 2 weeks after emergence died; however, no symptoms were observed on plants inoculated 4 weeks after emergence. All three-week old plants died when inoculated with isolate Pc5, and only one plant out of four died when inoculated with isolate Pc9. Older tomato plants have more resistance when root-inoculated than do seedlings.

Virulence of isolates. Tomato plants inoculated by soil drenching had no disease whereas all pepper plants wilted after 7 days. When pepper and tomato plants were foliar-inoculated, isolates Pc5 and Pc9 were significantly more virulent than the other isolates (Fig. 1). Tomato and pepper plants were equally susceptible after 7 days, and the relative ranking for each isolate was similar over both hosts. Isolate Pc3 was least virulent on pepper and tomato plants. Isolate Pc9 (tomato isolate) was most virulent while other isolates like Pc3 were low in virulence on pepper and nonpathogenic on tomato. Isolate Pc9 originated on tomato foliage and it is not known how frequently *P. capsici* occurs on tomato foliage under field conditions, but our studies show that it has the potential to cause foliar blight of tomato.



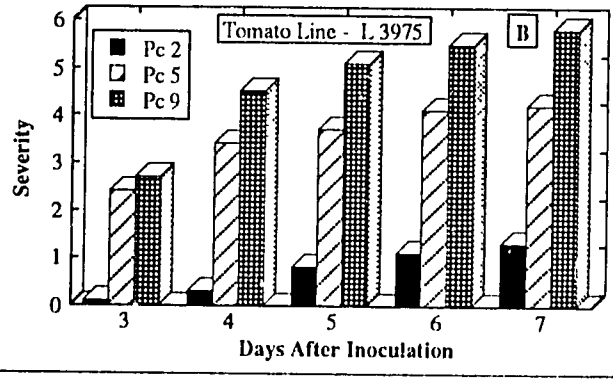


Fig. 1. Phytophthora blight severity on pepper (A) and tomato (B) plants soil-drench inoculated with different isolates of *Phytophthora capsici*.

Inoculation of tomato lines. Uninoculated had no symptoms. There were significant differences in disease severity among the tomato lines. L 418 had the lowest rating (3.3) which was significantly lower than severities from other lines. Although *P. capsici* has not been shown to cause late blight-like symptoms in the field, late blight occurs but in most cases the fungus has not been cultured or properly identified. It is suspected that in some cases the causal organism may be *P. capsici*. Under warm temperatures in the tropics, *P. infestans* probably does not survive based upon the low optimum temperature for causing disease. Isolates of *P. capsici* and *P. infestans* have been inoculated on foliage of tomato plants at different temperatures and no obvious differences in blight symptoms have been found. It appears that both fungi could be important in causing late blight of tomato in highland tropical environments.

Pepper Physiology

Direct Regeneration of Pepper Cotyledon Explants

Summary

Efforts to establish a protocol for the regeneration and multiplication of transformed pepper explants were made as part of a Council of Agriculture-funded AVRDC/DCB collaborative project to develop hot and sweet peppers with resistance to cucumber mosaic virus through the introduction of the viral coat-protein gene. With additions of ascorbic acid 50 mg/l, glycine 2.1 mg/l, and casein hydrolysate 0.25 g/l, explants of sweet peppers, C00157D and PBC 275, were regenerated into plantlets through callus within 35 days of culturing on MS medium supplemented with IAA 1 mg/l and BA 2 or 3 mg/l; and hot peppers, Szechuan and PBC 322, on MS medium supplemented with IAA 1 mg/l and BA 5 to 10 mg/l, or zeatin 5 mg/l. The regenerants were transplanted to soil and developed into normal plants with fruits. Work is still in progress on the regeneration of explants coincubated with *Agrobacterium tumefaciens* LBA4001 containing beta-glucuronidase and kanamycin resistance-marker genes.

Introduction

As part of a Council of Agriculture-funded AVRDC/DCB collaborative project, work was initiated to transform hot and sweet peppers with resistance to cucumber mosaic virus (CMV) through the introduction of coat-protein gene. However, a prerequisite for the *Agrobacterium tumefaciens*-mediated transformation is the success in plant regeneration. It is remarkable that species and genera of the *Solanaceae* differ widely in their in vitro regeneration responses. *Capsicum annuum* and related species are examples where most of the possible techniques of in vitro regeneration have been least demonstrated. Knowledge of the tissue-culture responses of pepper is limited, especially concerning detailed studies which are easy to reproduce. In the present study, the regeneration ability of cotyledon segments cultured in vitro was investigated.

Materials and Methods

Seeds of sweet peppers, C00157D and PBC 275, and hot peppers, Szechuan and PBC 322, were surface sterilized by immersing in 85% alcohol for 10 sec, and then in 1% sodium hypochloride with 1% Tween 20 for 5 min. After rinsing thoroughly with sterile, distilled water three times, seeds were germinated on full or half strength MS medium at 25–27°C with 16 hours of light at 2000–3500 lux and 8 hours of darkness. Twelve to 18 days after germination, expanded cotyledons were excised, cut into small segments (0.3–0.5 cm), wound, and then transferred to MS basal salt medium containing sucrose 30 g/l, and agar 0.8% at pH 5.8. Explants of sweet peppers C00157D and PBC 275 were cultured in MS medium supplemented with 2.1 mg/l glycine, 0.25 g/l casein hydrolysate, 50 mg/l ascorbic acid and different combinations of BA and IAA to induce shoot formation, and promote shoot elongation. Elongated shoots were then transferred to MS medium with 0.1 mg/l NAA to induce root formation before being taken out out from the test tubes and planted into pots.

Rooted calli were later transferred to MS media supplemented with 3 mg/l BA or 2 mg/l BA and 1 mg/l IAA to induce shoot formation. Calli with embryoids, with or without prior root initiation, were cultured in their respective media for 1 month and transferred to new media once during this period. Buds were later dissected and transferred to MS media supplemented with 2 mg/l BA and 1 mg/l IAA for shoot elongation, and then transferred to MS media supplemented with 0.5 mg/l IAA.

Results and Discussion

Shoots formed in MS medium were supplemented with 3 or 2 mg/l BA and 1 mg/l IAA after 2–3 weeks (Fig. 1). In a separate trial, roots were formed on explants cultured in MS medium supplemented with 0.5 mg/l IAA for 1 week. Plantlets were formed after 3 weeks of culturing. Under these culturing conditions, about 70–90% of multiple shoot formation were produced. However, the survival rates of dissected shoots were reduced and they also turned brown. The addition of ascorbic acid improved the survival rate of dissected shoots.

Explants of hot pepper were difficult to regenerate into shoots with the protocol established for sweet peppers. However, MS media supplemented with 5 mg/l zeatin, or 5–10 mg/l BA and 1 mg/l IAA were able to induce shoot formation but with slightly lower rates, i.e. 50–70%, than those for sweet pepper (Fig. 1). Hot pepper PBC 322 was slow to respond to in vitro culture. The regenerated plantlets of both hot and sweet peppers were maintained on MS basal medium for 2 weeks and then transferred to vermiculite medium irrigated with mineral nutrient solution under mist conditions before transplanting into soil. They developed into normal plants with a good number of fruit set.

Thus it was possible to raise full plants from cotyledons in *Capsicum annuum* with different hormonal combinations. However, work is still in progress at AVRDC to optimize and improve the protocol responsive to *Agrobacterium tumefaciens* LBA4001 containing beta-glucuronidase (GUS) and kanamycin marker genes, and at DCB to introduce CMV coat protein gene into *Agrobacterium tumefaciens* LBA4001 containing GUS and kanamycin marker genes.

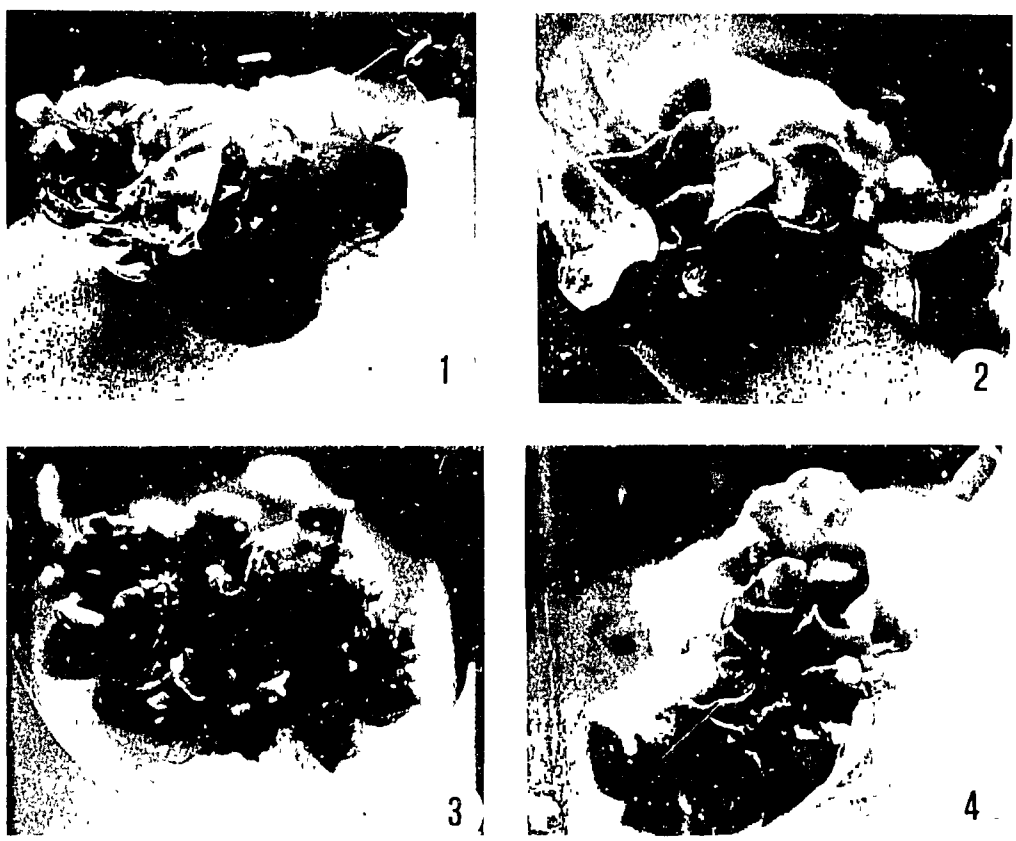


Fig. 1. A 4-week old culture showing shoot formation from dissected cotyledon segments on modified MS media: 1) sweet pepper, C00157D, on MS with IAA 1 mg/l and BA 3 mg/l; 2) sweet pepper, PBC 275, on MS with IAA 1 mg/l and BA 2 mg/l; 3) hot pepper, Szechuan, on MS with IAA 1 mg/l and BA 5 mg/l; and 4) hot pepper, PBC 322, on MS with IAA 1 mg/l and BA 7 mg/l.

High Temperature Acclimation of Hot Pepper Roots

Summary

Root growth and electrolyte leakage were used to quantify heat-stress injury in 'Passion' hot pepper excised roots. Lethal temperatures of 42°C were estimated from the limited growth increment. Exposure to 1 hour at 40°C or 5 hours at temperatures above 32°C increased heat tolerance of excised roots. This study demonstrated the capacity for in vitro acclimation of excised roots.

Introduction

High temperature tolerance of plants varies with genotype, physiological status, and tissue age. Tissue responses to heat stress can be measured following exposure to a series of temperatures for a fixed duration or by varying the duration at a fixed temperature. Heat tolerance levels can also be influenced by growth temperature and exposure to nonlethal doses of heat stress before the evaluation of heat tolerance.

Since the root development of pepper is sensitive to high temperature, the objective was to determine the capacity of hot pepper roots to acclimate to high temperatures. The relationship between exposure temperature and duration was also examined. Acclimation was studied by subjecting root segments to acclimating treatments in vitro.

Materials and Methods

Seeds of the hot pepper "Passion" were sterilized with 90% ethanol for 10 sec and then with 10% calcium hypochloride for 5 min before germinating in the dark for 8 to 9 days at 25°C. When the primary root reached 20–25 mm long, the terminal 10 mm section was excised and transferred to a test tube. Each tube contained five root segments, and 5 ml of liquid medium of $Ca(NO_3)_2 \cdot 4H_2O$ 236.0 mg/l, $FeSO_4 \cdot 7H_2O$ 2.0 mg/l, KCl 65.0 mg/l, KH_2PO_4 12.0 mg/l, KNO_3 81.0 mg/l, $MgSO_4 \cdot 7H_2O$ 36.0 mg/l, and sucrose 4%. Four test tubes were used for each treatment. Excised root segments were subjected to 40, 37, 36, 35, 33 or 32°C for 1, 3 or 5 hours right after excision. After that, they were incubated at 25°C for 24 hours. Stress responses were measured with root growth increments or heat injuries based on electrolyte leakage.

Root segments without brief heat treatment were also prepared (i.e. control).

Preliminary experiments indicated that incubation of root segments for 60 min at 42°C resulted in undetectable or minimal growth. Therefore, this treatment was used as a heat-killing treatment. At 24 hours after heat treatments, excised root segments were treated with 42°C for 60 min (i.e., heat killing) before returning to 25°C for 7 or 8 days (control).

Results and Discussion

Brief heat treatments increased the root segment's heat tolerance (Table 1). Heat tolerance was achieved after 1 hour at 40°C; however, extended duration at this temperature resulted in the loss of heat

Table 1. Growth Increments (mm) of excised root segments of hot pepper subjected to different temperature treatments[a].

Temp (°C)	1 hour	3 hours	5 hours
40	5.2±2.0	3.5±2 8	1 9±1.0
37	7 5±2.2	7 7±3 3	7.2±2.4
36	7 9±3.5	4.1±1.1	8.6±2.1
35	6 8±3.1	8.2±2 9	6.8±3 1
33	7.9±2.2	9.7±3.7	4.0±2.7
32	4 0±1 4	4.3±1 2	8.2±1.2
Control	3.6±1.6		

[a]Root segments are transferred to 25°C for 24 hours before heat-killing at 42°C for 60 min and then returning to 25°C for 7 days.

tolerance. On the contrary, extended durations to 5 hours at temperatures above 32°C could also increase heat tolerance. Results clearly indicated the capacity for in vitro acclimation of root segments.

Acclimation of excised root in vitro, as expressed by electrolyte leakage, was also observed with treatments at 40°C for 60 min (Fig. 2). Brief heat treatment at 32 or 36°C for 60 min was not effective in enhancing heat tolerance of root segments. Results also indicated that excised root segments deacclimated in 4 days after being transferred back to 25°C. However, with long exposure (2–6 days) to 32°C, excised root segments deacclimated slower, starting 6 days after being transferred back to 25°C (Fig. 3).

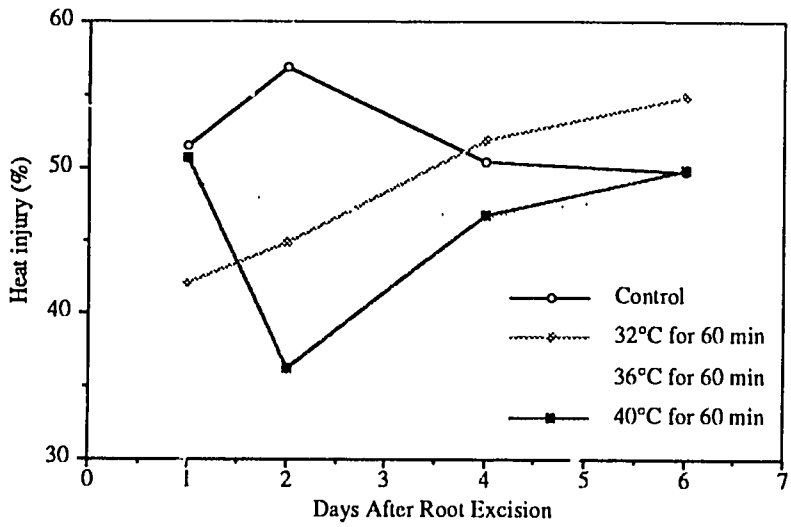


Fig. 2. Heat injury of excised root segments which were exposed to different temperatures for 60 min immediately after excision.

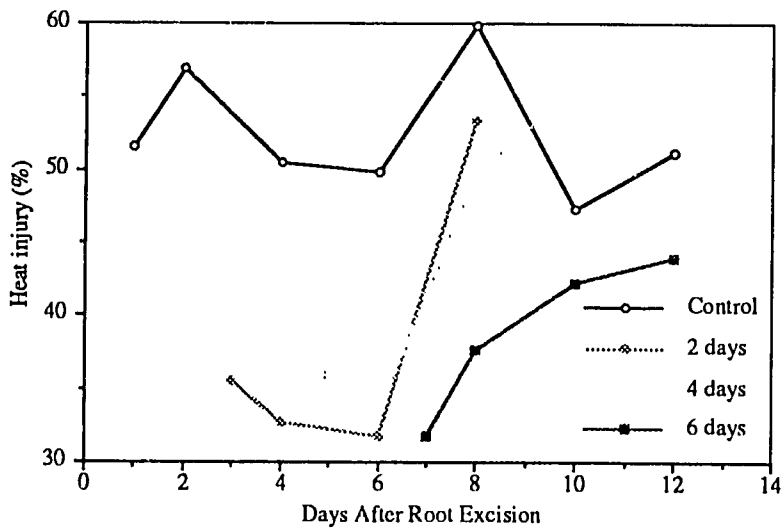


Fig. 3. Heat injury of excised root segments which were exposed to 32°C for different durations immediately after excision.

Pepper Virology

Virus Resistance Screening

Summary

Germplasm is routinely screened at AVRDC for resistance to cucumber mosaic virus (CMV) and other viruses such as chili veinal mottle virus (CVMV), potato virus Y (PVY), tobacco mosaic virus (TMV), tomato mosaic virus (ToMV), and pepper mild mottle virus (PMMV). These viruses are important in South and Southeast Asia.

Eighty-six GRSU accessions and 37 landraces from Thailand and Indonesia were screened in 1991. None were resistant to CMV or CVMV. Eighteen accessions and seven landraces from Thailand were resistant to PVY. ToMV resistance was present in 32 accessions and in one line each from Thailand and Indonesia. Most of these were also resistant to TMV. Three accessions were resistant to PMMV. One line (*C. chinense*) with multiple resistance (PVY, ToMV, TMV, PMMV) was also identified.

To improve the efficiency of virus screening, the use of detached leaves for tobamoviruses and mixed virus inoculum for CMV, CVMV and PVY was investigated. In the case of tobamoviruses there was no difference between inoculation of the whole plant and detached leaves at any leaf position up to the tenth leaf.

Multiple virus (CMV, PVY, CVMV) screening was found to be possible by inoculation of a virus mixture onto any of the leaves up to the fifth leaf. This inoculation scheme was tested on 13 *Capsicum* lines using virus in crude sap and inoculating the second true leaf. No significant difference was found between multiple and single virus inoculation of these lines.

Introduction

Capsicum germplasm is routinely screened for resistance to seven viruses. Among these are three aphid-transmitted viruses (CMV, PVY, CVMV) and three tobamoviruses (TMV, ToMV, PMMV). These viruses are all mechanically transmitted. The latter are highly contagious and thus screening has to be done in an isolated area to avoid contamination of the greenhouse. Screening for each virus individually takes considerable time, space and labor. Furthermore, efficiency of inoculation was found to depend on the plant growth stage and on the virus. A study was deemed necessary to investigate whether screening with at least some of the viruses might be combined.

In previous resistance screenings, resistance to PVY was readily found in *C. annuum* and related species. CVMV resistance however, was present only in a few lines obtained by INRA, France, which are all of the same parentage. Resistance to PMMV was found in only a few lines. Resistance to CMV was not found. For the 1991 screening of the germplasm collection accessions with reported virus resistance and some randomly chosen wild species were mainly selected. Main emphasis was on CMV, but also on CVMV and PMMV. Some field-tolerant landraces collected by cooperators in Thailand and Indonesia were also screened.

Screening of Germplasm for Resistance

Materials and Methods

Plants were inoculated either at the 2-leaf stage (for CMV), at the 4-leaf stage (CVMV, PVY) or at the 5-leaf stage (tobamoviruses). A first ELISA test was conducted 2 weeks after the inoculation. ELISA negative plants were reinoculated with the respective virus. A second ELISA test was then conducted

2 weeks after the second inoculation. Depending on the availability of seed, between 12 and 45 plants per accession were inoculated with each individual virus.

Thirty-one GRSU accessions were screened for CMV, CVMV, PVY, ToMV and PMMV. Another 55 GRSU accessions were screened for the same viruses and also TMV. Thirty-three landraces from Thailand and four landraces from Indonesia showing no or only mild symptoms in the field were screened for resistance to CMV, CVMV, PVY, ToMV and PMMV.

Results and Discussion

GRSU accessions. None of the accessions were resistant to CMV or CVMV. The lines resistant to the other viruses are listed in Table 1.

Table 1. Virus resistance in GRSU accessions.

Acc. No.	Species	PVY	ToMV	TMV	PMMV
002	?[1]	R/S	R	R/S	S
229-1	*annuum*	R	S	S	S
304	*chinense*	R	R	R	R
318	?	S	R	NT	S
352	?	R	S	S	S
373	?	R	S	S	S
574	?	R	S	S	S
595	?	R	S	S	S
753	*annuum*	R	S	S	S
753-1	*baccatum* var. *pendulum*	R	R	R	S
754	*baccatum* var. *pendulum*	S	R	S	S
774	*baccatum* var. *pendulum*	S	R	NT	S
755	*baccatum* var. *pendulum*	S	R	R	S
776	*chinense*	S	R	NT	S
776-1	*frutescens*	S	R	NT	S
773	*baccatum* var. *pendulum*	S	R	R	S
803	*baccatum* var. *pendulum*	R	R	NT	S
848	*frutescens*	R	R	R	S
883	*chinense*	S	R	NT	S
897	*frutescens*	S	R	R	S
917	*chinense*	S	R	R	R
940	*chinense*	R	R	NT	R
948	*baccatum*	S	R	R	S
966	*frutescens*	S	R	R	S
967	*chinense*	S	R	R	S
1090	?	R	R	R	S
1172	*baccatum* var. *pendulum 3-4*	R	R	R	S
1173	?	R	R	S	S
1174	*chinense*	S	R	R	R
1175	?	R	R	R	S
1176	?	R	S	S	S
1177	*chinense*	S	R	R	S
1178	*baccatum* var. *pendulum*	S	R	R	S
1218	*baccatum* var. *pendulum*	S	R	S	S
1511	*annuum*	R	S	S	S
1610	*frutescens*	S	R	R	S
2377A	?	S	R	R	S
5078	?	R	S	NT	S
5106	?	S	R	NT	S
5116	*annuum*	R	S	NT	S
5131	*annuum*	R/S	S	NT	S
5132	*annuum*	R/S	S	NT	S
5418	*frutescens*	S	R	NT	S
5552	*frutescens*	S	R	NT	S

[1]?=not known, R=resistant, S=susceptible, R/S=segregating for R and S, NT=not tested.

Landraces from Thailand. None showed resistance to CMV or CVMV, although a few lines, such as Huey Sithon Kanchanburi, Chee Pha Mundang #2, Chiang Mei See Som #4, and Sri Saket contained between 30 and 50% CVMV-resistant individuals. PVY resistance was present in seven lines: Hua Rua #1, #2, and #3, Sri Saket, Kee Noo Chinda #1, Chinda #23, and 24. A few lines contained a high proportion of PVY-resistant plants (Hua Rua #1 Ubonrathchathani, Huey Sithon Kanchanaburi, Kee Noo Chinda #2 and #4 and Chee Pha Mun #49). All lines but one were susceptible to the three tobamoviruses tested. Line Khi Noo Kao was resistant to ToMV and TMV.

Landraces from Indonesia. Only line LV 2411 was found to have resistance to ToMV and TMV.

Resistance to PVY, TMV and ToMV is readily available. In most cases the lines resistant to ToMV are also resistant to TMV but not necessarily to PMMV. Accessions with resistance to both TMV and ToMV most likely possess the L3 gene for tobamovirus resistance. Resistance to CVMV continues to be difficult to find. CMV resistance appears to be extremely rare. Most of the materials with reported resistance to CMV have been collected from various sources, but so far all of these were found susceptible to the Taiwan isolate of CMV. The few lines identified in 1990 which contained some individuals with resistance to CMV were escapes, since they proved to be susceptible in the 1991 confirmatory screenings.

In the future therefore, priority will be given to screening for resistance to CMV, CVMV and PMMV.

Improvement of Screening Efficiency

Materials and Methods

The processes and the materials used in this study are as follows:

Use of detached leaves for tobamovirus screening. Three lines (C00899, C00848 and VC 23a) and four tobamoviruses (ToMV, TMV, PMMV, TMGMV) were tested. The first, second, third, fourth, fifth, sixth, eighth, and tenth leaves were cut when fully expanded and inoculated with a 1:40 homogenate of the virus in 0.01 Na-Phosphate buffer pH7.0 containing 0.1% carborundum. Twenty leaves for each treatment were inoculated and placed on a moist paper towel in a sealed box with a translucent cover. Half of the leaves were placed at 22 and the other half at 32°C. Visual symptoms were observed after 3 and 5 days.

Inoculations with single and mixed pure viruses. Three viruses were used: CMV, CVMV and PVY. The cotyledon, second, third and fifth leaf were inoculated either with single viruses, or with mixed combinations of 2 and 3 viruses, at 260 µg/ml of individual virus. The hot pepper cultivar Newcomer which is susceptible to all three viruses was used.

ELISA tests were performed on the first, second and third leaf above the inoculated leaf at 6, 14, and 21 days after the inoculation, respectively. Leaf disks of 1-cm diameter (approximately 0.012 g) were used for the ELISA test. From plants inoculated with single viruses one disk was ground in 0.3 ml extraction buffer; in the case of mixed inoculation with two viruses, two leaf disks were ground in 0.6 ml extraction buffer, to be tested for two viruses individually; and in the case of mixed inoculation with three viruses three leaf disks were ground in 0.9 ml extraction buffer, to be tested for three viruses individually. This assured that the same amount of plant tissue was used for the ELISA test of each virus. Also, the same batch of IgG and enzyme conjugates at the same concentrations were used. There were 10 replications consisting of single plants. Plants were arranged in completely randomized design.

Inoculations with single and mixed virus in plant sap. Twelve lines were used in this study: 3 *C. frutescens*, 2 each of *C. baccatum*, *C. chinense*, *C. annuum*, and an unidentified species, and line VC 23 which was previously found susceptible to all three viruses. The lines were inoculated at the 2-leaf stage with single viruses (CMV, PVY, CVMV) and with a mixture of the three viruses in crude plant sap. An ELISA test was conducted on the first leaf above the inoculated leaf 6 days after inoculation. Twenty plants were inoculated for each line, each virus and virus mixture. There were three replications and plants were arranged in a completely randomized design.

Results and Discussion

Use of detached leaves for tobamovirus screening. The reactions on detached leaves appeared as early as 3 days after inoculation and were the same as those on the whole plant. When local lesion symptoms

appeared on the plant, they also appeared on the detached leaves. However, when the plant reacted with systemic mosaic, detached leaves showed no symptoms. Leaves at all positions reacted the same way. There was also no difference observed between leaves kept at 32 and at 22°C.

The detached leaf method is thus useful for screening for resistance to tobamoviruses. Resistance can be readily identified after 5 days by the appearance of local lesions at either 32 or 22°C. In routine resistance screening 40 plants are usually used. CMV and CVMV are usually inoculated at the 2- and 4- leaf stage, respectively. The same plants can be used for tobamovirus resistance screening simply by excising the first fully expanded leaves and inoculating these with the individual tobamoviruses.

Inoculations with single and mixed pure viruses. CMV: In the case of CMV, the highest OD values were generally obtained when the second, third or fifth leaves were inoculated and the first leaf above the inoculated leaf was used for the ELISA test, 6 days after the inoculation (Fig. 1). The OD values obtained from mixed inoculation were generally, similar or higher (particularly when PVY was involved) than when CMV was used alone.

PVY: In the case of PVY, the highest OD values were obtained when the cotyledon, second, third and fifth leaves were inoculated and the second leaf above the inoculated leaf was used for the ELISA test at 14 days after inoculation (Fig. 1). This may reflect the slower movement of PVY within the plant, compared to CMV. The OD values were generally lower in mixed virus inoculation.

CVMV: The OD values for mixed inoculations were generally lower or similar to those of the single virus inoculations (Fig. 1). There were no great differences between the different plant stages at inoculation, except when CVMV was inoculated singly at the cotyledon stage. In that case, OD values were extremely low at the first ELISA test on the first leaf above the inoculated leaf, but then increased at the second ELISA test on the second leaf, indicating that the virus gets established slowly and moves only slowly within the plant.

Based on the above results, multiple virus screening can be effectively done by inoculation of any of the leaves up to the fifth leaf. To save on time and greenhouse space, future virus resistance screening will be done by multiple virus inoculation at the second fully expanded leaf stage. The ELISA test for all three viruses, CMV, PVY and CVMV will be conducted on the first leaf above the inoculated leaf 6 days after the inoculation.

Inoculations with single and mixed virus in crude plant sap. In the 13 lines tested there was no significant difference observed in the percentage of CMV, CVMV, and PVY infection when the viruses were used individually or when all three viruses were mixed together in the inoculum.

Virus Detection, Purification and Antiserum Production

Summary

Seven viruses which are important on peppers in Southeast Asia (CMV, CVMV, PVY, ToMV, PMMV, TMV, and TMGMV) have been purified and polyclonal antisera produced for use in resistance screening, surveys and diagnosis. Polyclonal tobamovirus antisera were found to cross-react in ELISA. Therefore, the production of monoclonal antibodies was attempted and PMMV-specific MCAs have been produced.

Introduction

For resistance screening, surveys, and diagnosis of viruses, antisera are needed. Cucumber mosaic virus (CMV), chili veinal mottle virus (CVMV), potato virus Y (PVY), tobacco mosaic virus (TMV), tomato mosaic virus (ToMV) and pepper mild mottle virus (PMMV) are important in Southeast Asia. Because of the large number of samples handled by AVRDC and the great demand by its partners in the national programs, particularly the network cooperators, maintaining a constant large supply of antisera to these viruses is important.

The tobamoviruses [TMV, ToMV, PMMV, and tobacco mild green mottle virus (TMGMV)] all of which have been isolated from peppers in Taiwan are very closely related and thus cannot be readily

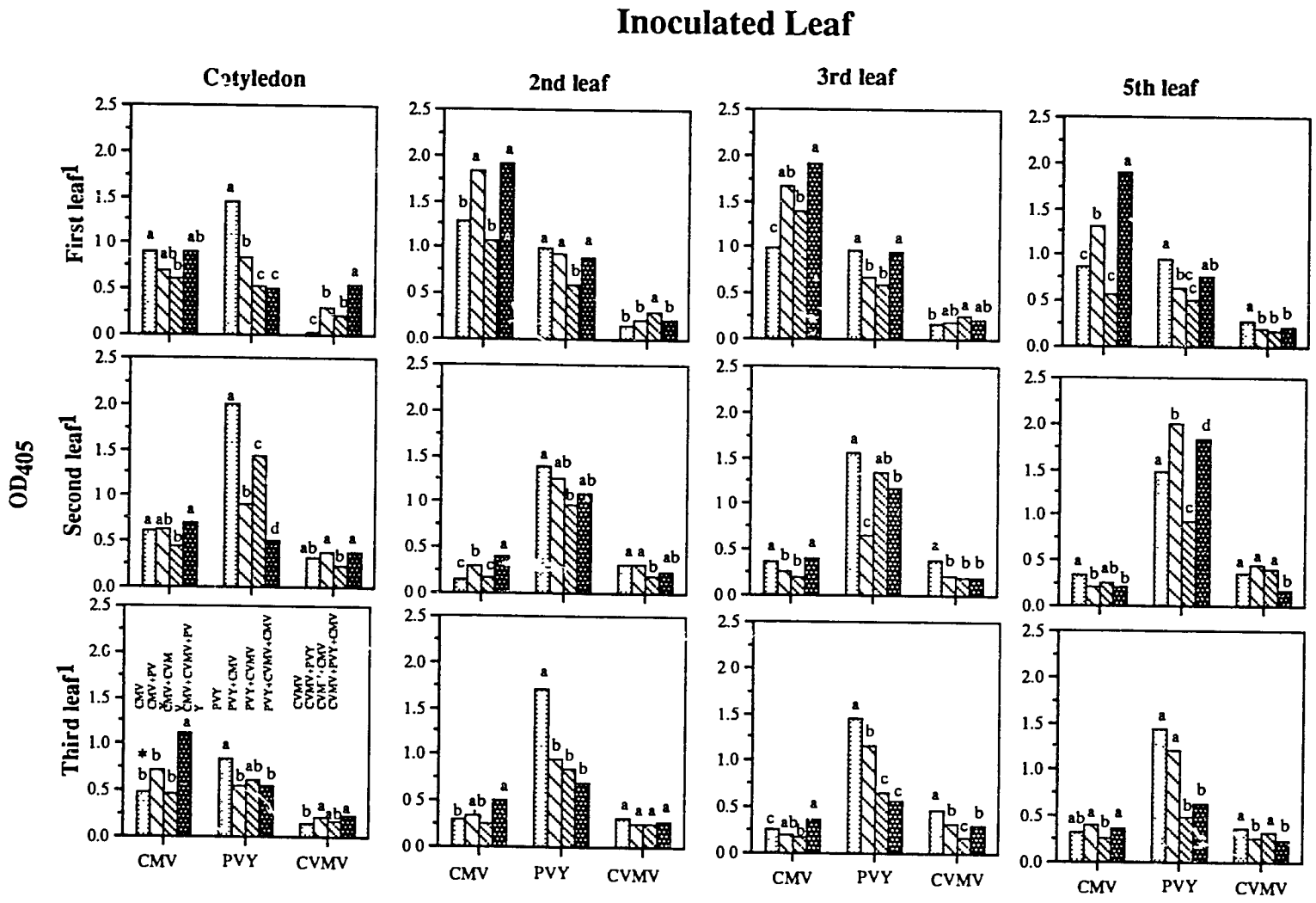


Fig. 1. ELISA OD_{405} values of single and mixed virus inoculations (*above the inoculated leaf).

detected by routine serodiagnostic methods such as ELISA using polyclonal antisera. Monoclonal antibodies should be more effective for rapid differentiation of these viruses.

Monoclonal Antibodies for the Serological Differentiation of Tobamoviruses

Materials and Methods

Initially one tobamovirus, PMMV, was selected for monoclonal antibody production.

Virus purification. PMMV isolate 1504, originating from hot pepper in Taiwan, was multiplied in *Nicotiana tabacum* Samsun following four single local lesion transfers in *N. glutinosa*. Leaves were harvested two weeks after inoculation. Virus purification was done using a modification of Garcia-Luque (1991)'s procedure.

Polyclonal antibodies. Polyclonal antiserum was prepared by five intramuscular injections of rabbits with purified virus (2 mg/ml) at weekly intervals. For the first injection 1 ml virus suspension was emulsifield 1:1 with Freund's complete adjuvant. For the following three injections incomplete adjuvant was used. The rabbit was first bled 1 week after the last injection.

Monoclonal antibodies. Four to eight-week old BALB/c mice were used for immunization. They received three intraperitoneal injections of 50–70 µg purified virus, at 1–3 week intervals between injections. For the first injection, the virus was emulsified (1:1) in Freund's complete adjuvant. For the remaining two injections incomplete adjuvant was used. Three days before the fusion, the mice received a final intraperitoneal immunization of 100-140 µg virus in phosphate buffered saline (PBS).

Three days after the last injection, isolated spleen cells were fused with myeloma cells, using 45% PEG 4000, 50% RPMI medium and 5% DMSO as the fusion medium. A total of five fusions were made following five different immunization schemes. Selection of virus-positive hybridoma cells was in HAT medium. The selected hybridomas were cloned by limiting dilution, using mouse thymocytes as feeder cells. Cloning was repeated two times. Hybridomas were stored in liquid nitrogen.

Screening for PMMV-specific hybridomas was by indirect ELISA, using PMMV-specific rabbit polyclonal antiserum for coating (at 1:3000 and 100 µl/well). Goat antimouse horse radish peroxidase (GAM-HRP) and the substrate 0-phenylenediamine (OPD) were used to detect positive hybridomas.

Results and Discussion

The purification method used yielded 29–65 mg PMMV per 100 g virus-infected leaves. The virus concentration was calculated at 3.7–14.6 mg/ml, using an extinction coefficient of $E^{(0.1\%/1cm)}$ at 260 nm = 3.18 (Wetter et al. 1984)[1].

The results of the fusions are summarized in Table 2. The highest percentage of PMMV positive hybridomas was achieved from fusion V, where immunizations were every 7 days and the myeloma line NS-1(S) was used. None of these PMMV positive hybridomas reacted in indirect ELISA with ToMV, TMV or TMGMV.

Production of Antisera to Important Viruses of Peppers

Materials and Methods

Seven viruses were purified for antiserum production to be used in AVRDC's virus surveys and resistance screenings and for distribution to the ADB AVNET virus network cooperators. The purification hosts were as follows: *N. glutinosa* (CMV), *Petunia hybrida* (CVMV), *N. tabacum* 'Xanthi (PVY), *N. sylvestris* (TMV), and *N. tabacum* 'Samsun' (PMMV, ToMV, TMGMV).

A modified method of Garcia-Luque (1990)[2] was used for the purification of tobamoviruses.

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[1]Wetter, C., Conti, M., Altschuh, D., Tabillion, R. and van Regenmortel, M. H. V. 1984. Phytopathology 74.405-409.
[2]Garcia-Luque, M. T., Serra T., Alonso, E., Wicke, B., Ferrero, M. L. and Diaz-Ruiz, J. R. 1990. J. Phytopathology 129: 1-8.

Table 2. Production of PMMV-specific monoclonal antibodies.

Fusion	Immunization intervals (days)[a]	Myeloma line[b]	PMMV-specific % positive hybridomas
I	7[c]	NS-I (W)	20
II	14	FO	29
III	21	NS-I (S)	36
IV	3	NS-I (W)	20
V	7	NS-I (S)	50

[a]The mice were immunized by intraperitoneal injection of purified virus with the exception of fusion IV, where the virus was injected directly into the spleen.
[b]NS-I (W) (W. Y. Wang, Taipei), NS-I (S) (Veterans General Hospital, Taipei); FO (M. V. Lin, NPPI, Taichung).
[c]Time between injections

The method described by Lot et al. (1972)[3] was used for CMV purification and for CVMV and PVY, the method described by Lisa et al. (1981)[4] was followed.

Results and Discussion

The following virus yields were obtained: CVMV 10.49–16 mg, CMV 0.25–1 g, PVY 80.4 g, TMV 1.27 g, TMGMV 0.71 g, ToMV 0.31–1 g, PMMV 0.3–0.65 g per kg infected leaf tissue.

Polyclonal antisera to all viruses were produced in New Zealand white rabbits for use in DAS ELISA. All IgGs can be used at 1:1000. The yield of CVMV was rather low and for future purifications the purification host, or the purification method will need to be modified. It was noted that antisera to some of the tobamoviruses, particularly TMV, ToMV and PMMV cross-reacted with one another, because these viruses are very closely related. More specific monoclonal antibodies and DNA probes that do not cross-react are therefore being produced.

Reduction of Virus Incidence in the Field

Summary

In a preliminary field test, the aphid-repellent properties of various reflective mulches were tested. Highest repellency was observed on the Japanese metallized film POLYSHINE N, and the whitewash-coated Taiwan foil which attracted an average of 54 and 39% fewer aphids, respectively, than the mulch commonly used by the pepper growers in Taiwan. Aphid repellency was found highly positively correlated to virus incidence.

A floating net cover, an aphid alarm pheromone, whitewash coating of the plants and reflective mulches were tested in the field in fall. Highest yields were on POLYSHINE N-mulched plots plus insecticide and Taiwan reflective foil covered plots plus 1/3 insecticide and 0.01% alarm pheromone on the plants. These treatments also had the highest number of aphid-free plants and lowest CMV incidence.

In spring the same treatments were tested as well as additional ones including straw mulch, whitewash-coated straw mulch, a leaf protectant, close plant spacing and the biological insecticide Neem, which in a preliminary laboratory study was found to adversely affect aphid feeding. CMV incidence was delayed by three treatments: Taiwan reflective foil plus insecticide, POLYSHINE reflective foil plus insecticide and close plant spacing. The Taiwan reflective foil plus Neem had the highest number of aphid-free plants, followed by Taiwan reflective foil plus whitewash on the plants and by the POLYSHINE foil plus weekly insecticide. These three treatments also had the lowest number of aphids on the plants. The three treatments

[3]Lot, H., Marrou, J. and Esvan, C. 1972. Annals of Phytopathology 4: 25-38.
[4]Lisa, V., Baccardo, G., D'Agostino, G., Delavalle, G and Aquila, M. 1981. Virology 71: 667–671.

with the highest total yield were POLYSHINE N plus insecticide (1/3 strength), and whitewash-coated Taiwan foil with either whitewash or leaf protectant on the foliage. Correlation was low between yield and virus incidence, aphid-free plants and the number of aphids colonizing the plants. Several insecticide-free treatments (whitewash-coated Taiwan foil, Taiwan reflective foil plus whitewash on the plants, POLYSHINE mulch and Taiwan reflective foil plus leaf protectant on the plants) were identified, which gave yields comparable to or higher than those obtained by the local farmers using Taiwan reflective foil plus weekly insecticide on the plants.

Introduction

Virus diseases are considered the major constraint to economic production of peppers in the tropics. In the Asian tropics cucumber mosaic virus (CMV), potato virus Y (PVY) and chili veinal mottle (CVMV) predominate on both hot and sweet peppers. These viruses are transmitted by aphids in a nonpersistent manner, i. e. aphids acquire the virus within seconds while probing on infected hosts and are able to transmit the virus to healthy plants immediately thereafter. Thus, insecticides are of little use in the control of these viruses, because the aphids would have already transmitted the virus before they could be killed by the insecticide. Alternative control measures, which are aimed either at the landing behavior of the aphids, or at interfering with the transmission process, could offer more effective control of these nonpersistently aphid-transmitted viruses. A series of experiments was therefore initiated to investigate the effectiveness of some of these alternative methods, which have been tried successfully in temperate, but rarely in tropical and subtropical environments.

This year, the effectiveness of various reflective mulches with or without insecticides, whitewash on the mulch and on the foliage, an alarm pheromone (Farnesene), a protective net cover, close spacing and the biological insecticide Neem in reducing virus/vector incidence and increasing yield was investigated. Extracts from seeds of the Neem tree (*Azadirachta indica*) are known for their insecticidal properties; however, the usefulness of Neem in controlling aphids and ultimately aphidborne viruses has not been tested.

Effect of Azadirachtin (Neem) on Aphid Deterrence and on Aphid Feeding (Experiment 1)

Materials and Methods

Aphis gossypii which had previously been collected from fieldgrown pepper at AVRDC was used.

Aphid deterrence. Two fully expanded leaves of the sweet pepper cv. Blue Star were dipped for two minutes in either 1:10 or 1:100 solutions of Neem-Azal-S (1500 ppm) and allowed to air-dry. Two leaves with the stems wrapped in moist cotton were placed side by side in a plastic box (21 × 13 × 7 cm). Two water-treated leaves were placed in the same box, with their tips opposite those of the treated leaves but not touching them. Twenty winged aphids were placed on each of the Neem-treated leaves. The boxes were covered with cheesecloth and kept at room temperature. After 2 days, the number of aphids which had moved to the untreated leaves were counted. Ten replications were made.

Feeding behavior of aphids. One individual alate aphid, starved for 45 minutes, was placed on the third fully expanded leaf of a sweet pepper plant (cv. Blue Star), treated with 1:10 or 1:100 Neem. Aphid behavior was observed for 20 minutes. Water-dipped leaves were used as control. Ten plants served as 10 replications. A different aphid was used for each plant.

Results and Discussion

Neem-treated leaves are unattractive to *A. gossypii*. Aphids moved away from Neem-treated leaves (Table 3). There was no significant difference however between the two dilutions of Neem used.

The aphid feeding behavior was also affected by Neem. The total walking time was significantly increased while the total probe time was significantly decreased on Neem-treated leaves (Table 4). Furthermore, the time to first probe was significantly longer on the Neem-treated leaves than on the water-treated check. Neem may thus be effective in reducing the incidence of nonpersistently aphid-transmitted viruses because it causes the aphids to delay their first probe and to reduce their total probe time.

Table 3. Aphid deterrence by Neem.

Treatment	No. of aphids moving from treated to untreated leaves[1]
Neem 1:10	25 0 a
Neem 1:100	23 8 a
CK (water-treated)	4.5 b

[1]Numbers represent the means of 10 replications Mean separation within columns by DMRT (P=0 05).

Table 4. Aphid feeding response on Neem-treated *C. annuum* cv. Blue Star.

Treatment	Total walking time (sec)		Total probe time (sec.)		Time to first probe (sec.)	
Neem 1:10	418	a	695[1]	c	87	a
Neem 1:100	311	b	849	b	47	c
CK (water dipped)	224	c	941	a	35	b

[1]Numbers represent the means of 10 replications. Mean separation within columns by DMRT (P=0 05).

Effect of Reflective Mulches on Aphid Repellency and Virus Incidence (Experiment 2)

Materials and Methods

The aphid repellent property of five different mulches was tested, using the hot pepper cultivar Passion (Known You Seed Company). Treatments were as follows:

- Taiwan reflective foil (silvery side up) = TS
- Taiwan black foil = TB
- Japanese reflective foil I (metallized film POLYSHINE-N Hitachi) = J_1 (nontranslucent, thin)
- Japanese reflective foil II = J_2 (translucent, thick)
- Taiwan reflective foil (silvery side up), painted with a layer of the commercial white wash LOVEN = TSWW
- No mulch = check

Seed was sown in an insect-proof nethouse and transplanted to the field on 7 January. One day prior to transplanting, plants of all treatments were treated with insecticide (Decis 0.1%). A randomized complete block design was used with four replications. Plots of 3.2 × 3 m consisted of 2 double row beds with seven plants per row. Plant to plant distance was 45 cm and between plant distance, 55 cm. Distance between plots was 2 m. Plots were covered with the mulches 18 days before transplanting of the seedlings.

Aphid repellency. Aphid repellency of the mulches was measured by the numbers of aphids trapped on yellow sticky traps (40 × 25 cm) placed horizontally in the center of each plot. Initially, the traps were 30 cm above the bed, but were adjusted to canopy level after transplanting.

Aphid populations on the plant. Aphid counts on the plants were taken at 8, 16, 24, 36, 43, 50, and 57 days after transplanting (DAT) on all plants of the two center rows of each plot, except the end plants.

Virus incidence. Incidence of cucumber mosaic virus was recorded three times, at 14, 35 and 56 DAT, on the two center rows of each plot. Three leaves from the top, middle and bottom part of each plant were collected and pooled for the ELISA test.

Results and Discussion

Aphid repellency. All 5 mulches tested were effective in repelling aphids (Table 5) as measured by the number of aphids trapped on yellow sticky traps. The highest repelling effect was by the Japanese foil I, followed by the whitewash-painted Taiwan reflective foil on which an average of 74 and 64% fewer aphids respectively alighted, compared to the unmulched plots (Table 5). The aphid repellent effect was active up to 56 DAT, i. e. even when the plants had almost reached maturity (Table 5).

Table 5. Number of aphids trapped on yellow sticky traps[a].

Treat-ment	Before Transplanting[b] 1-7 DBT		8-14 DBT		After Transplanting 15-21 DAT		22-28 DAT		29-35 DAT		36-42 DAT		43-49 DAT		50-56 DAT		43-49 DAT		50-56 DAT		Ave.
TS	206	b[c]	223	cd	112	d	87	d	64	c	33	cd	86	c	105	c	41	bc	53	b	73
TB	253	ab	299	bc	142	c	101	c	61	c	40	bc	112	b	119	b	47	ab	57	b	85
J1	71	d	91	e	38	e	31	f	28	d	18	e	49	d	61	d	20	d	24	c	34
J2	229	b	314	ab	172	b	127	b	75	b	47	b	101	bc	104	c	38	c	51	b	89
TSWW	132	c	163	de	63	e	60	e	36	d	27	d	52	d	69	d	25	d	24	c	45
CK	295	a	388	a	234	a	204	a	106	a	64	a	157	a	191	a	53	a	94	a	138

[a]One yellow sticky trap (40 × 25 cm) was placed horizontally in the center of each plot. The height was adjusted to 20 cm above the canopy.
[b]Transplanting date 7 Jan. DBT = days before transplanting, DAT = days after transplanting
[c]Numbers represent the means of 4 replications. Mean separation within columns by DMRT (P = 0.05)

Aphid population on the plants. By 8 DAT almost all plants of the unmulched plots were infested with aphids whereas in unmulched treatments, aphid infestation ranged from 37 to 22% of the plants.

Up to 16 DAT, plants mulched with JF_1 had the lowest numbers of aphids. However, thereafter the aphid population increased in this treatment, which had the highest average number of aphids (Table 6). This high aphid population after 16 DAT could be associated with the more vigorous plant growth which was observed on plants in these treatments. This may be due to the higher soil temperature under this mulch and to increased photosynthesis of the lower canopy because of the high reflectancy of this foil. The lowest number of aphids was found on the unmulched check plants, whose growth however was very poor (Table 6).

Table 6. Aphid populations on the plants.

Treat-ment	Jan 15 (8 DAT)		Jan 23 (16 DAT)		Jan 31 (24 DAT)		Feb 12 (36 DAT)		Feb 19 (43 DAT)		Feb. 26 (50 DAT)		March 5 (57 DAT)	
TS	6	b[a]	30	b	49	bc	67	ab	68	bc	81	bc	78	b
TB	9	b	25	bc	149	a	147	a	97	b	84	b	81	b
J1	3	b	13	c	101	ab	146	a	168	a	170	a	161	a
J2	4	b	39	ab	37	bc	43	b	49	bc	31	cd	31	cd
TSWW	6	b	31	b	151	a	146	a	59	bc	55	bcd	62	bc
CK	46	a	56	a	7	c[b]	6	b[b]	16	c[b]	15	d[b]	15	d[2]

[a]Average of the number of aphids on 10 plants per plot and 4 replications. Mean separation within columns by DMRT (P=0.05).
[b]Plants of this treatment were not growing as vigorously as those of the other treatments

Incidence of cucumber mosaic virus. CMV was not found up to 14 DAT. By 35 DAT however, it was already present in all treatments (Table 7). Lowest incidence was in plots mulched with the Japanese foil 1, followed by plots mulched with the Taiwan reflective foil and the whitewash-coated Taiwan

Table 7. Incidence of cucumber mosaic virus (CMV).

Treatment	CMV Incidence (No of infected plants[a]) Feb 11 (35 DAT)	% decrease[c]	March 4 (56 DAT)	% decrease[c]	Ave. % decrease
TS	2.25 d[b]	72	6.75 c	49	65.5
TB	4.25 bc	47	12.00 ab	10	28.5
J1	1.75 d	78	6.75 c	49	63.5
J2	5.25 b	34	10.75 b	19	26.5
TSWW	2.75 cd	66	6.50 c	51	58.5
(CK)	8.00 a		13.25 a		

[a]The experiment was transplanted to the field on Jan. 7. All plants of the two center rows (= 14 plants) per plot were tested by ELISA.
[b]Numbers represent the means of 4 replications, mean separation within columns by DMRT (P = 0.05).
[c]With respect to the check (= treatment 6).

reflective foil. By 56 DAT CMV incidence reached nearly 100% in the unmulched plots. In plots of treatments TS, J_1 and TSWW incidence of CMV was significantly lower (about 50%) than in the unmulched plots.

The mean temperature, aphid and virus incidence during the course of the experiment are shown in Figure 2.

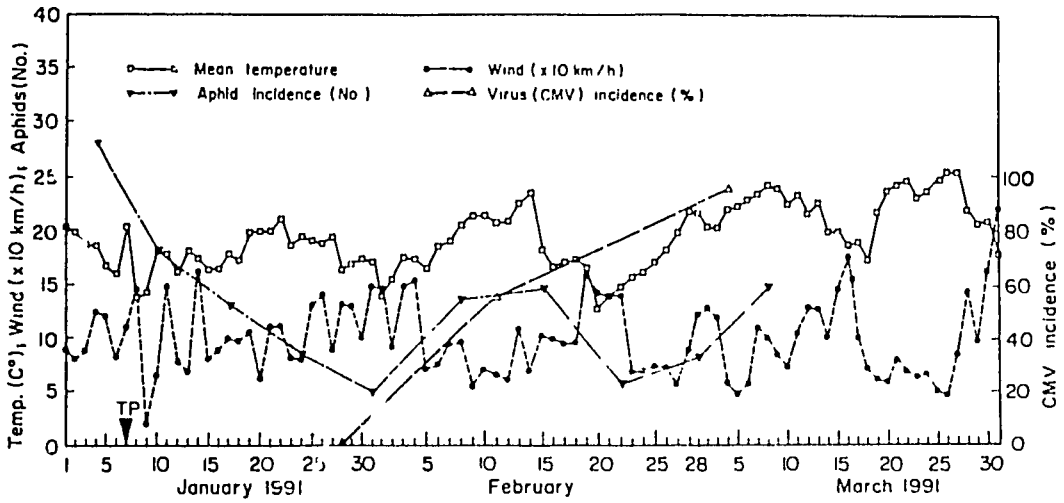


Fig. 2. Mean temperature, aphid and virus incidence during the course of the experiment.

Virus incidence was found highly positively correlated to the number of aphids caught on the yellow traps, an indication of the reflective capacity of the mulches. Incidence of CMV at 35 DAT was also highly negatively correlated to the number of aphid-free plants at 8, 16 and 24 DAT (Table 8). Correlation coefficients for CMV incidence and the number of aphids colonizing the plants were high only up to 16 DAT.

The low correlation coefficient of CMV incidence and the number of aphids colonizing the plants indicates that nonpersistent viruses are generally not transmitted by aphids colonizing the plants, but rather by migratory aphids which alight shortly on a plant and then move on. Therefore, it is expected that mulches with the highest aphid repellent property will be most effective in reducing virus incidence.

Aphids tend to colonize and multiply on the vigorously growing plants such as those on the JF_1 mulch. When high build up of aphids is observed in farmers' fields it may become necessary to apply systemic insecticide, in order to avoid direct damage to the plants by these aphids.

Effect of Various Measures Affecting Insect Behavior on Virus Incidence and Yield (Experiment 3a, Fall 1990–Winter 1991).

Materials and Methods

The hot pepper cultivar Passion (Known-You Co., Taiwan) was used with the following 14 treatments.

1. Taiwan reflective foil (silvery side up) no insecticide (= TS);
2. TS mulch plus weekly insecticide (alternating Kestrel (10%) at 1:1000 and Decis, 2.8 EC (1:1000) applied at 1 l/ha (= TSI_{KD}) (= Farmer's practice);
3. TS plus floating net up to first harvest (= TSN);
4. TS, plants sprayed weekly with commercial white wash LOVEN (= $TSWW_p$);
5. TS plus weekly Decis 2.8 EC (1,1000) applied at 1 l/ha (= TSI_D);
6. TS mulch, plus weekly Decis at 1/3 strength (= $TSI_{D0.3}$);

Table 8. Relationship between virus (CMV) incidence, and aphids on the plants, aphid-free plants, and aphids caught on yellow traps.

Variable 1	Variable 2		Correlation coefficient
CMV incidence 35 DAT	Aphids on the plants	8 DAT[a]	0.83
		16 DAT	0.89
		24 DAT	0.58
		8 DAT	-0.87
		16 DAT	-0.90
		24 DAT	-0.81
	Aphids on yellow traps	1-8 DAT	0.90
		9-14 DAT	0.93
		15-21 DAT	0.85
		21-28 DAT	0.93
		29-35 DAT	0.88
	Aphids on yellow traps AA[b]		0.89
CMV incidence 56 DAT	Aphids on the plants	8 DAT	0.68
		16 DAT	0.65
		24 DAT	-0.37
		36 DAT	-0.54
		43 DAT	-0.52
		50 DAT	-0.58
	Aphid-free plants	8 DAT	-0.75
		16 DAT	-0.51
		24 DAT	-0.85
		36 DAT	-0.11
		43 DAT	-0.05
		56 DAT	-0.11
	Aphids on yellow traps	1-8 DAT	0.89
		9-14 DAT	0.85
		15-21 DAT	0.81
		22-28 DAT	0.88
		29-35 DAT	0.92
		36-42 DAT	0.84
		43-49 DAT	0.83
	Aphids on yellow traps AA[b]		0.88

[a]Average no. of aphids per plant (10 plants/rep.; 4 reps).
[b]Average of all assessments.

7. $TSI_{D0.3}$ plus weekly alarm pheromone farnesene (0.1 g/l) (=$TS1_{D0.3}F_{0.1}$) (Farnesene was supplied by Dr. L. J. Wadhams of Rothamstead Experimental Station U. K.
8. $TSI_{L0.3}$ plus weekly alarm pheromone farnesene 0.01 g/l (=$TS1_{D0.3}F_{0.01}$);
9. Japanese reflective foil 1 (POLYSHINE N), no insecticide (= JF_1);
10. JF_1 plus weekly insecticide (alternating Decis and Kestrel as in treatment 2) up to first harvest (= JF_1I_{KDa});
11. JF_1 plus weekly insecticide (alternating Decis and Kestrel as in treatment 2) starting at 4 weeks after transplanting (Nov. 13) (= JF_1I_{KDb});
12. Japanese reflective foil mulch 2, no insecticide (= JF_2);
13. JF_2 plus weekly insecticide (as in treatment 2), starting at 4 weeks after transplanting (JF_2I_{KDb})
14. Black plastic mulch, no insecticide (= TB).

All chemicals were applied with a handpump knapsack sprayer using 550 l/ha up to 1 month after planting, 740 l/ha from 5–9 weeks after planting and 835 l/ha thereafter. Prior to sowing, seeds were soaked for 2 hours in 10% sodium triphosphate and rinsed for 1 hour with tap water to eliminate possible seed-borne tobamoviruses. Seeds were sown on 4 September in an insect-proof screenhouse and transplanted to the field on 12 October 1990. Prior to sowing, seeds were soaked for 2 hours in 10% sodium triphosphate and rinsed for 1 hour with tap water to eliminate any seed-borne tobamoviruses.

The trial was arranged in an RCB design with four replications. Plot size was 3 × 4.5 m. Plots consisted of two double row beds with 10 plants per row. Distance between plots was 3 m. Plant to plant distance was 45 cm and between plant distance was 55 cm. CMV-, CVMV- and PVY-inoculated plants were planted alternatively between the ends of each row, set 1.75 m equidistantly from the end plants of each row. A fungicide (Mancozeb 45) was applied at 2-week intervals.

Aphid populations on the plant. Aphid counts were made at 15, 22, 29, 39 and 43 days after transplanting (DAT) on the two middle rows of each plot. A total of 10 plants, consisting of five plants in the middle of each of the two center rows were counted.

Natural aphid population. To obtain information on the natural aphid population, yellow sticky traps (25 × 40 cm) were placed vertically at 25 and 80 cm above the canopy in the center of the plots of the TB treatment. One set of traps was placed in a north/south direction, the other set in an east/west direction. The traps were changed three times a week. Aphids were counted on both sides of the sticky traps.

Aphid repellency. To test the aphid repellent effect of the different treatments one yellow trap (40 × 25 cm) was placed horizontally for 5 days at the canopy level in the center of each plot, at 29 and at 36 DAT. The trapped aphids were counted.

Virus incidence. Incidence of CMV, PVY and CVMV was recorded on the two center rows of each plot without the end plants. One leaf from the top, middle and bottom of each plant was collected, pooled and tested by DAS ELISA. Four ELISA tests were conducted on 5 (24 DAT), and 19 Nov. (38 DAT), and 3 (52 DAT), and 17 Dec. (67 DAT).

Yield. Total yield and fruit number were recorded on the two center rows of each plot on seven harvests, conducted between 8 Jan. and 12 March.

Transmission of pepper viruses by aphids collected from the field. During the course of Experiment 3a, it was noticed that CMV was the only aphid-transmitted virus present in the pepper plants. A small experiment was therefore conducted to determine whether this might have been due to the differential transmission efficiency of the predominant aphid species, which was identified as *A. gossypii* by entomologists at TARI.

The aphid culture originated from one single virus-free *Aphis gossypii* which had been collected from a pepper plant in the untreated plot of Experiment 3a. The aphid culture was maintained on *C. annuum* cv. Newcomer.

Purified viruses (PVY, CMV, CVMV) were inoculated at 260 µg/ml to the first true leaf of hot pepper plants (cv. Newcomer) individually, as well as in combination of two and three viruses. At the 3-leaf stage all plants were tested by ELISA. For transmission studies one plant of each virus combination was chosen which showed OD values in ELISA of > 1.6 for each of the inoculated virus(es).

Alate aphids starved 45 min were placed singly or in groups of 2, 5 and 10 on the virus-infected source plant for acquisition feeding. They were observed with a magnifying glass to assure that each aphid was probing for no less than 40 and no longer than 60 sec. Probes of 40–60 sec length are generally considered most effective for transmission of nonpersistent, aphid-transmitted viruses. After one such probe, the aphids were transferred to the top leaf of healthy plants of the same cultivar at the 2-leaf stage where they remained for 1 day before they were killed by insecticide. Ten plants were used for each virus/aphid combination. A DAS ELISA test was conducted for PVY, CMV and CVMV at 4 and 8 weeks after the insects were placed on the plant.

Results and Discussion

Aphid repellent effect. The lowest numbers of aphids were attracted by treatments 9 (POLYSHINE N), 10 (POLYSHINE N plus weekly insecticide up to first harvest) and 11 (POLYSHINE N plus weekly insecticide, starting 4 weeks after transplanting) on which 41, 30 and 27 aphids and 106, 94 and 91 aphids were caught respectively at the two assessments at 29 and 36 DAT (Table 9). The highest number of aphids were caught on plots mulched with black plastic.

Aphid populations on the plants. Aphids started to appear on the plants as early as 15 DAT in treatments 9, 12, 13 and 14 (Table 10). By 22 DAT aphids were found colonizing plants of all treatments

Table 9. Effect of various aphid-repellent treatments, measured by aphids caught on yellow sticky traps.[a]

Treatment	No. of aphids	
	Nov. 9-13 (29–33 DAT)	Nov 16-20 (36–40 DAT)
1	59 ab[b]	117 abc
2	52 bcd	119 ab
3	44 cd	124 ab
4	52 bcd	107 cd
5	59 ab	113 bc
6	63 ab	127 ab
7	54 abc	123 abc
8	54 abc	118 abc
9	41 d	106 cd
10	30 e	94 d
11	27 e	91 d
12	66 ab	122 abc
13	56 a	116 abc
14	66 a	130 a

[a]One trap (40 × 25 cm) placed horizontally at the canopy level in the center of each plot.
[b]Values are the means of 4 replications. Mean separation by DMRT (P=0 05)

Table 10. Aphid populations on the plants.

Treatment	No. of aphids				
	Oct. 25 (15 DAT)	Nov. 2 (22 DAT)	Nov. 9 (29 DAT)	Nov. 16 (36 DAT)	Nov. 23 (43 DAT)
1	0 a[a]	21 bc	555 b	1383 c	8004 b
2	0 a	6 c	32 c	543 cd	2760 c
3	NT	0 c	0 c	52 d	1074 c
4	0 a	5 c	91 c	386 d	2378 c
5	0 a	25 bc	92 c	279 d	3275 c
6	0 a	11 bc	126 c	338 d	2396 c
7	0 a	27 bc	142 c	622 cd	3072 c
8	0 a	23 bc	14 c	406 d	1762 c
9	8 a	11 c	143 c	623 cd	2175 c
10	0 a	40 bc	9 c	42 d	665 c
11	0 a	30 bc	97 c	299 d	1473 c
12	1 a	59 bc	151 c	2204 b	3129 c
13	12 a	118 b	236 c	548 cd	2842 c
14	34 b	439 a	1332 a	4721 a	13045 a

[a]Values are the means of the total no. of aphids counted on 10 plants (5 plants in the middle of each center row) and 4 replications. Mean separation by DMRT (P=0.05). NT = not tested

except in the plots covered by the floating net. *Aphis gossypii* was the predominant aphid species found on the plants. By 36 DAT aphids had begun to appear even under the floating net, which they could have entered through holes made as a result of the wind rubbing the net against the bamboo stakes. Aphids colonized the plants very erratically. By 43 DAT the aphid population was highest on plants of the black mulch treatment, followed by the Taiwan silver mulch treatment. The lowest number of aphids, although not significant, was recorded on treatment 10 (POLYSHINE N plus weekly insecticide). The highest number of aphid-free plants were in treatments 3, 10, 11 (Table 11).

Aphid population in the field. There was no significant difference between the number of aphids caught on traps positioned in an E/W and N/S direction. Generally more aphids were caught on the low traps positioned at 25 cm above the canopy than on the high traps, positioned 80 cm above the canopy. However, with the exception of four sampling dates (21, 28 Nov., 11, 18 Dec.) this difference was in most cases not

Table 11. Aphid-free plants.

Treat-ment	Oct. 25 (15 DAT)	Nov. 2 (22 DAT)	Nov. 9 (29 DAT)	Nov. 16 (36 DAT)	Nov 23 (43 DAT)	Average
1	10.0 a[a]	8.3 bc	3 8 e	1.0 f	0 c	4 6
2	10.0 a	9.0 ab	8 8 abc	2 8 c	0 c	6.1
3	10.0 a	10.0 a	10 0 a	9.0 a	2 3 b	8 3
4	10.0 a	9.3 ab	7 3 cd	2.8 c	0 c	5 9
5	9.8 a	8 8 abc	8 0 bcd	2.8 c	0 c	5 9
6	10.0 a	8.8 abc	6.8 d	2 0 cd	0 c	5 5
7	10.0 a	9.0 ab	7.3 cd	2 3 c	0 c	5 7
8	10.0 a	9 5 ab	8.8 abc	1 8 cde	0 c	6 0
9	9 5 a	9 3 ab	8.3 bcd	0.5 ef	0 c	5 5
10	10.0 a	10.0 a	9.0 ab	8.0 a	4.0 a	8.2
11	10.0 a	10.0 a	8 9 ab	7 5 b	2 6 b	7 8
12	9.8 a	8 8 abc	4.3 e	0.3 f	0 c	4.6
13	9.5 a	7.5 c	3 5 e	0 8 def	0 c	4 3
14	7 5 b	0.8 d	0 f	0 f	0 c	1 7

[a]Average no. of aphidfree plants out of 10 plants assessed in each plot (5 plants each in the middle of each of the two center rows were assessed) and 4 replications Mean separation by DMRT (P=0 05)

significant. Significant differences were however observed on some sampling dates between the number of aphids caught on N/S traps and E/W traps. The higher aphid number on the N/S traps usually coincided with a strong N/S wind. The aphids caught on the low traps were most likely those moving from plant to plant. Aphid population in the field and virus incidence together with the average temperatures, rainfall and wind velocity are shown in Figure 3.

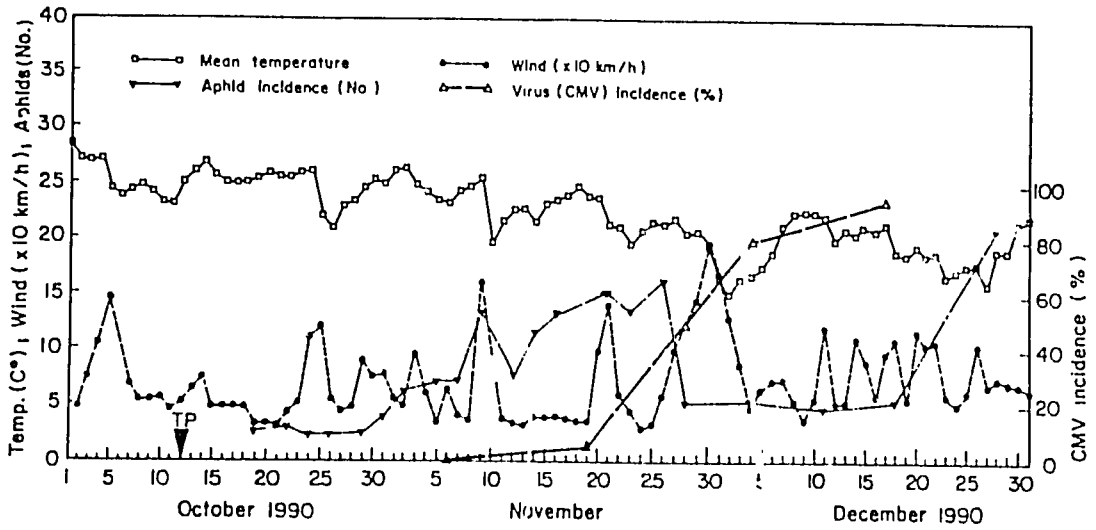


Fig. 3. Mean temperature, wind velocity, aphid and virus incidence during the course of the experiment.

Virus incidence. Cucumber mosaic virus was the only virus found. PVY and CVMV were not detected. CMV began to appear as early as 38 DAT in all plots except those covered with the floating net, with POLYSHINE N plus weekly insecticide up to first harvest and in plots covered with POLYSHINE N plus weekly insecticide starting 4 weeks after transplanting (Table 12). At 52 DAT only the floating net treatment was virus-free, whereas in the other treatments CMV incidence ranged from 15.6 (treatment 11) to 83.1% (treatment 14; black plastic mulch, no insecticide). By 67 DAT CMV incidence in the floating net treatment was 12.5% ranging from 70.6% in treatment 11 to 95.6% in treatment 14.

Transmission of pepper viruses by *A. gossypii*. CMV was found to be more effectively transmitted than CVMV (Table 13). However PVY was not transmitted by this particular aphid species. Two reasons may account for this finding, first *A. gossypii* may not be a vector or a highly inefficient vector of PVY, and the virus isolate used in this study may have lost its aphid transmissibility while being maintained by mechanical inoculation on suitable hosts in the screenhouse.

Table 12. Incidence of cucumber mosaic virus (CMV) %.

Treat-ment	Virus incidence (% of infected plants)[a]			
	Nov. 19 (38 DAT)	Dec 3 (52 DAT)	Dec. 17 (67 DAT)	Average
1	3.1 ab[b]	42 5 bc	93 8 ab	46.5
2	1 9 ab	28 1 d	78 1 abc	36.0
3	0.0 b	0.0 e	12 5 d	4.2
4	1 9 ab	30.0 cd	75.0 bc	35 6
5	1.9 ab	26 9 d	81 3 abc	36.7
6	1 9 ab	23.8 d	89 3 abc	38.3
7	1.9 ab	31.3 bcd	81.3 abc	38.2
8	1.9 ab	30.0 cd	83.1 abc	38.3
9	1.9 ab	28.1 d	76.8 abc	35.6
10	0.0 b	17.5 d	71.8 c	29.8
11	0.0 b	15 6 d	70.6 c	28.7
12	5.0 ab	21.8 d	92.5 ab	39.8
13	6.3 a	43.8 b	89.3 abc	46.5
14	6.3 a	83 1 a	95.6 a	61.7

[a]Out of 16 plants tested (8 plants in the middle of each of the 2 center rows of each plot were tested by ELISA).
[b]The numbers represent the means of 4 replications Means within columns not followed by the same letter differ at P = 0 05

Table 13. Percent transmission efficiency of pepper viruses by *A. gossypii* after acquisition feeding on plants infected with single, two and three viruses.

No. of aphids	Single virus			2 viruses combined						3 viruses combined		
	CMV	CVMV	PVY	CMV	CVMV	CMV	PVY	CVMV	PVY	CMV	CVMV	PVY
1 aphid	10[a]	10	-	10	-	-	-	10	-	20	-	-
2 aphids	10	10	-	20	-	20	-	10	-	30	10	-
5 aphids	40	20	-	30	10	50	-	20	-	40	20	-
10 aphids	50	20	-	50	20	80	-	20	-	70	30	-

[a]values represent the averages of 10 plants

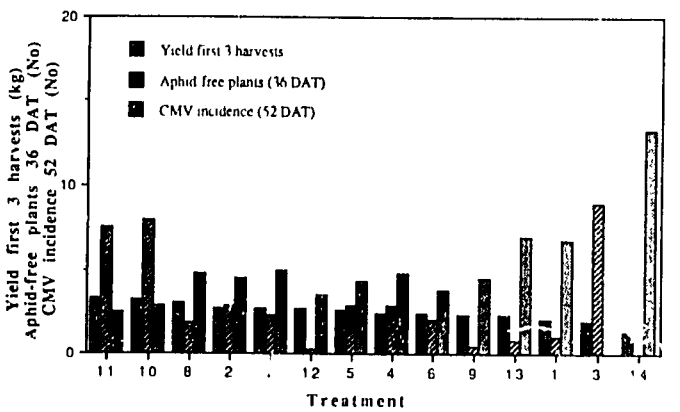
Yield components. The highest yield of the first three harvests and the highest total yield was obtained in treatment 11 (3.3 and 13.7 kg), followed by treatment 10 (3.2 and 13.0 kg) and 8 (3.0 and 10.2 kg) (Table 14). The Taiwanese farmers' practice of using reflective mulch plus weekly insecticide application which constitutes the check treatment produced a yield of 2.7 kg/plot in the first three harvests and a total yield of 9.8 kg. Lowest yield was obtained from plots mulched with black plastic mulch (no insecticide).

Figure 4 clearly shows that the two treatments with the highest yields also had the highest number of aphid-free plants and the lowest virus incidence. Neither total yield nor yield of the first three harvests was very highly correlated to CMV incidence. The correlation coefficients between CMV incidence at 52 DAT and yield of the first three harvests and total yield were only 0.589 and 0.719, respectively. The highest correlation (R=0.822) was that between total yield and aphid-free plants averaged across all assessments (Table 15). CMV incidence (52 DAT) was found to be highly negatively correlated to the number of aphid-free plants at 22 DAT (R=0.916) and at 29 DAT (R=0.853). CMV incidence (52 DAT) was also positively correlated to the number of aphids colonizing the plants at 22 (R=0.850) and 29 DAT (R=0.898).

Table 14. Effect of virus control measures on hot pepper yield.[a]

Treatment	First three harvests: Total fruit wt (kg)	First three harvests: Total fruit no	First three harvests: Average fruit wt (g)	All harvests: Total fruit wt (kg)	All harvests: Total fruit no	All harvests: Average fruit wt (g)
1	2.0 cd[b]	121 cd	15.9 bc	6.9 c	506 c	13.9 b
2	2.7 a-c	158 abc	17.3 ab	9.8 bc	653 bc	15.0 ab
3	1.9 cd	130 bc	14.5 c	8.2 c	672 abc	12.3 c
4	2.4 a-c	140 bc	17.3 ab	9.3 bc	620 bc	15.0 ab
5	2.6 a-c	148 abc	17.7 a	9.4 bc	627 bc	15.0 ab
6	2.4 a-c	134 bc	17.5 ao	8.7 c	584 bc	15.0 ab
7	2.7 a-c	156 abc	17.1 ab	9.7 bc	636 bc	15.2 a
8	3.0 ab	167 abc	18.1 a	10.2 abc	660 bc	15.5 a
9	2.3 bc	130 bc	17.2 ab	9.2 bc	616 bc	14.7 ab
10	3.2 ab	175 ab	18.3 a	13.0 ab	850 ab	15.2 a
11	3.3 a	190 a	17.5 ab	13.7 a	910 a	15.0 ab
12	2.7 a-c	149 abc	17.8 a	8.8 c	569 c	15.5 a
13	2.0 bc	136 bc	17.0 ab	7.9 c	551 c	14.3 ab
14	1.3 d	77 d	16.5 ab	3.5 d	221 d	15.4 a

[a]The experiment was transplanted on Oct. 12, harvesting started Jan. 8, the last harvest was conducted on March 12.
[b]Yield data were taken on the two center rows of each plot. Data are means of 4 replications and when followed by the same letter are not significatnly different at the 5% level according to DMRT



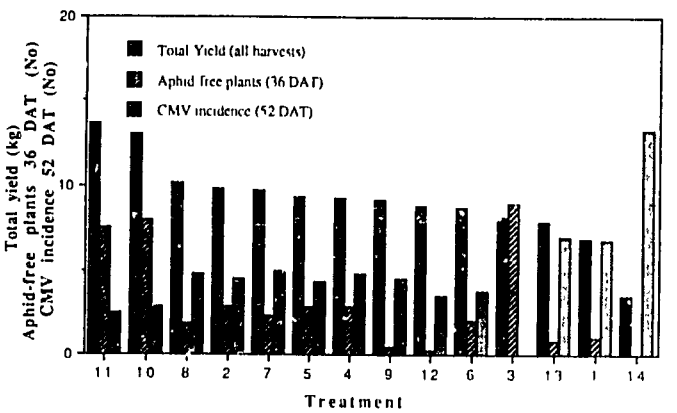


Fig. 4. Virus incidence, aphid-free plants, yield of first 3 harvests and total yield.

Table 15. Relationships between yield, and virus incidence, aphid-free plants, aphids colonizing the plants, and aphids caught on yellow traps.

Variable 1[a]	Variable 2[b]	Correlation coefficient
Total Yield	AYT36/40 DAT	- 0.78
	AYT 29/33 DAT	- 0.79
	CMV incidence 52 DAT	- 0.72
	CMV incidence 67 DAT	- 0 23
	AFP 22 DAT	0.79
	AFP 29 DAT	0.77
	AFP 36 DAT	0.61
	AFP AA	0.82
	AOP 22 DAT	- 0.66
	AOP 29 DAT	- 0.78
	AOP 36 DAT	- 0.73

[a]AFP=aphid-free plants; AOP=aphids on the plants.
[b]AYT=aphids caught on yellow traps, AA=average of all assessments.

By using a highly reflective mulch (POLYSHINE N), the same total yield as that produced by existing farmers' practice (Taiwan reflective mulch plus weekly insecticide) can be obtained without insecticide application. By using the POLYSHINE N as a mulch plus weekly insecticide (starting at 4 weeks after transplanting) the yield of the first three harvests and total yield can be increased by 22 and 49% respectively over the present farmers' practice. The floating net treatment in which virus appeared later and in which virus incidence was lowest, yielded lower than the check. This may be attributed partly to the reduced photosynthetic activity as a result of the shading effect and to excessive leafdrop which was observed probably as a result of fungal infection due to increased humidity under the net. The use of this type of net is thus not recommendable in this season.

The positive correlation of CMV incidence and the number of aphids colonizing the plants comes as a surprise, since it is generally known that migratory aphids and not those colonizing the plants are the virus transmitters. However in this case, where aphid pressure on the plants was so high it is possible that a certain amount of CMV was also transmitted by aphids moving from plant to plant.

The reason why only CMV and neither of the other 2 viruses appeared in the test plots is not fully understood. One explanation may be that the predominant aphid species in the field is an inefficient vector of CVMV and no vector of PVY as suggested by the virus transmission study. Another reason may be that there were no PVY or CVMV infected crop plants or weeds in the vicinity of the experimental plot, which could have served as the inoculum sources. CMV is generally known to have a wider host range than PVY and CVMV.

Effect of Various Measures On Insect Behavior, Virus Incidence and Yield (Experiment 3b, Spring–Summer 1991)

Materials and Methods

The hot pepper cultivar Newcomer (Known You Company, Taiwan) was used with the following 16 treatments:

1. Taiwan reflective foil (silvery side up) no insecticide (=TS);
2. TS, plus weekly insecticide, Decis (2.8 EC 1:1000) (=TSI_D) (= local farmers' practice);
3. TS plus weekly insecticide, Decis (2.8 EC) at 1/3 strength (=$TSI_{D0.3}$);
4. $TSI_{D0.3}$ plus weekly alarm pheromone farnesene (0.1 g/l); (=$TSI_{D0.3}F_{0.1}$)
5. $TSI_{D0.3}$ plus weekly alarm pheromone farnesene (0.01 g/l); (=$TSI_{D0.3}F_{0.1}$)
6. TS plus whitewash painted on the foil (=$TSWW_F$);
7. TS plus whitewash painted on the foil, plus commercial white wash (LOVEN, Tapazole Co., Israel) sprayed on the foliage weekly (=$TSWW_{FL}$);

8. TSWW plus weekly leaf protectant (5,000 ppm) (MFSBRANE; AEFA CHEMI (HongKong LTD.) (=TSWWLP);
9. TS plus weekly spray of leaf protectant (=TSLP);
10. $TSI_{D0.3}$ and close spacing of plants (12 plants/row); (=$TSID_{0.3}CS$)
11. Japanese reflective mulch (metallized film POLYSHINE-N, Hitachi), no insecticide (=JF_1);
12. JF_1 plus weekly insecticide (Decis 2.8 EC at 1/3 strength) starting at 4 weeks after transplanting; ($JF_1I_{D0.3}$)
13. Straw mulch plus weekly insecticide (Decis 1/3 strength); ($SMI_{D0.3}$)
14. Straw mulch, whitewash on straw plus weekly Decis (1/3 strength); ($SMWWI_{D0.3}$)
15. Straw mulch, whitewash on straw, plus white wash (LOVEN) sprayed on the foliage weekly; ($SMWW_{FL}$)
16. TS plus weekly spray of Neemazal (1500 ppm)(1:100) (TSN).

Seeds were sown in an insect-proof screenhouse on 4 January and transplanted to the field on 14 March. Prior to sowing, seeds were soaked for 2 hours in 10% sodium triphosphate and rinsed for 1 hour with tap water to eliminate possible seed-borne tobamoviruses.

The same experimental design was used as for experiment 3a. The plants were left to natural aphid and virus epiphytotics. The following data were taken:

Aphids on the plants. Aphid counts were taken on 22 March (8 DAT), 1 April (18 DAT), 10 April (27 DAT), 17 April (34 DAT), 23 April (40 DAT), 1 May (48 DAT), 8 May (55 DAT) and 14 May (61 DAT) on the 2 middle rows of each plot. A total of 10 plants, consisting of 5 plants in the middle of each of the two center rows were assessed.

Natural aphid population in the field. To obtain information on the aphid population in the field, yellow sticky traps (25 × 40 cm) were placed vertically at 10 cm above the canopy in the center of plots of the TS treatment. The traps were changed three times a week..

Virus incidence. Incidence of CMV, CVMV and PVY was recorded on the two center rows (without the end plants) on 8 April (25 DAT), 22 April (39 DAT), 7 May (54 DAT), 21 May (68 DAT) and 4 June (82 DAT).

Yield. Total yield and fruit number were recorded on the two center rows of each plot in seven harvests, conducted between 27 May (74 DAT) and 12 July (120 DAT), 1991.

Temperatures below the mulches. The temperatures directly below the mulches and at 10 cm below the soil surface were measured at 0800, 1300 and 1600 on 18, 19 March, 16, 17 April, 15, 16 May, and 13, 14 June.

Results and Discussion

Aphid population in the field. The natural aphid population in the field, mean temperature, rainfall and wind velocity during the course of the experiment are shown in Figure 5. The aphid population in the field was observed to fluctuate with temperature. However, the lower temperature usually also coincided with increased wind velocity. It is thus difficult to determine which one of the two factors is responsible for the fluctuation in aphid population.

Aphid population on the plants. Aphids began to colonize the plants as early as 27 DAT (Table 16). At 27 DAT only six treatments (Treatments 3, 5, 10, 11, 12 and 16) were found in which aphids were not yet present. By 48 DAT aphids were seen colonizing plants of all treatments. The lowest average number of aphids colonizing the plants were found on treatment 16 (Neem) and 7 (Taiwan reflective foil plus whitewash on the foil and on the leaves). The highest average number of aphid-free plants was in the Neem-treated plots (Treatment 16) followed by the Taiwan silver mulch with whitewash on the foil and on the leaves (Treatment 7) and the POLYSHINE N foil with weekly insecticide (1/3 strength) starting at 4 weeks after transplanting (Treatment 12) (Table 17).

Virus incidence. Virus incidence is shown in Table 18. CMV was the first virus to appear. It was detected as early as 39 DAT in all but four treatments: treatment 2 (Taiwan reflective foil plus weekly insecticide, 1/3 strength), treatment 12 (POLYSHINE N foil plus weekly insecticide, 1/3 strength starting

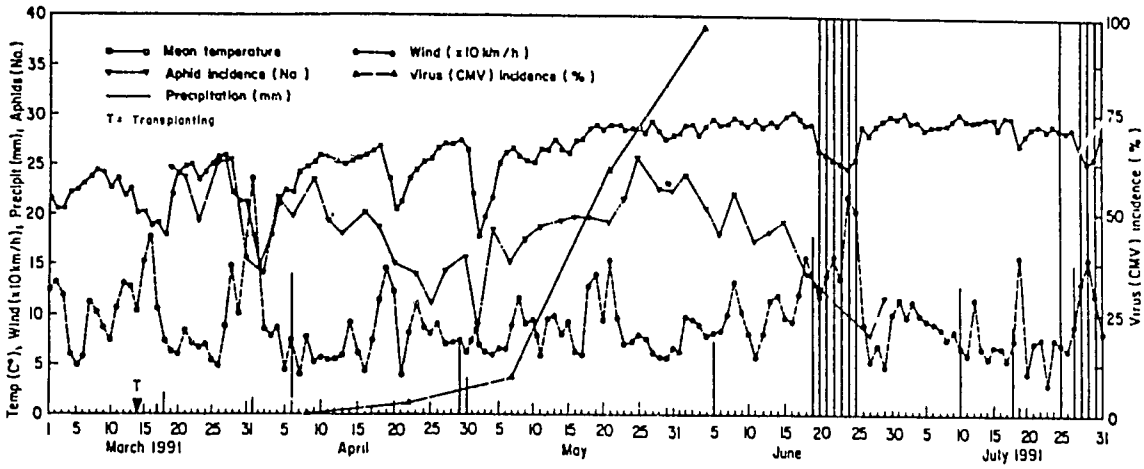


Fig. 5. Mean temperature, wind velocity, aphid incidence and virus incidence during the course of the experiment (spring season).

Table 16. Aphid population on the plants.

Treat-ment	April 10 (27 DAT)	April 17 (34 DAT)	April 23 (40 DAT)	May 1 (48 DAT)	May 8 (55 DAT)	May 14 (61 DAT)	Average
1	1 b[a]	25 a	309 a	522 a	1075 a	1390 a	554
2	1 b	4 b	22 cd	205 c-f	310 def	496 def	173
3	0 b	7 ab	36 bcd	186 c-g	306 def	444 ef	163
4	1 b	11 ab	64 bc	176 d-g	229 f	492 def	162
5	0 b	8 ab	32 bcd	282 cd	275 f	517 ed	186
6	0 b	19 ab	40 bcd	164 efg	268 f	255 gh	125
7	1 b	3 b	19 cd	60 gh	184 fg	261 gh	91
8	10 a	15 ab	64 bc	153 efg	244 f	347 fg	139
9	1 b	9 ab	80 b	388 b	648 b	764 b	315
10	0 b	3 b	17 cd	200 c-f	492 c	623 bcd	223
11	0 b	17 ab	42 bcd	288 c	439 cde	720 bc	251
12	0 b	7 ab	23 cd	140 fg	223 f	573 cde	161
13	2 b	12 ab	49 bcd	250 cde	311 def	449 ef	179
14	3 b	10 ab	52 bcd	245 c-f	299 ef	436 ef	174
15	1 b	18 ab	33 bcd	168 efg	458 cd	582 cde	210
16	0 b	1 b	3 c	16 h	49 g	152 h	37

[a]Data represent means of 4 replications (5 plants in each of the two middle rows of each plot were evaluated). Mean separation within columns by DMRT (P = 0.05)

at 4 weeks after transplanting), treatment 4 (Taiwan reflective, plus 1/3 strength insecticide plus weekly alarm pheromone 0.1 g/l) and treatment 10 (close plant spacing).

CVMV was first detected at 54 DAT in all treatments except treatment 12 (Japanese foil plus weekly insecticide 1/3 strength). Similarly PVY was first found at 54 DAT in all but 2 treatments (treatment 2 and 12). The lowest average virus incidence for all 3 viruses was in treatment 12 (POLY SHINE N mulch plus weekly insecticide at 1/3 strength, starting at 4 weeks after transplanting).

Virus incidence was not highly correlated to the number of aphid-free plants and the number of aphids colonizing the plants.

Table 17. No. of aphid-free plants.

Treat-ment	April 10 (27 DAT)	April 17 (34 DAT)	April 23 (40 DAT)	May 1 (48 DAT)	Average
1	9.3 abc[a]	6 0 c	4 0 fg	0 8 fgh	5 0
2	8.8 bc	8 8 ab	7 0 bcd	3 8 b	7 1
3	10.0 a	8.8 ab	7 5 abc	3 5 bc	6 6
4	9.5 abc	8.0 abc	5 8 c-f	2 5 b-e	6 5
5	10 0 a	8.5 ab	5 3 d-g	1 3 e-h	6 3
6	9 8 ab	7 0 bc	5 8 c-f	2 0 def	6 2
7	9.5 abc	7.8 abc	7 3 bc	5 5 a	7 5
8	8.5 c	7.8 abc	5 0 efg	1 5 efg	5 7
9	9.3 abc	7 5 abc	3 8 g	0 0 i	5 2
10	10.0 a	8 8 ab	7 8 ab	1 5 efg	7 0
11	10.0 a	9.0 ab	5 8 c-f	1 8 efg	6 7
12	10 0 a	9 0 ab	7 5 abc	2 3 cde	7 2
13	8 8 bc	7 3 abc	5 8 c-f	0 5 gh	5 6
14	9.3 abc	7.5 abc	6 0 b-e	3 3 bcd	6 5
15	9.3 abc	7 5 abc	5 3 d-g	0 8 fgh	5 7
16	10 0 a	9 3 a	9.3 a	6 5 a	8 8

[a]Data represent means of 4 replications (5 plants in each of the two middle rows of each plot were evaluated) Mean separation within columns by DMRT (P = 0 05)

Temperatures under the mulches. Temperatures were highest under the Taiwan reflective mulch followed by the Taiwan silver mulch painted with whitewash. Temperatures under the POLYSHINE N foil, under the straw mulch and whitewash-coated straw mulch were similar but significantly lower than those under the Taiwan reflective mulches.

The temperature directly under the polyshine N foil was an average of 4.2 °C lower, whereas that at 10 cm in the soil was an average of 2.7 °C lower than that under the TS foil.

Yield. The highest yield of the first three harvests was from treatment 12 (Japanese foil 1 plus weekly insecticide at 1/3 strength) followed by treatment 2 (Taiwan silver foil plus weekly insecticide full strength) (Table 19, Fig. 6). The highest total yield was also obtained from treatment 12. This was followed by treatment 6 (whitewash coated Taiwan reflective foil) and treatment 8 (Taiwan reflective foil mulch plus plants sprayed with leaf protectant). The largest fruit both at first harvests, and in the overall harvests were obtained from treatment 4 (Taiwan reflective foil plus alarm pheromone at 0.1%) (Table 19).

Straw mulch plus insecticide (treatment 13) produced significantly lower yields than the local reflective mulch plus insecticide (treatment 3). The reason for this is not clear. One reason may be the higher CMV and CVMV incidence at 68 DAT and/or the lower number of aphid-free plants in the straw mulched plots.

Correlation was low between yield and virus incidence, aphid-free plants and the number of aphids colonizing the plants. The highest correlation coefficients of 0.685 and 0.604 were obtained between yield of the first three harvests and CVMV and CMV incidence at 68 DAT, respectively. The correlation coefficient for total yield and CVMV incidence at 68 DAT was 0.654.

It is not clear which factors exactly were responsible for the high yield of treatment 12 (POLYSHINE N foil plus weekly insecticide at 1/3 strength). One of the reasons may be that infection with all three viruses was delayed and that this treatment had the lowest average incidence for all three viruses. Furthermore, plants of this treatment also had a high number of aphid-free plants, particularly during the first few weeks after transplanting. Another explanation may be that the high reflectancy of this foil resulted in a higher photosynthetic rate, especially of the lower leaves.

The aphid population was lowest in plots treated with Neem. However, virus incidence in these plots was neither delayed nor much lower than in plots of other treatments. The low yield of this treatment may be explained by the phytotoxic effect caused by Neem application.

The four insecticide-free treatments had yields similar to or higher than yields obtained using Taiwan reflective foil with weekly insecticide (Treatment 2). These four treatments were: POLYSHINE N, Taiwan

Table 18. Virus incidence (%).

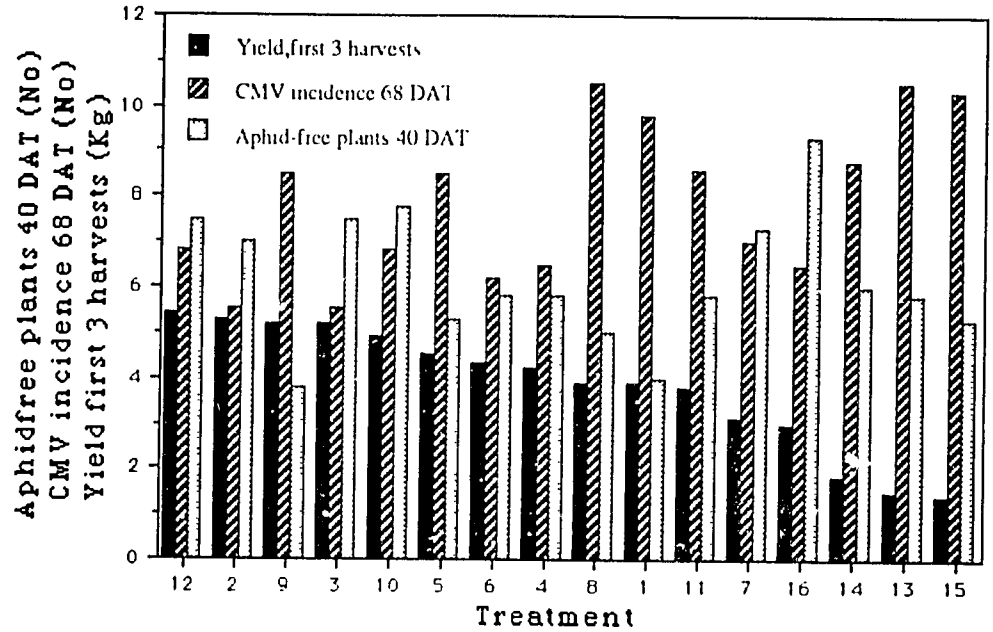
Treat-ment	April 22 (39 DAT)	May 7 (54 DAT)	May 21 (68 DAT)	June 4 (82 DAT)	Ave
		% CMV infected plants			
1	3 1 b[a]	9 4 ab	61 3 abc	96 9 ab	42 7
2	0 0 b	1 9 d	34 4 f	95 6 ab	33 0
3	1 9 b	11 3 ab	34 4 f	100 0 a	36 9
4	0.0 b	6 3 bcd	40 6 f	96 9 ab	36 0
5	9 4 a	12 5 a	53 1 cd	95 6 ab	42 7
6	3 1 b	6 3 bcd	38 8 f	98 1 ab	36 6
7	3 1 b	9 4 ab	43 8 def	96 9 ab	38 3
8	3 1 b	6 3 bcd	65 6 a	96 5 ab	42 9
9	1.9 b	6 3 bcd	53.1 cd	98 8 ab	40 0
10	0 0 b	3 1 cd	42 5 ef	100 0 a	36.4
11	1.9 b	15 6 abc	51 9 cde	83 1 c	38 1
12	0 0 b	3.1 cd	23 8 g	90 6 bc	29 4
13	1 9 b	9 4 ab	65 6 a	100 0 a	44 2
14	5 0 ab	11 3 ab	55 0 bc	95 6 ab	41 7
15	3.1 b	11 3 ab	64 4 ab	98.8 ab	44 7
16	3.1 b	3 1 cd	40 6 f	95 6 ab	35 6
		% CVMV infected plants			
1		11 3 a	71 9 cde	92 5 bc	43 9
2		6 3 abc	55 0 g	96.9 ab	39.6
3		6 3 abc	59 4 fg	100 0 a	41.4
4		6 3 abc	68 8 def	98 8 ab	43.5
5		11 3 a	73 8 cde	95 6 ab	45.2
6		1.9 cd	68.8 def	96 9 ab	41.9
7		5 0 bcd	81 3 abc	100 0 a	46.6
8		1 9 cd	55 0 g	100 0 a	39.2
9		5 0 bcd	80 0 b-d	98.8 ab	46 0
10		6 3 abc	73 8 cde	98 8 ab	44.7
11		9 4 ab	71 9 cde	93 8 abc	43 8
12		0 0 d	65 6 efg	87 5 c	38.3
13		5 0 bcd	92 5 a	100.0 a	39 5
14		1.9 cd	80 0 bcd	96.9 ab	44 7
15		3 1 cd	87.5 ab	96.9 ab	46.9
16		5 0 bcd	67 5 ef	98.8 ab	42 8
		% PVY infected plants			
1		12 5 ab	46 9 b-e	98.8 a	39.5
2		0.0 d	53.1 abc	93.8 abc	36.7
3		3.1 cd	53 1 abc	87 5 bcd	35.9
4		1.9 d	50 0 bcd	86 3 cd	34.6
5		14.0 a	51 8 a-d	86 3 cd	38.0
6		1.9 d	45 6 c-f	86 3 cd	33.5
7		3.1 cd	56.3 ab	96 9 ab	39.1
8		1.9 d	34.4 gh	96.9 ab	33.3
9		1.9 d	61 3 a	90 6 a-d	38.5
10		5 0 cd	36 3 fgh	87 5 bcd	32.2
11		3 1 cd	38 0 efg	93 8 abc	33 7
12		0 0 d	26 9 h	81 3 d	27 1
13		5 0 cd	43 0 d-g	95 6 abc	35 9
14		8 1 bc	51.9 a-d	95.6 abc	38.9
15		1 9 d	45.6 c-f	93 8 abc	35 3
16		3 1 cd	61.3 a	90 6 a-d	38 8

[a]Recorded on 16 plants/plot (= two center rows without the end plants) Data are the means of 4 replications Mean separation within columns by DMRT (P = 0 05)

Table 19. Yield components.

Treat-ment		1st–3rd harvest[a]			4th–7th harvest[b]			harvest 1–7 combined		
		Total fruit weight (kg)	Total fruit no.	Ave. fruit weight (g)	Total fruit weight (kg)	Total fruit no.	Ave. fruit weight (g)	Total fruit weight (kg)	Total fruit no	Ave. fruit weight (g)
1	TS	3.9 ab[c]	170 ab	22 8 b-f	2.1 g	273 b-d	7.6 d	6 0 cd	443 cd	30 4 b-g
2	TSI_D	5 3 a	212 a	25 0 abc	2 5 e-g	284 b-d	8 8 a-d	7 8 bc	496 c	33 9 a-c
3	$TSI_{D0\,3}$	5 2 a	204 a	25 5 ab	2 6 e-g	309 b-d	8 4 b-d	7 8 bc	512 c	33 9 a-c
4	$TSI_{D0\,3}F_{0\,1}$	4.2 ab	158 ab	26 8 a	2 6 e-g	304 b-d	8 4 b-d	6.7 bcd	462 c	35 1 a
5	$TSI_{D0\,3}F_{0\,1}$	4 5 ab	191 a	23.7 a-e	2 3 e-g	247 c-d	9 2 a-c	6 8 bcd	439 cd	32 0 a-e
6	TSWWF	4 3 ab	192 a	22 5 b-f	4 1 bc	530 a	7 8 d	8.5 b	722 a	30 3 c-g
7	TSWWFI	3.1 bc	151 ab	19 9 f	4.6 ab	535 a	8 6 a-d	7 7 bc	686 ab	28 5 g
8	TSWWLP	3.9 ab	163 ab	24 0 a-e	4.4 ab	522 a	8 5 a-d	8 4 b	685 ab	32 5 a-f
9	TSLP	5 1 a	199 a	25 8 ab	2 0 d-f	365 bc	9 3 b-d	8 1 bc	564 bc	34.1 ab
10	$TSI_{D0\,3}CS$	4.9 a[d]	189 a	25 8 ab	1 7 g	218 d	7.8 d	6.6 bcd	407 cd	33 6 a-d
11	JF_1	3 8 ab	183 a	21 0 def	4 2 a-c	530 a	8 0 cd	8 1 bc	712 ab	29 0 fg
12	$JF_1I_{D0\,3}$	5.4 a	212 a	25 3 ab	5 2 a	536 a	9 7 a	10 6 a	748 a	35 0 a
13	$SMI_{D0\,3}$	1.5 d	74 c	20 8 ef	1.9 fg	220 d	8 7 a-d	3 4 e	294 d	29.5 e-g
14	$SMWWI_{D0\,3}$	1 8 cd	84 c	21 9 c-f	2 1 fg	221 d	9 6 ab	3 9 e	304 d	31.4 a-f
15	SMWWFL	1 4 d	67 c	20 6 ef	3.3 c-e	350 b-c	9 5 ab	4 7 de	417 cd	30.1 d-g
16	TSN	3 0 bc	124 bc	24 3 a-d	3.6 b-d	393 b	9 3 ab	6 7 bcd	516 c	33 6 a-d

[a,b]Harvesting started May 27 (=74 DAT) The last harvest was conducted July 12.
[c]Data represent averages of 4 replications [Yield data were recorded on the 2 center (=10 plants each) rows of each plot] Mean separation within columns by DMRT (P = 0 01).
[d]Data calculated on the 2 center rows on the basis of 10 plants/row



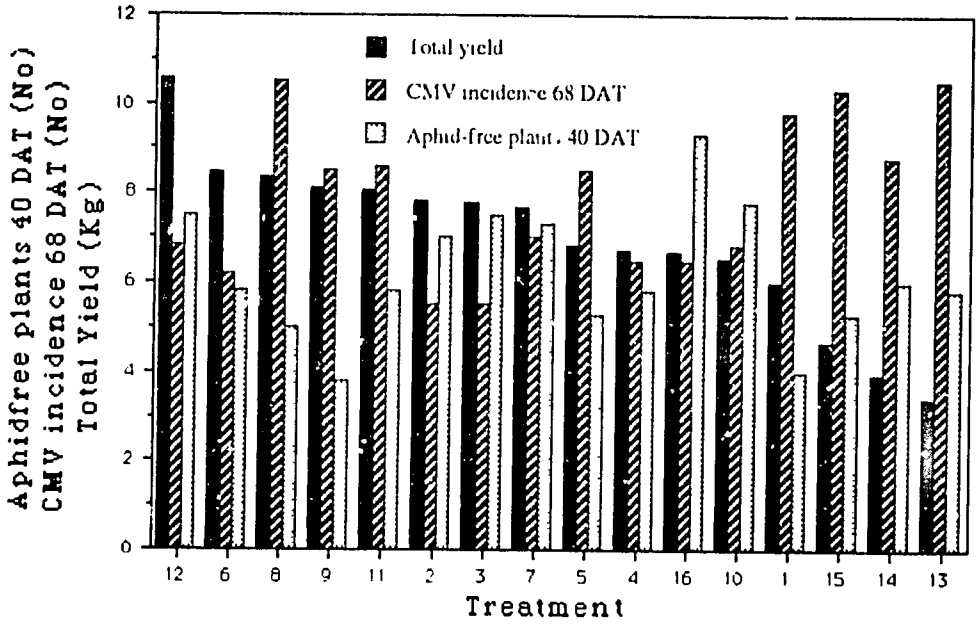


Fig. 6. Aphid-free plants, CMV incidence, yield of first three harvest and total yield.

reflective foil painted with whitewash, Taiwan reflective foil plus whitewash on the plants and Taiwan reflective foil plus leaf protectant. It was also noted that yields of the 1/3 strength (treatment 3) and the full strength insecticide treatments (treatment 2) were not significantly different. Thus, farmers may be advised to reduce insecticide use for their own and the consumers' safety.

Soybean Breeding

Hybridization

Summary

New crosses have been made to improve the yield and quality of existing vegetable soybeans and to develop tropical vegetable soybeans. Specific crosses between *Glycine max* and *G. soja* have been made for possible RFLP collaborative study.

Introduction

Incorporating multiple disease resistance with high yield, adaptability and good seed quality continues to be the driving force for grain soybean-crossing program. Development of vegetable soybeans adapted to the tropics with good quality pod and seed combined with high yield levels are the major objectives in making appropriate crosses. Specific crosses have also been made for possible collaborative research.

Materials and Methods

Specific crosses were made to incorporate downy mildew and/or bacterial pustule resistance in otherwise promising lines.

Utilizing Kaohsiung No. 1, 2, and 3 vegetable soybean crosses have been made with newly introduced large-podded soybean from China to further improve the existing vegetable soybean varieties. Backcrosses and modified backcrosses have been made with F_1s made in the past between tropical grain soybeans and vegetable soybeans to improve the seed size of tropical vegetable soybean.

Additional backcrosses have been made to understand the inheritance of extra-narrow leaflet.

Crosses have been made between *G. soja* and selected rust-resistant/ tolerant accessions for possible RFLP research.

Results and Discussion

A total of 44 crosses and 12 backcrosses were made. Fourteen crosses, including reciprocals were made for RFLP mapping research. Eighteen crosses are for improving vegetable soybean for the tropics. The twelve backcrosses were made to determine the inheritance of extra narrow leaflet, narrow leaflet and broad leaflet.

Yield Trials

Summary

The results of 1990 yield trials confirmed those of the 1989 yield trials in that the variance components for season were much larger than either the G × S interaction or genotypic variance. Since the ranking of some of the genotypes remains unaltered regardless of seasons it should be possible to select multiple-season adapted genotypes. However, most of the other genotypes are highly season-specific. The σ^2SG for summer plus autumn 1989 or 1990 was considerably larger and therefore specific genotypes need to be selected for these seasons.

Introduction

Intermediate and advanced yield trials (IYT and AYT) include promising breeding lines with high yield potential, resistance/tolerance to multiple diseases and carry other desirable agronomic characteristics. Trials were conducted during spring, summer and autumn. In this section IYT in spring, summer, and autumn and AYT in summer will be discussed Since AYT in spring and autumn are related to soybean rust resistance breeding, they will be discussed under soybean rust. Vegetable soybean yield trials will be discussed separately.

Materials and Methods

Plot size for IYT was 3 m × 2 m and for AYT, it was 6 m × 3 m. The harvest plot size for IYT was 6 m^2 and AYT 10 m^2. Selections included in the AYT are listed in Table 1. Data on yield, selected agronomic characters, and disease ratings were collected and analyzed. In data analysis, the genotypes and treatments were considered fixed while the replication was at random. Selection of entries from IYT to AYT was based on multiple criteria. Genotype × season interaction response was evaluated from the combined analysis of the data in the three seasons. AVRDC's suggested cultural practices were used in growing the crops.

Table 1. Selections and their parentage, included in AYT 1991.

Cross designation	Parents
GC 86017-170-1N[a]	(Shih Shih × SRF 400) × PI 153240
GC 84058-21-4	PI 79712613 × (PI 79712613 × SJ #4)
GC 84058-21-2	PI 79712613 × (PI 79712613 × SJ #4)
GC 86049-35-2-1-1-8-1N[a]	(PI 157424 × KS 8) × (Shih Shih × SRF 400)
GC 84051-32-1	TN #4 × (Shih Shih × SRF 400)
GC 84051-9-1	TN #4 × (Shih Shih × SRF 400)
GC 84058-18-4	PI 79712613 × (PI 79712613 × SJ #4)
GC 84040-27-1	(Shih Shih × SRF 400) × PI 200492
GC 86018-427-3	(Shih Shih × SRF 400) × PI 194647
GC 84040-16-1	(Shih Shih × SRF 400) × PI 200492
GC 84040-7-1	(Shih Shih × SRF 400) × PI 200492
AGS 129 (CK)	Shih Shih × SRF 400
AGS 302 (CK)	Shinsei × PI 248407
SRE-D-14B (CK)	From plant pathology

[a]N indicates narrow leaflet.

Results and Discussion

AYT—spring, summer and autumn 1990. The results of the analysis of variance for spring and summer, summer and autumn, and spring, summer and autumn 1990 for AYT are given in Tables 2–4. As in the past, highly significant differences were observed between genotypes (G), between seasons (S) and the G×S interaction was also significant for yield and 100-seed weight (Tables 2–4) with the exception of summer and autumn for yield, for which the differences between seasons were insignificant (Table 3). The estimates of components of variance for yield in AYT were calculated. As seen in Table 5, the variance due to season and season × genotype interaction are the largest. Although the proportion of genotypic variance was large when summer and autumn season data were combined still a significant G × S interaction was observed. The data suggest that it is necessary to select specific genotypes for specific seasons. The results of 1990 contrasted with 1989 results. Two possible explanations could be given for the differential pattern namely, genotypic differences and differences in environmental conditions between the two years.

The mean yield of selected genotypes in AYT for multiple seasons are given in Tables 6 and 7. The results suggested the potential to identify genotypes that could be grown in different seasons without drastic reduction or change in yield.

IYT-1990 spring, summer and autumn. The results of pooled analysis of the data from spring, summer, and autumn for yield and 100-seed weight for IYT suggested that there are highly significant

Table 2. Combined analysis of variance of AYT data from spring and summer in 1990.

Source of variance	Yield				100-seed weight			
	DF	MS(1 × 10⁶)	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	16	0.4	12.0	0.0001	16	99.6	225.9	0.0001
Between seasons (S)	1	9.2	298.4	0.0001	1	469.5	306.2	0.0001
G × S	16	0.4	13.7	0.0001	16	23.0	52.2	0.0001
Error	96	0.0			96	0.4		

Table 3. Combined analysis of variance of AYT data from summer and autumn in 1990.

Source of variance	Yield				100-seed weight			
	DF	MS(1 × 10⁶)	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	16	0.5	15.3	0.0001	16	62.6	204.3	0.0001
Between seasons (S)	1	0.2	2.5	0.1629	1	1055.6	289.0	0.0001
G × S	16	0.2	5.0	0.0001	16	11.3	37.1	0.0001
Error	96	0.0			96	0.3		

Table 4. Pooled analysis of AYT trial data in spring, summer and autumn 1990.

Source of variance	Yield				100-seed weight			
	DF	MS(1 × 10⁶)	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	16	0.5	14.3	0.0001	16	140.8	327.1	0.0001
Between seasons (S)	2	5.4	93.0	0.0001	2	547.4	161.9	0.0001
G × S	32	0.3	10.4	0.0001	32	16.8	39.0	0.0001
Error	144	0.0			144	0.4		

Table 5. Percent contribution of each component of variance to the total variance for yield of AYT 1990.

Component of variance	SP + SU	SU + AU	SP + SU + AU
σ^2G	14% (0.0001)	46% (0.0001)	16% (0.0001)
σ^2S	44% (0.0001)	2% (0.1629)	35% (0.0001)
σ^2SG	32% (0.0001)	26% (0.0001)	34% (0.0001)
σ^2	10%	26%	15%

Table 6. Selections, and their yield included in AYT 1990.

Variety	Yield (t/ha)							
	SP+SU	rank	SU+AU	rank	SP+AU	rank	SP+SU+AU[a]	rank
GC 81027-6-10 NL	2.0	7	2.1	3	1.8	1	2.2	4
GC 82334-7-8 NL	2.4	1	2.1	1	1.6	6	2.2	2
GC 84036-22-5-1	2.2	4	1.9	7	1.8	2	2.2	3
GC 81027-6-15-1 NL	2.1	5	2.0	5	1.6	7	2.1	5
GC 86026-48	1.8	11	1.7	11	1.5	9	1.9	10
GC 86022-17	1.8	13	1.8	9	1.4	14	1.8	12
GC 86040-1	1.7	17	1.6	14	1.3	17	1.7	15
GC 86028-4	1.8	12	1.7	10	1.4	13	1.8	11
GC 86032-17	1.7	16	2.0	6	1.3	15	1.8	13
GC 86025-10	2.3	2	2.0	4	1.7	3	2.2	1
GC 86031-4 NL	1.9	10	2.1	2	1.5	10	2.0	7
GC 87009-71-1-28	2.1	6	1.6	12	1.7	5	1.9	9
GC 86056-11 NL	1.8	14	1.4	16	1.4	11	1.7	14
GC 86056-40 NL	2.0	9	1.4	17	1.4	12	1.7	16
AGS 129 (CK)	2.2	3	1.8	8	1.6	8	2.1	6
AGS 181 (CK)	1.7	15	1.4	15	1.3	16	1.6	17
AGS 302 (CK))	2.0	8	1.6	13	1.7	4	1.9	8

[a]SP = spring; SU = summer; AU = autumn.

Table 7. Promising selections from the combined analysis of AYT in spring, summer and autumn 1990.

Adaptation to seasons	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction		
				DM	BP	Rust %
Spring, summer and autumn						
GC 86025-10	2 2 a	101 gf	14 3 efgh	HR	HR	35
GC 82334-7-8 NL	2 2 a	102 ef	15 0 de	HR	MS	43
GC 84036-22-5-1	2 2 ab	93 jk	15 4 cd	HR	HS	30
GC 81027-6-10 NL	2 2 ab	93 k	13 8 hi	HR	MR	39
GC 81027-6-15-1 NL	2.1 ab	93 k	13 5 i	HR	HR	46
Summer and autumn						
GC 82334-7-8 NL	2 1 a	95 cd	15 9 d	HR	MS	43
GC 86031-4 NL	2.1 a	98 b	14 1 gh	HR	HR	35
GC 81027-6-10 NL	2.1 a	87 g	14 0 ghi	HR	MR	39
GC 86025-10	2.0 a	95 cd	14.1 gh	HR	HR	35
GC 81027-6-15-1 NL	2.0 ab	86 g	13 4 i	HR	HR	46
GC 86032-17	2 0 abc	99 b	14 9 ef	HR	HR	39
GC 84036-22-5-1	1 9 abcd	87 g	14.8 ef	HR	HS	30
Spring and autumn						
GC 81027-6-10 NL	1 8 a	90 f	13 0 h	HR	MR	39
GC 84036-22-5-1	1 8 ab	90 f	14 8 de	HR	HS	30
GC 86025-10	1 7 ab	101 d	13 7 g	HR	HR	35
Spring and summer						
GC 82334-7-8 NL	2 4 a	109 c	13 9 gh	HR	MS	43
GC 86025-10	2 3 ab	104 e	13.3 hi	HR	HR	35

Values followed by the same letter within a column are not significantly different from each other according to Duncan's Multiple Range Test at P = 0 05

differences between genotypes, seasons and G×S interaction (Table 8). GC 87019-4-1B-4 yielded 4.3 t/ha in 94 days whereas GC 87012-95-B-1-W yielded 3.8 t/ha in 89 days. Although there were significant effects for genotypes and G×S interaction, their magnitude is much smaller than for seasons. Promising selections with high yield potential (≥ 3 t/ha) and resistance to downy mildew in IYT-I and IYT-II are listed in Tables 9 and 10. The maturity duration of these selections ranged from 88 to 102 days in spring. All the selected entries were either higher yielding than one of the checks or are resistant to either downy mildew, or bacterial pustule or both.

Tables 8. Pooled analysis of IYT trial data in spring, summer and autumn 1990.

Source of variance	Yield				100-seed weight			
	DF	MS(0.1[6])	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	63	0 5	9.7	0 0001	63	42.4	85.6	0.0001
Between seasons (S)	2	4 9	89.2	0 0001	2	1325.0	2671.6	0.0001
G × S	126	0.2	3.8	0 0001	126	3.3	6 58	0.0001
Error	189	0.1			189	0 4		

Breeding Vegetable Soybeans

Summary

Vegetable soybeans developed at AVRDC have the potential to produce up to 12 t/ha of graded pod yield at the AVRDC experimental fields and at Kaohsiung DAIS. In autumn the yield could go to 7 t/ha at AVRDC. Since many of these selections carry genes from tropical and subtropical soybeans they have good chances of adaptation in the tropics and subtropics.

Table 9. High yielding selections from IYT I in spring 1991.

Entry	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction DM	BP
GC 87012-9S-B-1 W	3 8	89	26 2	R	HS
GC 87021-23S-B-1	3 6	88	24.6	R	HS
GC 84056-1-1-3-1	3.6	98	12 0	R	MS
GC 84050-19-2-1-2	3.6	100	23 3	R	HS
GC 85039-1-2-1-1	3.5	96	19.7	R	HS
GC 87016-12S-B-2	3 5	91	27 3	R	MS
AGS 129 (CK)	3.5	94	18 7	HS	MS
AGS 181 (CK)	3.3	86	18 0	R	-
AGS 302 (CK)	3.1	95	22 5	R	HS
SRE-B-15C (CK)	3.0	92	19.7	R	
TK #5 (CK)	2.7	92	17.2	R	
Mean of 81 entries	2.9	99	18.7		
CV	10.4	2.1	4 7		
LSD (0 05)	0.6	4.0	1 7		

Table 10. High yielding selections from IYT II in spring 1991.

Entry	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction DM	BP
GC 87019-4-1B-4	4.3	94	25.5	R	HS
GC 87019-4-1B-1	4.1	93	25 1	R	HS
SS 84065-2-3	4.0	90	24.2	R	HS
GC 87021-26-B-1	4 0	94	28 6	R	MR
SS 86045-23-2	4.0	91	29.4	R	HS
SS 84065-2-2	4.0	90	23 4	R	HS
GC 86004-9	3.9	98	21.3	R	MR
SS 86013-7-4	3.8	91	27.1	R	HS
GC 87020-16-B-3	3.8	96	29.8	R	HS
AGS 302 (CK)	3.6	95	24.9	R	HS
TK # 5 (CK)	3.3	93	18.2	R	-
AGS 129 (CK)	3.2	93	18.8	HS	MS
SRE-B-15C (CK)	3.2	91	20.5	R	
AGS 181 (CK)	3.1	89	18 8	MR	
Mean of 84 entries	3.4	93.4	23 5		
CV	11.8	1.8	5.0		
LSD (0.05)	0.8	3.4	2.4		

All SS lines are from the Korean breeding program.

Selections with yield potential similar to KS #1 but better in other horticultural characteristics such as 100-seed weight, harvest index, color of pod and seed have been selected for evaluation in the tropics and subtropics. A combined analysis of the trials from different seasons and different locations will be presented in the 1992 Progress Report.

Introduction

Vegetable soybeans have been used for a long time in the Orient. Japan, China, Indonesia, Korea, Nepal, Philippines, Taiwan and Thailand produce and use vegetable soybeans. There is a growing awareness to produce vegetable soybeans both for domestic consumption and for export. There is great potential to produce and use vegetable soybeans in the developing Asian countries to improve the

nutritional value of a mostly cereal-based diet. Since vegetable soybean varieties adapted to the tropics are unavailable, AVRDC has a vegetable soybean breeding program specifically for the tropics and subtropics.

The primary breeding objectives are productivity, adaptability to tropical latitudes, disease resistance and consumer quality. The quality characteristics include pod and seed color, appearance, flavor, texture, taste, the size of pod and seed and number of seeds per pod.

Vegetable soybean breeding activities include greenhouse and field observation of new accessions, generation advance, pedigree evaluation and yield trials at AVRDC and at Kaohsiung DAIS. Pedigree evaluation trials and yield trials alone will be presented here.

Materials and Methods

Yield trials in 1990

In autumn 1990 five yield trials were conducted at AVRDC and one trial at Kaohsiung DAIS. In 1991 four trials at AVRDC and three trials at Kaohsiung DAIS were conducted. The plot size was 3 m × 2 m. AVRDC's suggested cultural practices were followed. Observations were made on days to R_1 and R_2 growth stages; 100-seed weight at R_6 growth stage, graded pods (≥ 2 seeded unblemished pods) weight and total plant weight were taken for five randomly chosen plants for each variety from each replication. Number and weight of one-, two- and three-seeded pods and pod length and width of two- and three-seeded pods were observed. Number and weight of damaged pods was also calculated. Harvest index for graded pod was computed. All the trials at Kaohsiung DAIS were planted following the rice crop.

Results and Discussion

Yield trials in 1990

IYT at AVRDC. Among the 24 entries evaluated, five entries outyielded Ryokkoh for graded pod yield and two entries had significantly higher total pod yield. However, all the selected entries had similar yield as KS # 1 (Table 11). Since they have a different genetic background from KS # 1 it is worth evaluating them to select for other desirable horticultural characteristics such as harvest duration, color of pod and seed, flavor, texture, first pod height, etc.

Table 11. Promising selections from IYT vegetable soybean, autumn 1990.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No. of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87010-93-1-6	8 3	12 4	49.7	33 1	75	5.1	1 3	63.8	200
GC 87008-55-1-9-2	7.1	12.1	50.7	29 9	75	5.1	1.3	31 2	215
GC 87009-71-1-6	7.0	9.4	43 1	32.3	75	5.1	1 3	62 4	196
GC 87010-35-2-6	7.0	9.6	50 4	36 9	69	5.1	1.3	68 8	177
AGS 292 (CK)	7.8	10.4	49 2	37.0	68	5.4	1.3	68 2	188
G 9053 (CK)	6 8	9.9	48.4	33 4	68	4.9	1 3	66 8	189
G 10134 (CK)	4.5	7.2	41.3	25 9	68	5.6	1.5	70.9	176
Means	6 7	9.7	49.8	34.4	69	5 1	1 3	62.1	198
CV	14.3	13.7	6.6	7.9	1.6	4 0	4 1	4.6	5.8
LSD (0.05)	2.0	2.7	6.7	5.6	2.2	0.4	0.1	5 9	23.5

AYT I and AYT II at AVRDC. Two to three selections in AYT I and AYT II produced significantly higher graded pod yield or total pod yield than the checks. A few other selected entries had yields similar to the check's but their 100-seed weight is higher (Tables 12, 13). Highest graded pod (6.9 t/ha) and total pod yield (9.3 t/ha) observed was in GC 84128-17-2-1. GC 84126-13-4-1 had a 100-seed weight (green) of 76.1 g and GC 84130-12-2-1, 75.7 g.

Tables 12. Promising selections from AYT I vegetable soybean, autumn 1990.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 86056-45	5 2	8 6	51 4	30 7	71	5 3	1 4	60 0	208
GC 84130-12-2-1	4 8	7 9	49 1	29 9	73	5 6	1 3	75 7	194
GC 84126-10-1-1	4 3	7 7	49 4	27 4	70	5 0	1 4	66 1	207
GC 84128-9-2-1	3 7	5 8	47 0	29 7	73	5 3	1 3	61 5	208
GC 84126-13-1-2	3 7	5 8	48 3	30 1	70	5 0	1.4	69 8	202
GC 84126-13-4-1	2 9	4 0	51 0	37 3	73	5 3	1 4	76 1	184
GC 84126-13-4-4	2 6	3 7	54 7	39 4	73	5 2	1 4	72 8	200
G 9053 (CK)	3 9	6 4	51 2	31 6	67	5 0	1 3	60 5	205
AGS 292 (CK)	3 9	5 9	53 0	35 0	67	5 2	1 3	58 2	209
G 10134 (CK)	1 6	2 8	43 3	25 5	66	5 1	1 4	63 1	194
Means	3 8	6 4	48 5	29 0	69 8	5 1	1 3	62 8	208
CV	20 5	17 0	10 1	11 2	1 4	2 9	3 6	4 7	5 1
LSD (0 05)	1 1	1 5	6 9	4 6	1 4	0 2	0 1	4 1	15 0

Table 13. Promising selections from AYT II vegetable soybean, autumn 1990.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 84128-17-2-1	6 9	9 3	48 7	36 0	74	5 3	1 4	65 9	206
GC 87009-71-1-5	6 3	9 5	51 1	33 7	75	5 1	1 3	60 0	208
GC 86008-35-1	5 9	8 7	51 6	34 8	75	4 8	1 3	67.4	208
GC 87008-77-1-2	3 5	6 9	51 0	25 7	74	5 4	1 3	53 6	229
AGS 292 (CK)	4 6	6 8	52 2	35 3	68	5 1	1.3	58 6	211
G 9053 (CK)	2 9	5 0	49 9	29 1	68	4 8	1.4	62.7	208
Means	4.7	7 8	49 3	28.9	73	5.0	1 3	57 8	230
CV	14 9	8 6	3 6	11.3	0	2 9	3 8	3 8	3 5
LSD (0.05)	1.0	1 0	2.5	4.7	0	0 2	0 1	3.1	11 5

AYT at Kaohsiung DAIS. GC 84137-8-2-1 produced a significantly higher graded pod yield (5.2 t/ha) than all three check varieties, KS # 1, Tzurunoko and Ryokkoh (Table 14). Average graded pod harvest index during spring was about 24% whereas in autumn, the graded pod harvest index was nearly 53%. One-hundred seed weight was lower in autumn than in spring. A combined analysis of vegetable soybean trials will be presented in the 1992 Progress Report.

Table 14. Promising selections from Kaohsiung DAIS AYT vegetable soybean, autumn 1990.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No. of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 84137-8-2-1	5.2	5.9	58.1	51 1	71	4.7	1 4	76.3	182
GC 85062-10-2-1	3 9	4.9	56 2	46 6	72	4.7	1.3	75 0	183
GC 84126-13-1-2	2 8	3.4	60.4	50 6	72	4.7	1 4	75.5	192
GC 84128-17-2-1	2 6	3 0	61 2	52 8	72	5 0	1.4	68.8	189
GC 84130-12-2-1	2 6	3.6	54.5	39 4	72	5.3	1.5	78 8	171
G 10134 (CK)	4.0	5.1	59.4	47 1	71	5.0	1 4	83 5	161
G 9053 (CK)	2 9	3 4	60 7	53.1	72	4 5	1.3	66.3	207
AGS 292 (CK)	2.4	2.7	70.2	62.0	72	4.7	1.3	68.3	183
Means	2.7	3 2	64.9	52 9	75	4.8	1.3	68.7	208
CV	24.1	23.0	9 2	10.4	0	2 9	5 3	6.1	5.6
LSD (0.05)	0.9	1.1	8.4	7.7	0	0.2	0.1	5.9	16.3

Yield trials in 1991

IYT I and II at AVRDC during spring and IYT I in summer. Graded pod yield during spring (12.5 t/ha) and summer (11 t/ha) established records compared to the Tzurunoko yield of 8 t/ha in spring and the KS #1 yield of 10 t/ha in summer. GC 87020-20-B-5-1, GC 86057-6-1-9 and GC 86057-6-1-12 had high yields both in spring and summer (Tables 15, 16 and 17). In many selected entries the 100-seed weight was significantly higher than the check KS #1.

Table 15. Promising selections from IYT I vegetable soybean, spring 1991.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87010-50-1-15	11.7	16 5	51 6	36 5	71	4 9	1.3	78 8	147
GC 87010-19-1-1	11 4	15.6	51.3	37.5	70	5.0	1.3	72 2	148
GC 86057-6-1-12	11 0	15.7	50 8	35.4	71	4.9	1.3	74 2	157
GC 86057-6-1-9	10 9	15 2	49 7	35.5	71	5 1	1.4	74.4	144
GC 87009-3-1-1	10 7	15.4	50.8	35 4	71	4 9	1.3	72.1	146
GC 87020-20S-B-5-1	10 7	14.8	49 4	35.6	71	5 1	1.3	79.1	130
AGS 292 (CK)	10 2	15.1	49.7	33 5	70	5 3	1.3	67 6	166
G 9053 (CK)	7 9	13 9	47.4	27.0	77	4 5	1.4	74.0	180
G 10134 (CK)	7.5	13 3	45 8	25.9	77	4 9	1.5	89.1	146
Means	10 0	15.4	49 0	32 1	74	4.9	1.3	73 4	156
CV	10 2	5 2	3 5	9.8	0.2	3 1	4.1	4.3	6.5
LSD (0 05)	2.1	1 6	3 5	6.4	0.3	0 3	0 1	6.4	20.9

Table 16. Promising selections from IYT II vegetable soybean, spring 1991.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No. of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87012-10-B-6	12.5	16.5	46 6	35 5	73	4.9	1.3	73.6	147
GC 87009-1-1-1	12 4	16 6	53 6	40.1	71	4 9	1.3	79 9	141
GC 87012-20-B-2	11 2	17 6	49.9	31 8	80	5.0	1.3	78 1	161
GC 87021-10-B-1	10 8	17.4	52.2	32 3	79	5.1	1.3	74 7	150
AGS 292 (CK)	11.2	15 4	53 8	39 0	70	5 3	1.3	71 3	152
G 9053 (CK)	8 6	14.1	47.6	29.0	73	4.9	1.4	70.4	179
AGS 190 (CK)	5 4	9.3	31.9	18.4	80	4.5	1.3	71.8	173
Means	10 5	16.0	48 6	31.9	77	4.8	1.3	72.9	160
CV	11.1	4.9	3 6	9 8	0.7	2.4	4.0	4 3	6.9
LSD (0.05)	2.4	1 6	3.6	6 4	1 1	0.2	0.1	6.4	22.6

Table 17. Promising selections from IYT vegetable soybean, summer 1991.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No. of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87020-20-B-5-1	11 4	26.0	57.7	43.8	73	5.4	1 3	66.0	192
GC 87008-15-1-11	11.4	28.6	54.6	39.7	73	5 2	1 3	58.4	202
AGS 292 (CK)	9 8	25.3	54 5	38.7	73	5 3	1.3	64.4	202
Means	10.0	27.1	53.8	37 2	74	5.2	1.3	59.8	205
CV	11.6	5.3	4.5	8.3	0	2.2	2.3	6.4	3.7
LSD (0.05)	2 5	3.1	5.3	6.7	0	0.3	0 1	8.3	16.2

IYT I and II at Kaohsiung DAIS. In IYT I GC 86057-6-1-9 and GC 87012-20-B-2-1 produced significantly higher graded pod yields of 11.9 t/ha and 10.8 t/ha compared to 6.9 t/ha for KS #1. Harvest maturity of GC 86057-6-1-9 was 73 days, the same as that of KS #1. One-hundred seed weight of GC 87012-20-B-2-1 was 95 g compared to 100 g for Ryokkoh and 76.5 g for KS #1 (Table 18).

Table 18. Promising selections from Kaohsiung DAIS IYT I vegetable soybean, spring 1991.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87010-50-1-15	11.7	16.5	51 6	36.5	71	4.9	1 3	78.8	147
GC 86057-6-1-9	11 9	13 3	65.8	59.0	73	5 3	1 4	79 5	149
GC 87012-20-B-2-1	10 8	13 4	62 0	50 0	82	5 1	1 3	95 0	163
GC 87010-34-1	9.4	11.2	67 8	56.1	82	5 2	1 3	80.0	171
GC 87010 65-1-9	8.7	9 9	64 0	56 4	73	5.1	1 3	77 5	163
GC 87012-20-B 8-2	8 5	11 7	64.7	47.7	82	5 3	1.4	90.0	159
AGS 292 (CK)	6 9	8.2	59 9	50 7	74	4 8	1.3	76 5	178
G 9053 (CK)	5.5	7 0	59 7	46.8	74	4 8	1.3	65.5	197
G 10134 (CK)	2.7	5.6	56 9	26 9	78	5.3	1.5	100.0	140
Means	8.0	9.5	60.5	50 5	75	5.1	1 3	76 8	165
CV	17.6	15.9	5.8	7.4	0	3 9	4.9	7.2	5.3
LSD (0.05)	2.9	3.1	7 2	7.7	0	0.4	0.1	11 4	17 9

In IYT II five entries significantly outyielded Tzurunoko. The graded pod yield was from 8.9 t to 11.1 t/ha compared to 6.2 t/ha for KS #1 (Table 19).

Table 19. Promising selections from Kaohsiung DAIS IYT II vegetable soybean, spring 1991.

Entry	Yield (t/ha)		Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No. of graded pods/500 g
	Graded pod wt	Total pod wt							
GC 87021-13-B-7	11.1	11.8	62 0	58 4	82	5.1	1 2	75.0	167
GC 87009-8-4-2	9 8	10.7	53 8	49 2	82	5.3	1.4	80.0	164
GC 87009-71-1-8	9.6	11.2	56 3	47.9	82	5 3	1.3	80.0	173
GC 87012-20-B-2	9.3	11 8	63.9	51 0	82	5 1	1 3	81.0	163
GC 87012-10-B-6	8.9	10 0	64 3	57 2	78	5.1	1 3	90.0	157
AGS 190 (CK)	8 1	9.0	48.5	43 9	82	4.7	1.3	81 5	187
AGS 292 (CK)	6.2	7.4	55 3	46.0	74	4.6	1.3	80.5	184
G 9053 (CK)	4.2	5.4	60.3	47.1	74	4.8	1.2	72.0	180
Means	7.6	8.8	59 8	51.4	79	4.9	1 3	73.1	174
CV	16.9	16 3	7.8	8 4	0	3.7	5.1	11 5	8.0
LSD (0.05)	2.6	2.9	9 5	8.9	0	0 4	0.1	17 2	28.6

AYT during spring at AVRDC. Graded pod yield of 10 t/ha was recorded for GC 87010-65-1-4 compared to 6.7 t/ha for Tzurunoko, with KS #1 having a yield of 10.3 t/ha. However, the GC line had a 100-seed weight of 69 g compared to 62 g for KS #1 which was significantly lower. Several other selections that had yields similar to KS #1 but significantly larger seeds were selected (Table 20).

AYT during spring season at Kaohsiung DAIS. GC 87010-35-2-6 produced a graded yield of 9.6 t/ha which was significantly higher than KS #1 (8.6 t/ha). One-hundred seed weight of GC 87010-35-2-6 was also significantly greater (86 g) than KS #1 (72 g). In high-yielding selections the graded pod yield harvest index reached more than 50% (Table 21).

Table 20. Promising selections from AYT vegetable soybean, spring 1991.

Entry	Yield (t/ha) Graded pod wt	Yield (t/ha) Total pod wt	Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
GC 87010-65-1-4	10.0	14 9	51 2	34 5	70	5.1	1 3	68 8	145
GC 87010-50-1-17	10.0	14 5	51 8	35 7	70	5 3	1 3	72.7	147
GC 87008-65-2-9	9.2	16 0	52.7	30 7	76	5.0	1.3	82 0	160
GC 87010-35-2-6	9 1	13.6	46 5	31 0	76	4 9	1 3	83.8	151
GC 87008-65-2-1	8 2	14 2	49.4	28 5	77	5 0	1.3	85 8	146
GC 84137-8-2-1	8.0	13 7	44 6	26 0	77	5 3	1 4	86 0	156
GC 87008-77-1-13	7 8	15.1	51 4	26.5	76	5.1	1 3	71 9	163
AGS 292 (CK)	10.3	14 7	56 1	39 6	69	5 1	1 4	61 6	203
G 10134 (CK)	7 7	13 1	47 0	27 6	73	4 9	1 3	85 3	155
G 9053 (CK)	6 7	13 0	45.0	23.3	72	4 8	1 3	69.2	175
Means	8.6	14.2	48.3	29 3	75	4 9	1 3	73.7	164
CV	12 2	5 9	4.0	11 8	0 3	4 2	4 1	4.1	5 4
LSD (0.05)	1 5	1.2	2 8	4 9	0 3	0 3	0 1	4 2	12.5

Table 21. Promising selections from Kaohsiung DAIS AYT vegetable soybean, spring 1991.

Entry	Yield (t/ha) Graded pod wt	Yield (t/ha) Total pod wt	Harvest index	Graded pod harvest index	Days to maturity	Pod length 2 seeds (cm)	Pod width 2 seeds (cm)	100-seed wt (g)	No of graded pods/500 g
GC 87010-35-2-6	9 6	10 7	55.7	50.4	79	5 0	1 4	85 5	158
GC 86056-42	9 1	11.1	61 5	50 6	79	5 3	1 4	92 5	143
AGS 292 (CK)	8 6	9 7	63 9	56 6	73	5 0	1.3	71 5	160
G 9053 (CK)	7.5	9.4	57 6	46 2	74	4.6	1 3	73 8	177
G 10134 (CK)	6.8	8.3	56.1	45 6	77	5 3	1 4	82 5	162
Means	8.1	9 5	59 6	50 6	77	4 9	1 3	74 2	171
CV	8.5	7.4	8.1	9 8	0	3 3	3.1	6 1	4.4
LSD (0.05)	1.0	1.0	6 8	7.0	0	0.3	0.1	6 4	10.7

Breeding for Soybean Rust Tolerance

Summary

In autumn 1990 soybean rust severity was high. Soybean rust tolerance index (RTI) was lower for both yield and 100-seed weight. Some entries had considerably lower soybean rust infection in plots both with and without fungicide suggesting the possibility of this line carrying partial resistance genes. However, there were other lines with high rust infection that have high RTI suggesting their tolerance. Such phenomena were observed in spring 1991 as well. In spring 1991 lines with high RTI and high yield potential were identified.

A combined analysis of AYT for spring and autumn indicated that the largest source of genotypic variance was due to fungicide treatment and season × fungicide interaction. The response to fungicide is season-dependent. Fungicide spray schedule requirements for different seasons and different locations may be different and need to be established by trial. As suggested in last year's Progress Report, multiple season, in multiple years and possibly multiple location testing is required to identify stable rust-tolerant genotypes.

Introduction

Vertical resistance genes identified so far against different races of *Phakopsora pachyrhizi* are all short-lived since the pathogen produces new virulent races which easily overcome the single gene resistance.

Slow rusting, partial resistance and tolerance have been reported as other avenues to combat the soybean rust. If the rust incidence is severe the yield loss could be as high as 90%. In spite of high rust infection, genotypes are referred to as tolerant if the yield loss is minimal. Higher yield with minimal use of fungicides and increased income are the objectives in the incorporation of tolerance to soybean rust.

Materials and Methods

The details of AYT material and methods are given in Table 1. The main plot was placed in the split plot design with and without fungicides and the genotypes were placed in the subplot. Fungicide-treated plots were not inoculated with soybean rust fungus but the plots without fungicide were inoculated with soybean rust pathogen inoculum prepared by the Plant Pathology group. Data on percent soybean rust infection, yield, 100-seed weight were collected and subjected to pooled analysis to determine the source of variation for various components. In analyzing the data, the genotypes, treatment and seasons were all assumed as fixed while the replication was considered random.

From the observations, rust tolerance index (RTI) was calculated as follows:

$$\text{RTI} = \frac{\text{Yield or 100-seed weight without fungicide} \times 100}{\text{Yield or 100-seed weight with fungicide}}$$

A combined analysis of spring and autumn was conducted and estimates of components of variance were also determined.

Results and Discussion

Yield trials in 1990

Compared to autumn 1989 soybean rust severity, the autumn 1990 soybean rust severity was high. Maximum rust lesion percent was 39 in 1989 whereas in 1990 it was 71%. As a result the RTI was lower for both yield and 100-seed weight in 1990 (Table 22). GC 87009-71-1-28 had the highest RTI of 94 and 93% for yield and 100-seed weight. Percent rust lesion on this line was considerably lower, only 26% being recorded in plots without fungicide and 12% in plots with fungicide (Table 22). However, its yield potential is low. GC 82334-7-8NL had an RTI of 81% for both yield and 100-seed weight. It appears that GC 87009-71-1-28 has partial resistance plus tolerance while GC 82334-7-8NL has tolerance. However, GC 81027-6-10-NL has high yield potential and may be better than others.

Table 22. High yielding lines selected from AYT in autumn 1990.

Entry	RTI		Days to maturity		100-seed wt (g)		Rust lesion (%)	
	Yield	100-seed wt	with fungicide	without fungicide	with fungicide	without fungicide	with fungicide	without fungicide
GC 81027-6-10 NL	69	77	81	79	17.1	13.1	24	47
GC 86031-4 NL	69	82	93	86	16.3	13.4	24	36
GC 81027-6-15-1 NL	64	77	80	78	15.8	12.2	25	57
GC 84036-22-5-1	72	83	82	78	17.9	14.8	25	40
GC 86025-10	74	84	94	91	16.4	13.8	20	36
GC 86032-17	63	78	96	93	18.0	14.0	20	41
GC 82334-7-8 NL	81	81	88	90	17.2	14.0	31	44
GC 86028-4	62	71	82	79	18.2	13.0	33	71
GC 86026-48	66	75	96	94	18.5	13.8	23	44
GC 87009-71-1-28	94	93	87	84	24.7	23.0	12	26
AGS 129 (CK)	68	83	81	80	17.7	14.7	23	37
AGS 302 (CK)	74	83	88	85	22.7	18.9	26	39
AGS 181 (CK)	85	92	76	76	13.0	11.9	47	71
Mean of 17 entries	72	81	88	85	18.8	15.3	26	45
CV			3.0	2.8	3.4	3.5	17.1	17.8
LSD (0.05)			3.7	3.4	0.9	0.8	6.4	11.3

Yield or 100-seed weight with fungicide

The data from spring and autumn were pooled and analyzed. Variance components were calculated by equating appropriate mean squares to their expectations to the model and solving for the respective variance components.

As in the past year, the estimates of components of variance showed that fungicides treatment (F) and season (S) × F interaction were the largest source of phenotypic variance for yield (Table 23). Soybean rust infection during spring and autumn seasons are different. Furthermore, the photoperiod and temperature during the two seasons are different. Both these factors contribute to the interaction effects. Season × fungicide interaction clearly indicates the differential soybean rust incidence during different seasons. Therefore, soybean rust tolerance and RTI in one season or in one location may not be representative of other seasons or locations.

Table 23. Percent contribution of each component of variance to total variance for yield in spring and autumn 1990.

Component of variance	Estimate for AYT
σ^2G	3% (0 0001)
σ^2S	0 03% (0 2909)
σ^2F	57% (0 0001)
σ^2GS	7% (0 0001)
σ^2GF	2% (0 0001)
σ^2SF	26% (0 0001)
σ^2SFG	2% (0 0001)
ε^2	3%

Yield trials in 1991

Soybean rust infection severity was quite high—82% in plots without fungicide and 48% in plots with fungicide. Data from Table 24 suggests that there may be partial resistance and tolerance present in selected entries. Several entries exhibited little reduction in yield due to soybean rust—the RTI being 100 (Table 24). There was little reduction in 100-seed weight between the treatments with and without fungicide.

Table 24. Differences in yield, percent rust infection, and 100-seed weight of selected entries from AYT in spring 1991.

Entry	RTI[a]		Days to maturity		100-seed wt (g)		Rust lesion (%)	
	Yield	100-seed wt	with fungicide	without fungicide	with fungicide	without fungicide	with fungicide	without fungicide
GC 84040-27-1	65	81	3 4	2 2	17 9	14 5	13	82
GC 86018-427-3	92	99	3 3	3 0	19.2	19.1	20	23
GC 86017-170-1 N	89	98	3 1	2 7	23 6	23.2	19	44
GC 84040-16-1	79	85	2 9	2.3	19.6	16 6	28	61
GC 84058-18-4	100	100	2.8	2 8	23 3	23 4	39	38
GC 84051-32-1	104	99	2.5	2.6	14 3	14 2	37	33
SRE-D-14B (CK)	94	100	2.9	2.7	26.7	26.6	31	37
AGS 302 (CK)	103	98	2.6	2.7	23 1	22 6	46	62
AGS 129 (CK)	101	99	2.6	2.6	16 8	16.7	48	64
Mean of 14 entries	94	96	2 7	2.5	21.1	20 5	34	51
CV			8 6	6 9	4 7	3.6	35.4	18.3
LSD (0.05)			0 3	0.3	1.4	1.0	17 2	13.2

International Cooperation

Summary

Forty scientists from 28 countries received a total of 864 grain soybean entries and 10 ASETS for their trial and use. Similarly 39 scientists from 21 countries received a total of 691 entries of vegetable soybean, which shows the growing interest in exploiting the potential of vegetable soybean.

Kaohsiung DAIS has released two new vegetable soybean varieties: KS #2 (KVS 39) and KS #3 (KVS-124) for their farmers. The crosses for both varieties were made at AVRDC. Results of vegetable soybean trials in Indonesia indicate a yield potential of more than 8 t/ha graded pod. Vegetable soybeans AGS 190 and AGS 292 are multiplied by PLENTY Canada for distribution to farmers in Sri Lanka.

Three Korean soybean breeding lines have been successfully multiplied at AVRDC and returned along with several other advance generation materials grown at AVRDC during the off-season (spring 1991).

Introduction

The National Agricultural Research Systems (NARS) from the different countries request and receive germplasm and improved enhanced genetic materials for their evaluation and utilization either in their research program or for direct use by their farmers. The NARS scientists return the data to AVRDC commenting on the superiority of the AVRDC improved materials in relation to their native materials. NARS scientists also advise about constraints that remain to be resolved. Such valuable feedback help AVRDC to fine-tune the research program at AVRDC so that AVRDC's research can complement and supplement the efforts of the NARS scientists and hasten to resolve the constraints of soybean production efficiently.

Since AVRDC's new strategy calls for devolving soybean from the headquarters to the Regional Program in Thailand, shuttle breeding has been initiated between Thailand and AVRDC.

New Variety Releases

In Taiwan, Kaohsiung DAIS has proposed the release of two new vegetable soybean varieties: KS #2 (KVS 39) and KS #3 (KVS 124). The committee has approved their release. The cross for both varieties was made at AVRDC. KS #2 resembles that of Ryokkoh for most horticultural characteristics but it is slightly late-maturing and the yield is significantly higher than Ryokkoh.

KS #3 is similar to Tzurunoko for most of the horticultural characteristics but it is slightly late-maturing and the yield is significantly higher than Tzurunoko.

Nepal has released a new variety, Seti, from AVRDC breeding lines. The details of the release are being obtained.

Vietnam has released three grain soybean varieties from AVRDC breeding lines: G 87-1 (AGS 117), G 87-5 (AGS 129) and AK 05 (G 2261).

As of December 1991, 12 countries have officially released to their farmers 24 varieties by using AVRDC soybeans (Table 25).

Distribution of Germplasm, Elite Lines, and AVRDC Soybean Evaluation Trial and AVRDC Vegetable Soybean Evaluation Trial

Forty scientists from 28 countries requested and received from AVRDC 172 AGS lines, 468 *Glycine* crosses (GC) and pedigrees, 224 accessions and 10 ASETS.

The interest in vegetable soybeans can be seen from the fact that 39 scientists from 21 countries have received 181 AGS lines, 352 GC pedigrees and 158 accessions of vegetable soybeans for their evaluation and use in developing varieties for their countries.

Table 25. AVRDC soybean released by cooperators.

Local name	AVRDC ID #	Year	Country	Remarks
Darco 1	AGS 29	1981	Honduras	EM, UM, HY, CLS
KM 1	AGS 2	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]	AGS 2	1985	Indonesia	HY, (R), BF
Tidar	G 2120-M	1987	Indonesia	HY, EM, RF, LSV, G, ST
Taiwan 30050	AGS 17	1982	Malaysia	HY, MH
BPI Sy4	AGS 73	1985	Philippines	HY, EM, UM, LSV, BP, R, L, S, WA
Kaohsiung No 9	AGS 12	1982	Taiwan	HY, NP, SSP, 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
Kaohsiung No 1	AGS 292	1987	Taiwan	HY, MH, DM, VS
Sukothai No 1	AGS 9	1986	Thailand	NL, HY, NP, (R, DM, PSS)
Dowling	G 58	1978	USA[a]	R, HY
	GC 30229-8 (AGS 19)	1983	Zimbabwe	NL, EM
AKO 3	G 2261	1988	Vietnam	HY, EM
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 product
BPI-Sy6 (Saguisag)	AGS 19	1990	Philippines	NL, HY, resistant to virus
Kaohsiung No. 2	Ryokkoh x KS 8	1991	Taiwan	HY, MH, VS
Kaohsiung No 3	PI 157424 x KS 8	1991	Taiwan	HY, MH, VS
Seti	?	?	Nepal	HY
G 87-1	AGS 147	?	Vietnam	
G 87-5	AGS 129	?	Vietnam	
AK 05	G 2261	?	Vietnam	

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

RF. suited to cultivation in rice fallows
EM early maturing
UM: uniformly maturing
HY: high yielding
CLS: resistant to Cercospora leaf spot
NL: narrow-leaflet
L: nonlodging
MH suitable for mechanical harvesting
RCI: suitable for intercropping with rice or corn
DM: resistant to downy mildew
ST. preferred for making tempeh
BF: resistant to beanfly
VS: utilized as vegetable soybean
SQ: good seed quality for storage

CC: suited to crude cultivation
SC: suited to intercropping with sugarcane
BP: resistant to bacterial pustule
SSP: suited to spring and summer planting
R: rust tolerant
LSV: long seed viability
S. nonshattering
G: good germination
SP suited to summer planting

WA: wide adaptability
BS. suited to bean sprouting
PSS: resistance to purple seed stain

Vegetable Soybean Trials

Lesotho. Of the seven varieties, the differences in yield between varieties were insignificant. The CV was quite high, 52.1% and therefore, the results of the trial need to be viewed with caution. The cooperators, Mr. Michael H. Makhata and Mr. M. Mofoka, reported that people liked the varieties and they performed well. There is a need to know how they used the pod, shelled beans or seeds. Further trials are needed.

Indonesia. Ten entries were provided by AVRDC. Among them, three entries gave a graded pod yield of 7.7–8.7 t/ha in 72–79 days (Table 26). The cooperator from Miyakawa Enterprises, Mr. Ichiji Miyakawa, reported that for pod quality and yield GC 83008 was the best followed by GC 84126, GC 87010, GC 83006, AGS 190 and AGS 292. The trial will be repeated in December 1991 or January 1992.

Table 26. Promising selections from Indonesia vegetable soybean, spring 1991.

Entry	Yield (t/ha)	Days to maturity	Height at maturity	No of Graded pods/hill	No of pods/hill			Defective pods
					1 seed	2 seed	3 seeds	
GC 83008-16	8 7	79	27 6	33	7	25	8	5
GC 84126-10-1-1	8 0	72	26 7	46	2	36	10	8
GC 87010-35-2-7	7 7	72	24 7	39	8	32	7	1
Fuku Yutaka (ck)	7 4	79	26 4	45	3	30	15	2
Columbia (ck)	4 4	94	53 3	57	12	51	6	17

Argentina. Nine AVRDC selections were evaluated in an observation trial with five local check varieties. Grain yield data were collected and reported by the cooperator, Mr. Gimenez Kantolic, Charaf. One-hundred seed weight of all AVRDC entries was more than or equal to 30 g. Data for selected entries are given in Table 27.

Table 27. Promising selections from Argentina vegetable soybean, spring 1990.

Entry	Yield (t/ha)	Days to flowering	Days to maturity	Height at flowering	Height at maturity	100-seed wt (g)	Seed quality
G 10134	2 5	68	116	51 9	51 9	45 9	5
AGS 293	2 3	63	112	49 5	51.2	43 9	4
Blue Side	1 9	70	130	62 3	62 3	35 0	4
Shirofumi	1.6	51	104	38 4	38.4	43 3	2
GC 84136-P-4-1-8	1 5	65	116	60 2	61 7	37.9	3
AGS 292	1 2	51	104	43.8	43 8	44 8	3
Mitchell (ck)	3 5	77	112	77.9	77.9	19.2	4
A 3127 (ck)	2.4	68	104	52 6	52.6	15 6	3
A 5409 (ck)	2.0	82	133	85 7	90 1	16.1	5
Montera 74 (ck)	1.1	93	174	93 5	96 5	14.8	5
Hood 75 (ck)	0 5	91	145	84.0	85 2	13.7	5

Sri Lanka. From 400-g seeds of AGS 292, 7 kg have been multiplied for distribution to farmers. Similarly from 22 kg of AGS 190, 354 kg have been multiplied for distribution to the farmers as reported by the cooperator, Mr. D.C. Nanayakkara.

Korea. Three black-seeded breeding lines S 155, S 156 and S 157 were planted for seed multiplication. A total of 543 kg of seeds were produced from the 20 kg seed received. Seeds of all three varieties multiplied were shipped to Korea in time for their regular season planting. In addition, the training scholars made 30 different crosses at AVRDC, of which 11 were to combine genes with less lipoxygenase and 19 were for improving vegetable soybeans in Korea.

Soybean Entomology

Confirmation of *Melanagromyza sojae* Resistance in Soybean

Summary

Preliminary studies were conducted on the morphology of unifoliate and first trifoliate leaves of the apparently *Melanagromyza sojae*-resistant and susceptible soybean accessions to determine whether there are significant differences in these characters that could account for the differences in the infestation of *M. sojae*. Accession G11569, which was significantly less damaged than the susceptible check, had significantly thicker unifoliate and trifoliate leaves. G 11569 has significantly fewer trichomes on both upper and lower surfaces of the unifoliate leaves. Other characters such as leaf area, moisture content, dry weight, and petiole morphology did not differ between G11569 and the susceptible check.

Introduction

Melanagromyza sojae Zehntner (Diptera: Agromyzidae) attacks soybean throughout most of Asia. The infestation of this insect is especially serious in Taiwan, reaching up to 100% plant damage and 30% seed yield loss. *Melanagromyza sojae* rarely kills the soybean plant. It weakens it by larval feeding on the pith of the main stem resulting in yield loss. In 1980 AVRDC identified four *Glycine soja* accessions with high levels of resistance to this agromyzid. However, this resistance was found to be related to narrow stems and with thin pith cavity, too small to accommodate *M. sojae* larvae feeding inside the stem. Thin stem, however, is an agronomically undesirable character because plants lodge easily. Screening of newly received soybean germplasm was thus initiated to identify sources with true resistance to *M. sojae*. In 1989, screening tests by AVRDC showed five soybean accessions that were least damaged by *M. sojae* among the other accessions included in the test. To confirm the resistance and study the mechanism of resistance, a field test was conducted.

Materials and Methods

This experiment included three least damaged accessions from the 1989 test and three susceptible checks. Seeds of each entry were sown on 26 September 1990 in two rows on the top of three 1-m wide and 6-m long randomly selected beds, each bed being one replicate. No insecticide or fungicide was applied. Observations were made on the morphological characters of the plants and agromyzid infestation.

Plant characters. Morphological characters of unifoliate leaves were observed 6 days after emergence (DAE) and first trifoliate leaf 5 weeks after emergence (WAE). Ten plants from each plot were uprooted 6 DAE. Ten unifoliate leaflets were stripped off and their leaf areas were measured with a Li-Cor area meter. The fresh weights and dry weights (drying at 105-110°C for 48 hours) were simultaneously recorded. The moisture content was determined by the subtraction of dry weight from the fresh. In five leaflets of each accession, one 5 × 5 mm area on lower and upper leaf surface was selected carefully avoiding the main veins. The number of trichomes in this area was recorded. In another five leaflets, leaf thickness at two points in each leaflet was measured, carefully avoiding the main veins.

At 5 WAE 20 plants were uprooted from each plot. Ten fully opened first trifoliate leaflets were cut and the leaf area, fresh and dry weights, moisture content, leaf thickness and trichome density were recorded in a manner similar to the unifoliate leaf. From the first trifoliate leaves, 10 petioles were cut. The length, diameter, fresh and dry weight as well as moisture content of each petiole were recorded.

Insect infestation. At 3 and 5 WAE, 15 plants from each plot were uprooted and cut open and the number of larvae and pupae of *M. sojae* in the stems of each plant was recorded.

Results and Discussion

At 3 WAE, there were significantly fewer *M. sojae* larvae and pupae in G11569 and G12043 than in the susceptible checks, except in AGS66. Accession G11744 was as susceptible as the susceptible checks. At 5 WAE, both G11569 and G12043 had a significantly lower insect population than all the susceptible checks. *Melanagromyza sojae* larval and pupal population in G11744 was not different from one susceptible check, AGS66. In the two 1990 field tests G11569 and G12043 showed consistently lower *M. sojae* infestation. Characteristically, both accessions are black-seeded, whereas all susceptibles are yellow-seeded. Unifoliate leaves of both G11569 and G12043 had significantly lower trichome density than the unifoliate leaves of the susceptible checks. However, on the lower surface only G11569 had significantly lower trichome density than the susceptible checks. The unifoliate and trifoliate leaves of G11569 were significantly thicker than those of the susceptible checks. *Melanagromyza sojae* lays eggs in unifoliate and trifoliate leaves and the first instar larvae feed inside these plant parts. It is not certain how these characters, that differ between resistant, especially G11569, and susceptible accessions, affect the infestation of *M. sojae*. Other morphological characters did not differ between apparently resistant and three susceptible checks.

Study of Mechanism of Resistance in Soybean to Beanfly

Summary

Morphology and beanfly [*Ophiomyia phaseoli* (Tryon)] infestation characteristics of two resistant and two susceptible soybean accessions were studied for their resistance mechanism. The cotyledons, unifoliate leaves and hypocotyls of two resistant accessions, PI171444 and PI227687, were significantly smaller than those of two susceptible accessions, AGS66 and TK5. These differences explain the lower oviposition and lower insect feeding in the resistant accessions. Significantly fewer beanfly adults preferred to alight and lay eggs in the resistant plants than in the susceptible ones. Pupae from larval feeding in PI227687 were significantly lighter than in the pupae from susceptible accessions. This raises the possibility that some antibiotic factors may also be present in this accession which also resulted in significantly fewer larvae feeding in its stems. It is possible that several plant morphological and physiological characters contribute to the resistance of soybean accessions to the beanfly.

Introduction

Among various insects that attack soybean, the beanfly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae), is the first to damage the plants soon after germination. This pest is the most destructive in Indonesia and in the southern part of Vietnam. At present farmers use only insecticides to combat beanfly. In Taiwan this insect has already developed resistance to monocrotophos and dimethoate, the two most commonly used chemicals for beanfly control. AVRDC's research emphasizes breeding of soybean cultivars resistant to this pest as an alternative sustainable control measure. However, until recently, *O. phaseoli* host-plant resistance screening was not carried out in Taiwan because *O. phaseoli* does not cause significant damage to soybean in Taiwan although it is a serious pest of other legumes. However, a simple technique to mass-rear *O. phaseoli* in the laboratory has been developed recently. This technique enabled the screening of soybean germplasm for resistance to *O. phaseoli*. In the preliminary screening, PI 171444 and PI 227687 were consistenly less damaged and appeared to be resistant. They were studied in the laboratory to characterize their mechanism of resistance.

Materials and Methods

Beanfly rearing

Seeds of soybean (cv. KS 9) were sown on a small parcel of land in the field, and 1 week after germination all cotyledons were harvested. Cotyledons with beanfly eggs or larvae were maintained at 26 ± 2°C for 2 weeks and emerging adults were used for further mass rearing using cotyledons from freshly germinated soybean plants.

Plant morphology study

A detailed morphological study was done of cotyledons, hypocotyl and unifoliate leaves. Seeds of two apparently resistant (PI 171444 and PI 227687) and two known susceptible (TK-5, AGS66) accessions were sown in small plastic pots maintained in a greenhouse. After germination, 10 plants were maintained in each pot.

Cotyledons. The thickness of each cotyledon was measured at two points with a micrometer (Peacock dial thickness gauge). The average thickness of 10 cotyledons constituted one replicate; four replicates per accession were used. Cotyledonal leaf area was measured on a leaf area meter (Li–Cor Model LI-3000). Fresh and dry weights (72 hours drying at 105–110°C) of cotyledon were measured on a Mettler AE.240 electronic balance. Moisture content was determined. Cotyledon volume was measured by water displacement method.

Hypocotyl. Ten 1-week old plants from each of the four replicates of each accession were uprooted. Hypocotyl length was measured as the distance between cotyledonal joint and root shoot junction. Hypocotyl diameter was measured at three points on each plant with the Peacock dial thickness gauge. Fresh and dry weights (72 hours drying at 105–110°C) of the hypocotyls were measured on the Mettler AE.240 electronic balance and moisture content was determined.

Unifoliate leaves. Ten fully-opened unifoliate leaves of each accession were sampled and their areas were measured with a Li-Cor area meter. The number of trichomes on two 5 × 5 mm areas on both sides of each leaf was recorded on five unifoliate leaves in each replicate. Fresh and dry weights (72 hours drying at 105–110°C) of 10 fully-opened leaves of each of four replicates of each accession were recorded using a Mettler AE.240 balance. Moisture content was determined.

Host preference study

Seeds of PI 227687, PI 171444, TK-5 and AGS 66 were sown in soil placed in a plastic flat (45 × 30 × 8 cm) with perforated bottom to drain excess moisture. Each accession was planted in one randomly selected row in each of four flats, each flat being one replicate. Distance between two accession rows was 7.5 cm and that between two planting spots of each row was 4.8 cm.

Two days after germination when cotyledons were fully open, individual trays were placed in one screen cage (60 × 60 × 60 cm). One hundred beanfly adults (1 male: 1 female) were then released in each cage at 0800 hours. The number of adults resting or depositing eggs on the plants of each accession were recorded at 1 and 2 hours after the release of the adults. Four hours after the release of the adults, the cotyledons were cut and the number of eggs deposited in cotyledons and unifoliate leaves of 10 plants of each accession in each replicate was recorded.

Insect development study

Larval development. Seeds of PI 227687, PI 171444, TK-5 and AGS 66 were sown in vermiculite in plastic cups (11-cm diameter, 4-cm high). Each accession was sown in 24 cups and each cup had 15–20 seeds. Five days after germination, unifoliate leaves of each plant were cut leaving cotyledons intact. The plants were placed in a net cage (60 × 60 × 30 cm) containing 200 beanfly adults. After 30 min of exposure for oviposition, cotyledons with oviposition punctures were cut and placed in a petri dish lined with moist tissue paper. Each cotyledon was observed to make sure it had only one egg; excess eggs were removed. The cotyledons were maintained at 26 ± 2°C. Egg and larval stages of beanfly in the cotyledons of each accession were observed once every 4 hours until all larvae had pupated. The period between oviposition and pupation was recorded. Pupae were extracted from the cotyledons and their weights were recorded.

Adult fecundity. The adults that emerged within 24 hours from the pupae extracted from the cotyledons of each accession were placed in individual plastic cylinders (15-cm diameter, 30-cm high). Each pair (1 male + 1 female) among the 10 pairs of adults that emerged from each accession were placed in individual glass tubes (2.2-cm diameter, 9 8-cm high). One 2-day old seedling of soybean accession AGS 66 with only one cotyledon maintained intact was introduced in individual test tubes. The plant with one

cotyledon was replaced with a fresh one twice a day and the number of eggs laid in the cotyledon was recorded. This process was repeated for 9 days.

Results and Discussion

The cotyledons of resistant PI171444 and PI227687 were significantly smaller than the cotyledons of AGS66 or TK5 the susceptible checks (Table 1). This trend was detected in all quantifiable characters such as leaf area, volume, thickness and fresh and dry weights. The moisture content of cotyledons of PI227687 was significantly less than the cotyledons of both susceptible accessions although no such difference was found between PI 171444 and AGS 66 (Table 1). The smaller cotyledon volume of resistant accessions presumably sustains feeding of fewer insects than the larger cotyledons of the susceptible accessions. The larvae that feed on the cotyledons are responsible for mortality of plants. The first instar normally feeds in the cotyledon and the second instar larvae move from the cotyledon to feed on the hypocotyl which results in plant mortality.

Table 1. Morphological characters of cotyledons of selected soybean accessions.

Soybean accessions	Cotyledon characters[a]						
	Leaf area (cm^2)	Volume (cm^3)	Thickness (mm)	Fresh weight (g)	Dry weight (mg)	Moisture content (%)	Specific dry weight (g/cm^3)
PI 227687	1.4 d	0.2 d	1 8 d	0 1 d	16.1 d	87 5 c	0.1
PI 171444	1.9 c	0.2 c	2.1 c	0.2 c	23 3 c	88 0 bc	0.1
AGS 66	2 3 b	0.4 b	2.5 b	0.3 b	37.3 b	88.3 b	0.1
TK-5	3 6 a	0.6 a	2.9 a	0 5 a	57 8 a	89 2 a	0 1

[a]Data are means of four replicates. Means in each column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

The hypocotyls of both resistant accessions were also smaller than those of the susceptible accessions (Table 2). The smaller hypocotyl of the resistant accession probably, in turn, provides limited food and volume for the accommodation of the beanfly larvae. The unifoliate leaves of both resistant accessions were significantly smaller than those of the susceptible accessions (Table 2). When cotyledons are not accessible beanfly adults lay eggs inside unifoliate leaves. Unifoliate leaves of resistant accessions provide limited surface compared to the unifoliates of the susceptibles for laying eggs and feeding. This presumably reduces the larval population and damage in the resistant accessions. No consistent relation was found between trichome density on unifoliate leaves and beanfly infestation, although PI227687 tended to have higher density than the rest.

Table 2. Morphological characters of hypocotyls and unifoliate leaves of selected soybean accessions.

Soybean accessions	Hypocotyl characters[a]					Unifoliate characters[a]		
	Length (cm)	Diameter (mm)	Fresh weight (g)	Dry weight (mg)	Moisture content (%)	Number of trichome in 5 mm^2 upper surface	Number of trichome in 5 mm^2 lower surface	Leaf area (cm^2)
PI 227687	5 6 c	17.6 d	0.2 d	9.8 d	93.4 b	103 1 a	134.2 a	9.2 d
PI 171444	4.5 d	24.8 b	0.2 c	13.4 c	94.4 a	76.7 b	110.4 b	11.8 c
AGS 66	6.1 b	23.4 c	0.3 b	18 2 b	93.3 b	51.3 c	65.9 c	19.0 b
TK-5	6.8 a	27.2 a	0.4 a	27.9 a	93 3 b	81.5 ab	112 6 ab	22.2 a

[a]Data are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Significantly fewer beanfly adults were found alighting on the resistant than on the susceptible plants. They laid slightly fewer eggs in the cotyledons of the resistant accessions than in the cotyledons of the susceptible ones. Oviposition was, however, practically nonexistent in the unifoliate leaves of the resistant

accessions when a substantial number of eggs was laid in the unifoliate leaves of the susceptible accession. As a result, the total number of eggs laid in the plants of the resistant accessions was significantly less than in the plants of the susceptible accessions.

No difference was observed in the duration of egg and larval period of beanfly when the insects were reared on the cotyledons of the resistant or susceptible accessions (Table 3). Weights of pupae, the larvae of which were feeding on the cotyledons of resistant accessions, especially those of PI 227687, were significantly lighter than the pupae from susceptibles ones. This was true whether only one or more larvae were allowed to feed in the cotyledons. This shows that there might be some antibiotic factors in cotyledons of PI 227687. The adults raised from cotyledons of PI 227687 laid fewer eggs than those raised from AGS 66 or TK-5, the susceptible checks.

Table 3. Influence of soybean accessions on various biological characters of beanfly.

Soybean accessions	Larvae development[a]			Adult fecundity[a]	
	Duration of larval period (egg-pupal) (hours)	Pupal weight (mg/pupa) (1 larva/cotyledon)	Pupal weight (mg/pupa) (free choice)	Adult emergence (%)	Number of eggs laid each female/day
PI 227687	214 6 a	0 7 c	0 6 c	95 0	6 2 b
PI 171444	212 5 ab	0 8 b	0 7 b	96 0	6 4 b
AGS 66	211 0 b	0 9 b	0.8 b	99 0	16 7 a
TK-5	215 2 a	0 9 a	0 9 a	99 0	10.0 b

[a]Data are means of four replicates except larval period (six replicates) and number of eggs laid (10 replicates) Means in each column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Results of beanfly infestation of two apparently resistant and two susceptible accessions are summarized in Table 4. Infestation of beanfly in resistant accessions was significantly lower under high population pressure. Under low population pressure, PI 227687 was the least infested but because of the wide variation in plant damage data, this particular characteristic was not statistically different.

Table 4. Infestation of selected soybean accessions by beanfly at two population levels.

Soybean accessions	Low adult population[a]		High adult population[b]	
	Plant damage	Number of pupae+larvae /10 plants	Plant damage	Number of pupae+larvae /10 plants
PI 227687	51 7	9 7 b	88.3 b	37 0 b
PI 171444	65 0	17.3 a	93 3 a	60.7 a
AGS 66	56.7	17.7 a	96 7 a	73 0 a
TK-5	66 3	17 7 a	98 3 a	74 7 a

[a]29 adults/replicate
[b]50 adults/replicate Data are means of three replicates Means in each column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

It appears that many morphological and plant physiological characters are involved in the resistance of beanfly in soybean in Taiwan. It was found that small but at times significant differences in morphological characters of hypocotyl, cotyledon, and unifoliate leaves between the apparently resistant and susceptible accessions collectively contribute to differences in the infestation of beanfly between these accessions.

Susceptibility of *Riptortus clavatus* to *Beauveria bassiana*

Summary

Laboratory studies were conducted to test the susceptibility of *Riptortus clavatus* to a fungus *Beauveria bassiana* which infects several other insect species. *Riptortus clavatus* adults and 3rd, 4th and 5th instar

nymphs were all susceptible to the fungus. A highly significant linear dose-mortality response was observed at concentrations of 4.52×10^3 to 4.52×10^8 spores/ml suspension. Mortality of *B. bassiana*-treated insect declined steeply with increase in temperature between 25 and 30°C. Insect mortality was 100% at 15 and 20°C, 96% at 25°C, 45% at 30°C and 0% at 30°C.

Introduction

Riptortus clavatus (Thunberg) (Heteroptera: Coreidae) is a destructive pest of soybean and several other legumes in Asia. The insect lays eggs singly scattered over the host plant. The nymphs and adults with their piercing and sucking mouth parts bore into developing pods and suck juice from developing seed. As a result of such damage, seeds develop poorly or at times do not enlarge at all. There is considerable reduction in yield. This extremely agile insect is difficult to control by conventional insecticide application because a slight disturbance when chemicals are being sprayed causes adults to fly away. When feeding on pods, insects are not easy to reach because of the canopy of leaves that cover the pods. Unlike caterpillars, there is minimum contact between insect body and the plant surface which reduces the effectiveness of insecticide residue. AVRDC aims to breed soybean cultivars resistant to *R. clavatus*. Research so far reveals that resistant cultivars alone will not control this pest adequately and supplementary control measures may be necessary. A suitable and sustainable control measure is being sought. *Beauveria bassiana*, a soil fungus, shows pathogenic activity to numerous species of insects. In this study, therefore, the pathogenic activity of this fungus against *R. clavatus* was investigated.

Materials and Methods

All experiments were conducted in the laboratory. *Beauveria bassiana* culture was grown on potato dextrose agar. The fungus grows profusely on this medium at 28 ± 2°C. Spore suspension was adjusted to desired concentration for all experiments.

Riptortus clavatus was reared on potted soybean plants (growth stage R_3 to R_7) maintained at 28 ± 2°C. Various instar nymphs and adults were used for experiments.

In one experiment adults confined in individual petri dishes were sprayed with 1.5 ml at various concentrations of *B. bassiana* spores ranging from 4.52×10^3 to 4.52×10^8. Soon after the treatment, the insects were released on soybean plants in a cage. The caged plants were inspected and the number of dead insects was recorded daily for 3 weeks. Cadavers were observed for the growth of *B. bassiana*. Those that had white hyphal growth were considered killed by *B. bassiana*; those without this symptom were considered as having died by other causes. Corrected percentage mortality data were used to compare the insect susceptibility to *B. bassiana*. Using the same procedure and concentration of 2.165×10^8 spores/ml, the effect of constant (15, 20, 25, 30, 35°C) and varying temperatures (32°C during the day and 23°C during the night) on the susceptibility of adult *R. clavatus* to *B. bassiana* was studied. In another experiment the susceptibility of 3rd, 4th, 5th instar nymphs and adults of *R. clavatus* to 1.5 ml sprays of 2.165×10^8 spores/ml *B. bassiana* was investigated.

Results and Discussion

Insect mortality increased linearly with increasing concentration of *B. bassiana* spores in the suspension. A highly significant positive correlation was found in dose mortality parameters (r = 0.808**). The LC_{50} was 1.25×10^6 spores/ml. Based on this study the fungus seems to have a potential for controlling *R. clavatus*.

Mortality which was 100% at 15 and 20°C decreased only slightly (98%) at 25°C but declined drastically to 45% at 30°C and 0% at 35°C. The LT_{50} was 6.4 days at 15°C, 5.3 days at 20°C, 4.1 days at 25°C and 5.5 days at 30°C. Reduced effectiveness of the fungus at temperatures above 25°C will limit its utility in the tropics. At varying temperatures of 32°C during the day (12 hours) and 23°C at night (12 hours), mortality was comparable (54%) to the mortality at constant temperature of 30°C.

The 4th and 5th instar nymphs of *R. clavatus* were more susceptible than the 3rd instar or the adults (Table 5). The 1st and 2nd instar nymphs were too small and were excluded from the test; besides they rarely damage the plants.

Table 5. Mortality of various instars of *R. clavatus* infected by *B. bassiana*[a]

Instar	Host no.	Total mortality (%)	Mortality due to other factors (%)	Corrected mortality (%)[b]	LT_{50} (days)[c]
Adult	60	56.7	8.3	52.1 ab	38.0
5th instar	58	78.9	4.9	76.3 a	5.4
4th instar	60	71.7	5.0	70.2 ab	4.9
3rd instar	60	48.3	23.3	32.1 bc	-

[a]Concentration, 2.165 × 108 spores/ml; 1.5 ml suspension was sprayed on 60 insects per replicate.
[b]Corrected mortality: No. dead insects due to fungus/Total number of insects-No. insects died from other causes × 100 Data are means of three replicates. Means in column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.
[c]Lethal time to kill 50% of treated insect population

Screening of Soybean Germplasm for Resistance to Limabean Pod Borer

Summary

During summer to autumn 1990 selected soybean accessions for resistance to limabean pod borer, *Etiella zinckenella* (Trietsche) were screened under two trials. In the first screening, 960 soybean accessions, planted once each in September and October 1990, were screened. The mean podborer damage was 5.0 % damaged pods in the first planting and 10.25% in the second. None of the accessions was highly resistant. However, 24 accessions showed moderate levels of resistance in both plantings. In the second planting, wherein 30 accessions were planted in July, August, September and October, only three accessions (G958, G1099 and G1343) were less damaged than average in each of the plantings. These accessions showed potential for pod borer resistance. All were small-seeded but whether the resistance is caused by their small-seededness remains to be investigated.

Introduction

In Asia, limabean pod borer, *Etiella zinckenella* (Trietsche) (Lepidoptera: Pyralidae), is a destructive pest of soybean and to a lesser extent other legumes. The pod borer lays eggs mainly on young pods and soon after hatching the larva bores into the pod and feeds on developing seed. As a result of such feeding damage, yield is reduced. If not adequately controlled, yield reduction varies from 15 to 20% in Taiwan to up to 60% in Indonesia. The mature larva descends to the ground and pupates in the soil. The concealed feeding and pupation habits protect this insect from natural enemies and also renders conventional insecticide use ineffective. As a result, this insect is difficult to control. AVRDC's research goal is to breed pod borer-resistant soybean cultivars. In this respect, soybean germplasm are being screened for resistance to this insect for some years in autumn, the peak pod borer damage season. So far, however, no truly resistant accession has been found. The least damaged accessions in all past tests were all small-seeded. Small-seeded soybeans, irrespective of their varietal differences, are always less damaged. Even PI 227687 which shows some resistance to limabean pod borer is distinctly small-seeded. In 1990–91 screening germplasm for resistance to this pest was continued. In one test, 1000 soybean accessions were screened and planted in September and October 1990. In another confirmatory test, 30 selected accessions planted in June, July, August and September were screened.

Materials and Methods

For the first test, a 0.8-ha parcel of land was plowed and, after application of basal fertilizers, worked into 0.75-m raised beds. These beds were further divided into 5-m long individual plots. Seeds of each of 1000 soybean accessions were planted in single rows on the top of individual plots. Planting was done twice, in September and October 1990.

Planting procedure used in the second test was similar to that used in the first test. However in this test, only 30 accessions were used with each accession being planted in four randomly selected plots, each plot being one replicate. This planting was done four times, in June, July, August and September 1990.

The crop was raised using customary cultural practices including, when necessary, irrigation, weeding, fertilizer application and disease control to achieve high yield. No insecticide was applied. At the start of pod formation in the earliest maturing accession, in each planting, an undetermined number of laboratory-raised limabean pod borer adults were released to increase insect population and thereby minimize escapes. At harvest 25 plants were uprooted from each plot, the number of pod borer-damaged and healthy pods was recorded and the percentage damaged pods calculated.

In the first test, pod borer damage data were analyzed statistically based on mean (X) of percentage pod damage of all accessions included in the test and standard deviation (SD) of mean. The accessions that had a percentage pod damage of less than X - 2SD were considered highly resistant (HR); between X - 2SD and X - 1SD, moderately resistant (MR); between X - 1SD and X as having low resistance (LR); between X and X + 2SD, susceptible (S); and more than X + 2SD, highly susceptible (HS).

In the second test, the percentages of pod damaged were analyzed using ANOVA and means were separated by Duncan's multiple range test.

Results and Discussion

Among the 1000 accessions planted, only 960 could be evaluated. Others did not germinate or survive until pod formation. The insect damage ranged from 0.8 to 18.2% (mean 5.0 ± 2.3%) in the first planting and from 1.5 to 29.1% (mean 10.3 ± 4.5%) in the second planting. None of the entries showed a high level of resistance. Some entries that were moderately resistant in first planting were susceptible in the second and vice versa. The following accessions were moderately resistant in both plantings: G8459, G8483, G8502, G8503, G8507, G8565, G8594, G8619, G8631, G8666, G8673, G8688, G8710, G8719, G8735, G8755, G8759, G8766, G8831, G8833, G8862, G9332, G9341 and G9978. Most of these accessions are small-seeded. These accessions will be investigated in the 1991–92 season to judge their suitability for breeding purposes.

Except for standard susceptible checks, all entries included in these tests were selected for their low damage in the previous year. Pod borer damage in these entries varied considerably among the four plantings. The mean podborer infestation increased from June to September. The lower the mean damage, the higher was the correlation coefficient (r = -0.8). When pod borer population was high, the CV was low and there were clear statistical differences in percentage damaged pods. A similar trend was observed in all previous tests. Starting in 1991–92 germplasm will be screened in September and possibly October only. Three accessions in the present test had the lowest damage. All three accessions, however, have small seeds and thus may not be of much value in resistance breeding.

Mechanism of Limabean Pod Borer Resistance in Soybean

Summary

Various biological characteristics of limabean pod borer, *Etiella zinckenella* (Trietsche), as they are influenced by apparently resistant and susceptible host plants, were investigated in a laboratory study. The insect laid significantly fewer eggs on resistant PI227687 than on susceptible KS9. The number of neonate larvae of the pod borer boring inside the pods of PI227687 was significantly less than on the pods of KS9. Significantly fewer larvae feeding inside pods of PI227687 pupated successfully compared to those insects feeding from pupae which were significantly less when the larvae were fed on PI227687. Male pupal weight and wing expanse of male adults were both significantly less when larvae were raised on PI227687 than on KS9. A combination of various factors including antibiosis seem to be responsible for resistance of PI227687 to limabean pod borer.

Introduction

In Asia, soybean is attacked by a variety of insects from shortly after germination up to harvest, and in some cases even during storage. Among the four lepidopterous species that bore into the maturing pods and feed on developing seeds, the limabean pod borer, *Etiella zinckenella* (Trietsche) (Lepidoptera: Pyralidae), is the most serious. In the field, *E. zinckenella* lays eggs on immature pods and its neonate larvae bore into

pods and feed on developing seeds while remaining hidden in the pod. The fully mature larva leaves the pod and pupates in the soil. Larval feeding reduces seed yield. In Indonesia up to 80% of pods can be damaged with consequent yield loss approaching 60%. The cryptic nature of the life history of *E. zinckenella* makes it practically impossible to control by use of insecticides. The thick leaf canopy that covers pods when they are immature and vulnerable to the podborer damage, makes it difficult for insecticides to reach the pods and kill neonate larvae while still outside the pod. To minimize the limabean pod borer damage, research at AVRDC is directed towards breeding soybean cultivars that are resistant to this pest. In 1988–89 four insect-resistant plant introductions were screened and PI 227687 was found to be consistently more resistant than the others. In 1990 a study of the mechanism of resistance was initiated. Preliminary results of this study were presented in the 1990 Progress Report. The results of that study are presented here.

Materials and Methods

All experiments were conducted twice, once in 1990 and 1991 with potted soybean plants raised in a greenhouse. Planting was done once a week to assure supply of plants at every growth stage. An apparently limabean pod borer-resistant accession, PI 227687, and a commercial cultivar KS9, which is susceptible to this insect, were used.

In the first experiment, when plants were at R_2 stage, one plant of PI 227687 and one of KS9 were placed in each of the six nylon net cages, each cage being one replicate. Three newly emerged pairs of limabean pod borer adults were released inside each cage for oviposition. After 4 days the number of eggs laid on each plant, mainly on pods and adjacent plant parts was recorded. The eggs on the pods were marked and the number of those hatching and failing to hatch was recorded. The number of neonate larvae penetrating the pod and those that failed to do so was also recorded.

The pods that had larvae feeding inside were observed daily for exiting larvae in preparation for pupation in the soil. The exited larvae were placed in a container filled with tissue paper. This medium substituted for soil in which the limabean pod borer normally pupates. The insect pupated readily. The duration of larval period was recorded. The numbers of larvae that pupated and those that failed and subsequently perished were recorded and pupation percentage was computed.

The newly formed pupae were weighed individually and placed in a moist filter paper-lined petri dish. The number of pupae emerging into adults and the number that failed to emerge were recorded and the percentage adults that emerged were calculated. The newly emerged adults were killed and their forewings fully stretched. The distance between extreme wing tips of each adult was measured to compare the wing expanse.

Results and Discussion

The various characteristics of limabean pod borer oviposition and insect development are presented in Table 6. Limabean pod borer laid significantly fewer eggs on the plants of resistant PI 227687 accession than on susceptible check KS9. In both accessions eggs were laid on pods and inflorescences. Both accessions had practically similar numbers of pods per plant but the pods of PI227687 were distinctly

Table 6. Oviposition and development of limabean pod borer on selected soybean accessions.[a]

Characteristic	KS9	PI227687	t value[b]
Eggs per plant (No)	53.7 ± 7.0	22 7 ± 5.7	36 7**
Egg hatching (%)	82 1 ± 4.7	83.5 ± 3.0	-83 5NS
Larval boring in pods (%)	84 0 ± 3.6	70.0 ± 4.4	-70.0**
Larval period (days)	15.9 ± 1.4	16 2 ± 1.5	-0.3NS
Pupation (%)	84 1 ± 2 1	73.0 ± 3 7	11.0**
Pupal period (days)	9 8 ± 1.4	10.5 ± 1 5	0 7NS
Pupal weight (mg) male	31 9 ± 3.7	29.3 ± 3.8	2.6*
Pupal weight (mg) female	29 2 ± 3 3	27 9 ± 2.7	1 3NS
Adult emergence (%)	91 9 ± 4 4	62.7 ± 7.4	62 7**
Adult wing expanse (mm) male	19.5 ± 0.6	19.0 ± 0 4	53.4*
Adult wing expanse (mm) female	18.3 ± 0.6	18.3 ± 0.3	0NS

[a]Data are means of six replicates.
[b]* = significant at 5% and ** = at 1% probability level. NS= not significant.

smaller than those of KS9. There was no difference in egg hatching whether the oviposition took place on the pods of KS9 or PI227687. The numbers of limabean pod borer larvae boring inside the pods were significantly higher on KS9 than on PI227687. There was no significant difference in the duration of larval period whether insects were raised on PI227687 or susceptible check KS-9. The rate of pupation of limabean pod borer larvae feeding inside the pods was significantly less on PI227687 than on KS9. Like the duration of larval period, there was no significant difference in the duration of pupal period whether the larvae fed on KS9 or PI227687. Male pupae, the larvae of which were raised on PI227687, were significantly lighter than those of larvae raised on KS9. No such difference was observed in the case of female pupae. The emergence of *E. zinckenella* adults from the pupae was drastically reduced when the insects were raised on PI227687 but not when they were reared on KS9. The wing expanse of male adults, the larvae of which were raised on PI227687, was significantly smaller than that of males with larvae raised on KS9. No such difference was found in the female moths. It appears that the combination of various factors such as oviposition, larval boring in pods, pupation rate, and emergence of adults is responsible for resistance of PI227687 to limabean pod borer.

Selection of Egg Parasite Species and Strains for the Control of Limabean Pod Borer on Soybean

Summary

Some 19 trichogrammatid egg parasites were tested individually for their ability to parasitize eggs of limabean pod borer. All species were able to parasitize the eggs but the rate of parasitism varied greatly. *Trichogrammatoidea bactrae* and *Trichogramma ostriniae* parasitized more than 80% of the limabean pod borer eggs and appeared to be promising. Both trichogrammatids were used to control other insects in Taiwan and elsewhere, and it is possible to commercially use them for the control of limabean pod borer in soybean.

Introduction

Limabean pod borer, *Etiella zinckenella* (Treitsche), is a destructive pest of soybean in Asia. The adult lays eggs on immature pods and the inflorescence, and soon after hatching, the larva enters the pod and feeds on developing seed until it is ready for pupation, which takes place in the soil. Pod borer damage is more serious in the tropics. AVRDC's research emphasizes breeding limabean pod borer-resistant soybean cultivars. In this connection, screening for resistant soybean germplasm is ongoing and one accession (PI227687) with a moderate level of resistance has been identified. However, use of insect-resistant cultivars alone will not solve the pod borer problem and supplemental control measures are necessary. Since the pod borer spends its entire larval period inside the pod and pupal period in the soil, these stages are protected from natural enemies. Adults are too agile and die within a short period. Eggs, however, are stationary and for 4–5 days of incubation, they are vulnerable to attack by natural enemies. AVRDC maintains several species of egg parasites for its research on diamondback moth. These parasites were tested in the laboratory to investigate their ability to parasitize the eggs of limabean pod borer.

Materials and Methods

Soybean seeds of cultivar AGS 66 were planted in vermiculite placed in round plastic containers (10-cm diameter, 5-cm high). A week after germination when unifoliate leaves were fully opened, eight such containers were placed in one nylon net cage (30 × 30 × 30 cm) containing a large number of limabean pod borer adults. The plants were maintained inside the cage for 2 days for the insect to lay eggs on them. The limabean pod borer-oviposited plants were transferred to eight similar nylon net cages, one container per cage, each being one replicate. In each cage about 1000 *Corcyra* eggs parasitized with one species of the egg parasite were released. The emerging parasite adults were allowed to remain in contact with limabean

pod borer oviposited in plants for 4 days. The total parasitized limabean pod borer eggs were recorded and the percent parasitism was calculated as follows:

No. eggs parasitized/total number of eggs (parasitized + unparasitized + larvae) × 100

The parasitized eggs became darker as the parasite developed within the eggs.

Results and Discussion

The results of the parasitism of limabean pod borer eggs by various species or strains of egg parasites are presented in Table 7. Most of the species were able to parasitize limabean podborer. In eggs, however, the rate of parasitism varied considerably. *Trichogrammatoidea bactrae* recorded the highest parasitism. Two other species, *Trichogramma ostriniae* and *Trichogramma agrotidis* also had similarly high parasitism values. *Trichogrammatoidea bactrae* also showed a high rate of parasitism in diamondback moth. *Trichogramma ostriniae* is used commercially for the control of Asiatic corn borer, *Ostrinia furnacalis*, in Taiwan and elsewhere in Asia. A mass rearing procedure for both egg parasites is already available. These parasites seem to be suitable for the control of limabean pod borer in the field. The performance of both egg parasites in the field in autumn 1991 is still being investigated to assess their potential for commercialization.

Table 7. Parasitism of limabean pod borer eggs by various egg parasite species or strains.[a]

Strain No.[b]	Species	Parasitism (%)
1	*Trichogramma pretiosum*	64 6 cde
2	*Trichogramma cacoeciae*	58 6 defg
3	*Trichogramma chilonis*	67.3 bcd
5	*Trichogramma chilotraea*	26 0 j
6	*Trichogramma cordubensis*	44 1 hi
7	*Trichogramma japonicum*	31.6 ij
9	*Trichogramma confusum*	69 5 bcd
10	*Trichogramma maidis*	35.4 ij
11	*Trichogramma dendrolimi*	36.7 ij
12	*Trichogramma trjapitzint*	59.4 defg
16	*Trichogramma semblidis*	64.5 cdef
17	*Trichogramma* sp. France	37.3 ij
19	*Trichogramma agrotidis*	77.8 abc
21	*Trichogrammatoidea bactrae*	83 7 a
22	*Trichogramma principium*	40 0 hi
31	*Trichogramma embryophagum*	69.6 bcd
32	*Trichogramma evanescens*	39.1 hij
33	*Trichogramma ostriniae*	80 0 ab
37	*Trichogramma nubilale*	51.4 efgh

[a]Data are means of eight replicates. Means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Soybean Pathology

Screening Soybeans for Resistance to Anthracnose and Development of Anthracnose Under Field Conditions

Summary

Anthracnose is an important disease of soybean in the humid tropics and subtropics. There are no cultivars resistant to anthracnose, and few studies have reported on the development of anthracnose in the field. In this study, soybeans were screened for resistance, and the development of anthracnose was monitored under irrigated and nonirrigated conditions. Under controlled conditions, inoculated plants had symptoms of tip dieback, veinal necrosis, and distortion of leaves. There were two wild perennial *Glycine* accessions that had lower disease ratings than the other entries, and the wild perennial species had much lower ratings than the commercial cultivars. In another test, incubation under high humidity for 48 hours was sufficient to detect differences in disease rating among lines. In the field, anthracnose developed more under inoculated/irrigated conditions than in other treatments without irrigation or inoculation. The incidence of anthracnose on petioles was higher than those leaves and often reached 100% on those plants that were inoculated. Anthracnose on pods and stems from plants in inoculated/irrigated plots averaged 86%. Only 8% of germinated seeds were pathogen-free, and only 31% seed germination was recorded from plants grown in irrigated plots while 65% of the seeds germinated from noninoculated plots. From a field experiment of vegetable soybeans, 15% of the pod shells from plants at growth stage R_6 were infected with *Colletotrichum*. Seed germination was 0% from both fungicide-protected and nonfungicide-protected plots. Viability of seeds produced under humid tropical conditions remains a serious constraint to soybean seed production in many countries.

Introduction

Anthracnose is an important disease of soybean in the humid tropics and subtropics. The disease is caused by several species of the fungus *Colletotrichum* which infects foliage, stems, pods, and seeds of soybeans. The disease has been recorded in all soybean-growing areas of the world. The pathogen can cause a reduction in stand and lower seed quality and yield.

Symptoms typically appear in the early reproductive stages on leaves, petioles, stems, and pods as irregularly shaped brown lesions. Seeds are often infected with or without symptoms. Symptoms in the field are not always visible on living plant parts, but stromatic fungal bodies on dead or dying tissues lower in the canopy are visible. The fungus is known to cause latent infection in most soybean tissues. There are only a few reports about resistant sources of soybeans to anthracnose, and there are few active breeding programs developing resistance to anthracnose even though the disease is important especially in humid tropical environments.

Grain and vegetable soybean seed production in the tropics and subtropics has been limited by problems related to high temperature and high relative humidity during seed maturation that results in poor seed quality and is often associated with seedborne pathogens. Many of the seedborne pathogens can first be detected on plant parts by assays developed to detect latent infection. These seedborne pathogens often reduce seed quality and affect seed germination.

The objectives were to screen soybeans for resistance, monitor disease development under field conditions, and assay seeds for the occurrence of *Colletotrichum* and other seedborne pathogens.

Materials and Methods

Inoculation experiments. A series of inoculation experiments, using cultivars AGS 129, KS 1, KS 8, and SJ 5, were conducted under growth room conditions at high humidity (>98%) and at 25–28°C. Seeds were sown in 9-cm pots and thinned to three plants per pot before inoculating them at growth stage (GS) V2. For all experiments there were three replications of three plants per pot for each cultivar. Plants were inoculated by spraying a conidial suspension on foliage until runoff. The first two experiments used isolate Ct-111; experiment three used a mixture of three isolates; experiment four used isolates Ct-128 and Ct-130; and experiment five used isolates Ct-111 and Ct-130. In each experiment, noninoculated plants were used as controls. Disease was assessed 7-10 days after inoculation by using a 0-4 scale [disease index (DI)] where 0 = no disease; 1 = necrotic leaf veins, 2 = necrotic leaf veins and petioles; 3 = necrotic leaf veins, petioles, and stems; and 4 = dead plants.

Evaluation of resistance. Seeds of cultivars AGS 129, KS 1, KS 8, and SJ 5; *G. soja* accessions G 3080, G3084, G 3086, and G 3088; accessions of wild perennial *Glycine* species G 5154, G 5155, G 5156, G 9054, G 9941, G 9943, G 10360, and G 10361; and three unknown accessions, 336, 584, and 609 were planted in 12-cm diameter clay pots in the greenhouse with three replications. Three plants in each pot were kept after germination. Conidia of isolates Ct-111, Ct-130, and Ct-131 at 5×10^6 conidia/ml were sprayed until runoff on foliage of cultivated types at GS V2 and at an equivalent time period for wild types. Plants were covered with transparent plastic bags in the growth room for 1 week before assessing them for disease as previously described.

In another screening trial, 7-day old plants of eight entries were sown in flats and thinned to 10 plants per entry with three replications per treatment. Treatments were the time of incubation at high humidity after inoculation: treatment 1 = 0 time; 2 = 12 hours; 3 = 24 hours; and 4 = 48 hours. Plants were evaluated 6 days after inoculation using the following disease index (DI): 1 = no symptoms; 2 = slight veinal necrosis with curled leaf laminar; 3 = veinal necrosis with stem and cotyledon necrosis; 4 = severe veinal, stem, and cotyledon necrosis; and 5 = dead plant.

Anthracnose development under field conditions. Three soybean cultivars, AGS 129, KS 1, and SJ 5, were planted in the field on 19 March 1991. The experiment was a split-plot in a randomized complete block design with main plots as treatments and subplots as cultivars. Plants were inoculated at GS R_1 by spraying a conidial suspension of isolates Ct-77, Ct-99, Ct-111, Ct-128, Ct-130, and Ct-131 on 25 and 29 April; and on 1, 8, 15, and 24 May. The experiment had four treatments: 1 = inoculation with overhead mist irrigation, 2 = inoculation without overhead mist irrigation, 3 = no inoculation with overhead mist irrigation, and 4 = no inoculation and no irrigation. Overhead mist irrigation was done daily at 30-min intervals for 5 minutes from 25 April to 24 May.

Plant tissue samples were taken periodically to monitor infection. Twenty leaf blades and petioles were sampled 71 days after planting (DAP). Ten stems and 50 pods were also sampled 56 DAP from KS 1, 76 DAP from AGS 129, and 85 DAP from SJ 5. Samples were cut into 10-20-cm lengths and soaked in 1% sodium hypochlorite solution for 20 min, then soaked in paraquat (1:40 dilution with water) for 1 min and washed twice with sterile water before placing samples in culture dishes with moist filter paper. These were incubated for a week before recording the incidence and severity of the samples. Incidence was converted to percent. Disease severity was rated as follows: 0 = no necrosis; 1 = 1-20% of surface area with necrosis; 2 = 21-50% necrosis; and 3 ≥ 50% necrosis. Mature dry seeds from each plot were surface-sterilized by using 1% sodium hypochloride solution, and then rinsed in sterile water before placing seeds on PDA disks. Samples were incubated for 5–7 days at 24°C under 90–95% RH before evaluating the occurrence of seedborne pathogens.

Vegetable soybean. Cultivar KS-1 was planted in the field on 1 May 1991 in a randomized complete block design with two treatments (sprayed three times with Benlate 50% w.p. and not sprayed) and two replications. Five to 10 samples of stem bases, uppermost petioles, lowermost petioles, green pod shells, and green seeds were randomly collected from soybean plants at GS R_5, R_6, R_7 in each plot. Mature seeds were sampled after harvest. All samples (except mature seed) were prepared as previously described. Incidence and severity were recorded. Mature seeds were plated directly on potato dextrose agar, incubated for 7 days at 25°C, and evaluated for germination and the occurrence of seedborne pathogens.

Results and Discussion

Inoculation experiments. In all the experiments, the noninoculated plants were symptomless. Inoculated plants had symptoms of tip dieback, veinal necrosis, and distortion of leaves. In experiment one the DI on the four inoculated cultivars was 3.0 with no variation in the data. In experiment two, there was no significant difference between the lines and the DI was 2.1 for AGS 129, 2.6 for KS 1, 2.8 for KS 8, and 2.3 for SJ 5. In experiment three, using a mixture of three isolates, the ratings between lines were not significantly different and ranged from 3 to 3.3. In experiment four, lines, isolates, and their interaction were significant. Plants inoculated with Ct-130 had an average severity rating of 2.9 which was significantly greater than the severity of 2.3 caused by Ct-128. No significant differences were observed between the lines within isolate Ct-130, but SJ 5 was more susceptible than the other lines when inoculated with Ct-128. In experiment five, there were no significant differences in the rating between the lines and the average rating was three with little variation. These series of experiments indicated that isolates varied in their virulence, and that all lines were nearly equal in susceptibility.

Evaluation of resistance. The average anthracnose DI of the 19 entries was 2.3 and the DI significantly differed between the entries (Table 1). The cultivars generally had the highest ratings while the wild perennial species had the lowest rating. Two accessions, G 10361 and 609, had the lowest DI at 0.5 and 0.2, respectively.

Table 1. Anthracnose index on cultivated soybeans, *Glycine soja*, and perennial Glycine species inoculated with *Colletotrichum truncatum* 7 days after incubation.

Entry	*Glycine* species	Disease index
AGS 129	*G max*	3 3[a]
KS 1	*G. max*	3.0
KS 8	*G. max*	3.2
SJ 5	*G. max*	3.3
G 3080	*G. soja*	3.0
G 3084	*G. soja*	2.8
G 3086	*G soja*	2 8
G 3088	*G. soja*	3.0
G 5154	perennial type	1.8
G 5155	perennial type	3.0
G 5156	perennial type	2.0
G 9054	perennial type	3.0
G 9941	perennial type	1.0
G 9943	perennial type	1.0
G 10360	perennial type	2.0
G 10361	perennial type	0.5
336	perennial type	2.5
584	perennial type	2 7
609	perennial type	0.2
Average		2.32
LSD (5%)		0.63

[a]Values represent means of three plants per pot in each of three replications where 0 = no disease; 1 = necrotic leaf veins, 2 = necrotic leaf veins and petioles; 3 = necrotic leaf veins, petioles, and stems; and 4 = dead plants.

Based on the incubation time after inoculation, no symptoms occurred on plants that were not incubated at high humidity; plants incubated for 12 hours had no necrosis but were slightly stunted and had crinkled leaf laminars; plants incubated for 24 hours had a DI of 2 with no differences between the entries; and plants incubated for 48 hours had DI that differed significantly (Table 2). The line with the lowest severity was SRE-D-14A (DI = 3.6). A few lines like KS 8, SJ 5, and TK 5 had DI of over 4.8.

Anthracnose development under field conditions. Incidence of anthracnose on leaf samples prior to incubation over all lines and treatments averaged 32% with a severity of 0.3 (Table 2). There was a

significant difference between treatments and cultivars. Incidence of anthracnose on leaf samples from inoculated plants had an incidence of 49% and a severity of 0.5, whereas noninoculated plants had an incidence of 15% with a severity of 0.2. Cultivar KS 1 had significantly more anthracnose (44%) than AGS 129 (22%). Incidence of anthracnose on preincubated petioles was 55% with a severity of 0.7 (Table 2). Treatment, cultivars, and their interaction produced significant effects. Incidence of anthracnose on preincubated petioles from inoculated plants was 86% with a severity of 1.1 while on noninoculated plants it was 24% with a severity of 0.3. Incidence of anthracnose on petioles after incubation was 57% with a severity of 1.4 (Table 2). There was a significant effect due to treatment, cultivar, and their interaction. Incidence of anthracnose on petioles after incubation was 99% from inoculated plots and 16% from noninoculated plots.

Table 2. Incidence and disease severity of anthracnose on plant leaves and petioles before incubation and on petioles after incubation from samples taken on three cultivars under four treatments in the field 71 days after planting.

Leaves — preincubated								
	Cultivars							
	AGS-129		KS-1		SJ-5		Average	
Treatment[a]	Inc.[b]	Sev.[c]	Inc	Sev.	Inc	Sev.	Inc	Sev.
Inoculated + Irrig.	35.0	0.4	53 8	0 6	48 8	0.5	45 8	0.5
Inoculated	45 0	0 5	53 8	0.6	56.3	0.7	51.7	0.6
Noninoculated + Irrig	5.0	0.1	32 5	0.4	6.3	0.1	14.6	0.2
Noninoculated	2.5	0.0	37 5	0 5	6.3	0.1	15 4	0.2
Average	21.9	0.2	44.4	0 5	29.4	0.3	31.9	0.3
Petiole - preincubated								
Inoculated + Irrig	78.8	1.0	97.5	1.6	96.3	1.5	90 8	1.3
Inoculated	80 0	0.8	83 8	0.9	82.5	0.9	82.1	0.9
Noninoculated + Irrig	48.8	0 5	25 0	0.3	25 0	0.3	32 9	0.3
Noninoculated	12 5	0.1	17.5	0.2	16.3	0.2	15.4	0.2
Average	55.0	0.6	55.9	0 7	55 0	0.7	55.3	0.7
Petiole - after incubation								
Inoculated + Irrig.	100	2.5	100	2.0	100	3.0	100	2.3
Inoculated	96	2.3	95	2.2	99	2.7	97	2 4
Noninoculated + Irrig.	21	0.3	24	0 2	49	0.9	31	0.5
Noninoculated	0	0	1	0	3	0	1	0
Average	54	1.3	63	1.1	55	1.7	57.3	1.4

[a]Inoculation with overhead mist irrigation, inoculation without overhead mist irrigation, no inoculation with overhead mist irrigation, and no inoculation and no irrigation
[b]Incidence was converted to percentage
[c]Disease severity was rated as follows: 0 = no necrosis; 1 = 1-20% of surface area with necrosis; 2 = 21-50% necrosis; and 3 = > 50% necrosis.

The incidence of anthracnose on pods and stems averaged 43 and 48%, respectively, over all cultivars and treatments (Table 3). Incidence of anthracnose on stems from plants in inoculated plots was 76% compared to 11% in noninoculated plots. KS 1 had the highest pod incidence (52%) but lowest stem incidence (31%).

Germination of seeds that were not infected was low and did not differ by treatment with an average of 8% germination for SJ-5 and 3% each for AGS129 and KS 1. Overall seed germination (infected and noninfected) was 29, 60, 32 and 70% in treatments 1, 2, 3, and 4, respectively. With the addition of irrigation, seed germination was reduced by 50%. Seeds of SJ 5 had the highest germination (20%) among three cultivars in the four treatments. Of the seeds that did not germinate, there were significant differences in the number of seeds infected by *Colletotrichum* spp. among the four treatments. Seeds from plants in the inoculated and irrigated plots had the highest infection (17%) while seeds from noninoculated/nonirrigated plots had the lowest infection (1%). Seeds of KS-1 had the lowest overall infection of *Colletotrichum* spp. (1%). In addition to the infection of *Colletotrichum* spp., *Macrophomina phaseolina* and other microorganisms were detected.

Table 3. Incidence and disease severity of anthracnose on pods and stems before incubation of samples taken from three cultivars under four treatments in the field[a].

Pod								
Cultivars	AGS-129		KS-1		SJ-5		Average	
Treatment[b]	Inc.[c]	Sev.[d]	Inc.	Sev.	Inc.	Sev.	Inc.	DI
Inoculated + Irrig.	90.0	1.2	100.0	1.9	67.0	0.7	85.7	1 3
Inoculated	70.0	0.8	86.5	0 6	40.0	0 3	65.5	0.6
Noninoculated + Irrig.	7.5	0.0	14.5	0.1	34.0	0.2	18.7	0.1
Noninoculated	2.0	0.0	6 0	0.0	1.0	0.0	3 0	0 0
Average	42.4	0 5	51.8	0 6	35.5	0 3	43.2	0 5
Stem								
Inoculated + Irrig.	100.0	2.7	62.5	2.0	95 0	2.9	85.8	2.5
Inoculated	82.5	2.5	60.0	2.0	75.0	2.3	72.5	2.3
Noninoculated + Irrig.	35.0	0.4	2.5	0.0	52 0	1.5	30.0	0.6
Noninoculated	5.0	0.1	0.0	0.1	2.5	0 2	2 5	0.1
Average	55.6	1.4	31 3	1 0	56 3	1.7	47.7	1.7

[a]AGS 129 was sampled 76 days after planting (DAP), SJ 5 85 DAP, and KS 1 56 DAP.
[b]Inoculation with overhead mist irrigation, inoculation without overhead mist irrigation, no inoculation with overhead mist irrigation, and no inoculation and no irrigation.
[c]Incidence was converted to percentage.
[d]Disease severity was rated as follows: 0 = no necrosis; 1 = 1-20% of surface area with necrosis; 2 = 21-50% necrosis; and 3 = > 50% necrosis.

The addition of inoculum and irrigation succeeded in causing infection of anthracnose on plant tissue and on mature seeds. Irrigation was very important for the development of seedborne diseases both under inoculated and noninoculated conditions. The cultivar SJ 5, popular in Thailand and selected under high relative humidity and high temperature environment conditions, had the highest seed germination (20%) among three cultivars in four treatments. Development of both grain and vegetable soybeans for the tropics will have to have improved seed quality characteristics including seed germination, especially if seed production under tropical conditions is going to be successful.

Vegetable soybean. From tissue samples taken at three growth stages, *Colletotrichum* spp. was isolated most frequently from pod shells (15–22%) at GS R_6 (Table 4). *Colletotrichum* was not isolated from green seed. *Phomopsis* occurred at a low rate on pod shells at GS R_6. The use of fungicides did not significantly decrease *Colletotrichum* except on samples from upper petiole at GS R_6. Seed germination from fungicide-

Table 4. Percentage incidence and severity of fungi infecting plant tissue of KS-1 at growth stages R_5, R_6, R_7.

		Without fungicide		With fungicide	
Growth stage	Plant tissue	Incidence	Severity	Incidence	Severity
R_5	Upper petiole	5[a]	1	4	1
	Lower petiole	11	1	1	< 1
	Stem	0	0	0	0
	Pod shell	0	0	< 1	< 1
	Green seed	0	0	0	0
R_6	Upper petiole	30	7	0	0
	Lower petiole	10	2	1	< 1
	Stem	9	2	4	1
	Pod shell	17	2	22	4
	Green seed	0	0	0	0
R_7	Upper petiole				
	Lower petiole				
	Stem	6	1	5	> 1
	Pod shell	15	2	16	3
	Green seed	0	0	> 1	> 1

[a]Each value represents the mean of 5–10 samples from three replications.

protected plots and nonfungicide-protected plots was 0%. The incidence of bacteria from the nongerminated seeds averaged 57% from fungicide-treated and 44% from nonfungicide-treated plots. All seeds were free from *Colletotrichum*. *Fusarium* spp. occurred in 54% of the seed. Under high temperatures, *Bacillus subtilis* is known to infect and deteriorate seed which was probably the case in this study. This bacterium is also known to produce antifungal compounds which have been shown to reduce colonization of seed by fungi.

The most frequently isolated pathogen was *Colletotrichum* spp., which occurred on petioles, stems and green pod shells, but not on mature seeds. *Phomopsis* sp. and *Macrophomina* sp. did not attack the soybean plant tissue at GS R_5, R_6, and R_7, but did occur on mature seeds. When and how these pathogens enter the plants to cause seed infection needs more study. The results also indicate that a high percentage of nongerminated seed was infected with bacteria and *Fusarium* spp. Because of the need to produce quality seed in the tropics, more efforts are needed to understand the role of microorganisms in seed deterioration.

Soybean Physiology

Seasonal Effects on Yield and Quality of Vegetable Soybeans

Summary

Five vegetable soybean varieties were planted 19 times in three different seasons to examine the effect of certain environmental factors on yield and quality. AGS 292 was confirmed to have high yield potential, which could be attributed to high harvest index. Seeds of AGS 292 had the lowest protein content and the highest soluble sugars and starch contents. Pods of AGS 292 also tended to develop purple spots on their exposed surface. Although a new breeding line, KVS 124, had a relatively high pod yield, it had the smallest seed size.

Among 19 plantings, vegetable soybeans planted in February to June had consistently higher graded pod numbers and yields than in July–October. Generally low total and leaf dry matter production together with high humidity in July to October plantings could be factors that contribute to low-graded pod number and yields.

Introduction

Tropical countries have a great potential to produce and use vegetable soybean to increase the nutritive value of the cereal or root crop-based diet. However, the yield and quality of vegetable soybean are sensitive to environmental conditions. Thus maturity, marketable yield, pod and seed size, and pod quality are significantly different in various cropping seasons. In the southern part of Taiwan, which is the major vegetable soybean producing area, vegetable soybean is grown in the narrow range of spring and autumn plantings. Since information on environmental constraints that would limit vegetable soybean production in the tropics is unavailable, this study used seasonal plantings to examine specific factors that could limit the yield and quality of vegetable soybean.

Materials and Methods

Seeds of AGS 292 (Kaohsiung Selection No. 1), G 9053 (Tazurunoko, Tainung No. 205), G 10134 (Tainung 305, Ryokkoh), GC 84136, and KVS 124 were sown in spring and autumn at 10-day intervals 19 times, starting on 6 July 1990 and ending on 19 July 1991 (Table 1). In each planting, an RCBD with three replicates was used. Each plot, 5 m long, had 4 rows. Plant spacings were 10×50 cm^2. Total pod yield, 100-seed weight at R_6 growth stage, weight of graded pods (two- and three-seed, unblemished pods), and dry weights of different plant parts were taken from three randomly chosen plants from each variety of each replicate. Immature seeds were analyzed for protein, oil, soluble sugars and starch. Environmental data were also collected.

Results and Discussion

Combining data of 19 plantings, AGS 292 gave the highest mean graded pod yield (8.2 t/ha) (Table 1), followed by KVS 124, G 9053, GC 84136, and G 10134 in decreasing order. Although AGS 292 had the lowest total and leaf dry weights, it had the highest harvest index, resulting in the highest yield. On the other hand, although KVS 124 has the highest total dry matter (due to its late flowering and maturing), it had the lowest harvest index, thus a low yield potential. Among tested entries, an increase in harvest index or early maturity, therefore, would result in higher pod yield.

Table 1. Seasonal effects on growth and yield of promising vegetable soybean selections.

Entry/date	Pod yield (t/ha)	Total dry wt (g/plant)	HI (%)	Seed/pod (%)	Market pod (%)	Market pod (No /5 m²)
KVS 124	7 6 ab[a]	24 a	43 d	52 b	67 b	1670 a
G 9053	7 3 bc	18 c	49 b	51 c	69 ab	1616 a
AGS 292	8 2 a	16 d	55 a	50 d	71 a	1596 a
G 10134	6.7 c	19 c	48 b	54 a	61 c	1329 b
GC 84136	7.4 bc	22 b	47 c	46 e	59 c	1374 b
90/07/06	4.7	13	51	51	62	1103
90/07/16	3.6	15	52	51	61	1004
90/09/07	4 7	13	42	48	62	1176
90/09/17	7 8	18	47	53	76	1569
90/09/27	3.8	11	44	53	68	772
90/10/06	4 3	10	46	52	73	915
90/10/16	4.7	12	49	46	67	880
90/10/26	3.5	11	47	45	61	662
91/02/07	8.9	18	53	51	72	1646
91/02/19	9.8	20	54	53	70	1856
91/02/28	9.9	23	53	51	69	1878
91/03/07	10.2	23	54	52	74	2023
91/03/18	10.2	24	50	52	70	1854
91/03/27	9.1	24	50	54	64	1759
91/05/30	8.3	33	46	50	52	1755
91/06/10	11 4	32	49	51	55	2242
91/07/61	8 2	28	43	53	61	1932
91/07/10	8 0	26	45	51	64	1772
91/07/19	10.5	28	48	50	63	2198
Mean	7.4	20	49	51	66	1519
LSD (5%)	3.70	7	7	2	9	445

[a]Mean separation within columns at 5% level by DMRT

Pod number per unit land area was high in KVS 124, G 9053 and AGS 292, but seed/pod ratio on fresh weight basis was relatively low in AGS 292 and GC 84136. The extremely high seed/pod ratio in G 10134 may indicate competition of photosynthate between seeds, a factor that can reduce graded pod yield. Therefore, a medium seed/pod ratio may be beneficial for AGS 292 with high pod number, resulting in the highest marketable pod ratio.

Combined data of varieties indicated that February–June plantings consistently had higher graded pod numbers and yields than the July–October plantings (Table 1). Differences in seed/pod and marketable pod ratios between plantings with high and low yields were not as great as the total dry matter production. Low total and leaf dry matter production in July–October plantings could be the factors contributing to low graded pod number and yields. Poor growth of vegetable soybeans grown from July to October was likely due to either excessive rainfall before harvest or to decreasing temperature. In general, AGS 292 flowers and matures earlier than the other entries, thus avoiding these environmental stresses. Therefore, an improvement in early maturity or management in overcoming these abiotic stresses would increase graded pod yields from July to October.

Combined data of 19 plantings showed that G 10134 achieved the highest 100-seed weight (66 g) (Table 2). This was followed by GC 84136, AGS 292, G 9053 and KVS 124 in decreasing order. Although pod yield of KVS 124 came second to the highest yielder, AGS 292 (Table 1), KVS 124 had the lowest seed size, and could be undesirable as a vegetable soybean.

Seeds of GC 84136 contained the highest amount of protein, but the lowest oil content. On the contrary, seeds of AGS 292 had the lowest amount of protein, but the highest soluble sugar and starch content. Among 14 plantings, the February–March plantings consistently yielded seeds that were larger and had higher protein content. On the contrary, seeds from July to October plantings had high soluble sugar content. Among all entries in the 19 plantings, protein content was negatively correlated with starch content

(r = - 0.98, P = 1%), and soluble sugars (r = - 0.82, P = 0.1%). Plants from February to March plantings had greater nodule dry weight. This is attributed to moderate soil moisture and high temperature during these months. These conditions also resulted in large seed size and high protein content.

Oil content in the seed did not fluctuate as much as the content of other nutritional components, except for two plantings in the middle and the end of October. Decreasing temperature could have a negative effect on the oil content.

Table 2. Seasonal effects on 100-seed weight (g) and nutritional quality (% dry matter) of promising vegetable soybean selections.

Entry/date	100-seed wt.	Protein	Oil	Soluble sugars	Starch
KVS 124	54 e[a]	43.7 b	19.9 a	8 8 d	7 54 d
G 9053	56 d	42.0 c	20.0 a	9.2 c	8.53 c
AGS 292	58 c	39.5 d	19.9 b	10.5 a	9.54 a
G 10134	66 a	42.2 c	19.5 c	9.8 a	8.66 b
GC 84136	61 b	45.3 a	18.1 d	9 4 b	6.64 e
90/07/06	50	39.8	19.7	12.1	6.93
90/07/16	48	42.4	19.8	11 8	5.38
90/09/07	48	41.4	18 8	12 5	7.13
90/09/17	66	41 3	19.2	10.2	9 29
90/09/27	60	39.5	19.9	10.3	10 54
90/10/06	58	39.0	18.5	11.7	9.73
90/10/16	58	41.6	16.8	11.8	8.29
90/10/26	57	41.5	16 8	11.6	9 20
91/02/07	67	44.6	19.0	8.7	8.67
91/02/19	69	44.5	19.4	8.4	8 74
91/02/28	68	45.0	19.6	7.7	8.80
91/03/07	68	45.0	19 3	7.4	8.64
91/03/18	66	44.1	19.6	7.3	8.40
91/03/27	63	43.9	19.6	8.0	7.33
91/05/30	55	42.8	20.5	8.0	8.00
91/06/10	53	41.7	21.3	8.0	8.09
91/07/61	54	42.5	20.5	9.0	7.48
91/07/10	54	42.8	20.8	8.6	7.56
91/07/19	56	42.8	20.9	8.9	7.48
Mean	59	43.2	20.0	8.8	7.79
LSD (5%)	5	1.0	0.5	0.4	0.54

[a]Mean separation within columns at 5% level by DMRT.

Combined data of varieties showed that pods from 27 September planting (harvested in the first 2 weeks of December), and 28 February and 7 March plantings (harvested in the last 2 weeks of May) tended to develop purple spots on the outer surface. AGS 292 pods, harvested from 28 February and 7 March plantings, had 45% purple spots, followed by G 9053 (16%) and G 10134 (4%). These plants received excessive rainfall immediately before harvest; some plants lodged and their pods were exposed to the sun. These conditions could cause purple spot development. On the other hand, plants from the September planting were exposed to gusty winds (as high as 199 km/hour); this could be another cause of purple spot development. Leaves of AGS 292 and G 9053 had small leaf area and the lowest chlorophyll content throughout their growing period (Fig. 1). Whether or not small leaf area or chlorophyll content is related to purple spot development requires further study.

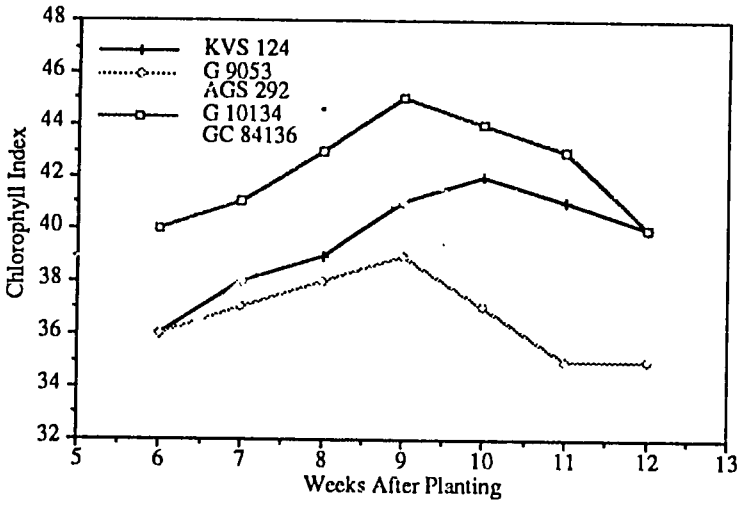


Fig. 1. Changes in chlorophyll contents in leaves of five vegetable soybean selections.

Purple Spots on Vegetable Soybean

Summary

Three vegetable soybean selections were examined for factors conducive to purple spot development on the pod shell. AGS 292 was the variety most prone to developing purple spots, likely due to its smaller leaf area. The reduction of light intensity by 55% shading was effective in reducing the incidence of purple spot.

Introduction

One of the major concerns in vegetable soybean production is the blemished pod shell. The blemishes on pod shells can be induced by disease, insects and physical conditions (e.g. by rubbing). The damage generally brings about brown spots. Purple spots on the pod shell, on the other hand, are occasionally found in some varieties in some seasons. To pinpoint the factors that cause purple spots on vegetable soybean, experiments including shading and defoliation were conducted.

Materials and Methods

Seeds of G9053 (Tzurunoko, Tainung No. 205), AGS 292 (Kaohsiung Selection No. 1) and G10134 (Tainung 305, Ryokkoh) were sown on 19 March 1991 in the field. At 9 weeks after planting, a split-split plot design was employed with entry as main plot, shading treatments as subplots and defoliation treatments as subsubplots. There were three replicates per subplot.

There were two shading treatments: control and black net shading (with 45% light penetration). Maximum and mean daily light intensities were 1980 and 607 mM/sec/m^2, respectively, for the control, and 907 and 244 mM/sec/m^2 for shade. Four defoliation procedures were done: 1) all leaves removed (0 leaflet), 2) one leaflet per leaf remained, 3) two leaflets per leaf remained, and 4) three leaflets per leaf remained. Six plants were randomly sampled from each replicate at 10 days and 14 days after treatment (i.e. 73 and 77 days after planting), and investigated for purple spot development.

Results and Discussion

G 9053 produced more leaves and had more leaf area (there was little canopy light penetration) than did G 10134 and AGS 292. AGS 292 had the least number of leaves and leaf area. At 10 days after

treatment, the incidence of purple spot was highest in AGS 292 followed by G 10134 and G 9053 (Table 3). High light intensity (without shading) resulted in more purple spots on the pod shell. Shading (reduced light intensity) tended to reduce the purple spot development on AGS 292. These results suggest that high light intensity is strongly related to purple spot incidence and that more leaves could reduce the exposure of developing pods to the light, thus, fewer purple spots could result. However; when the pods were exposed to sunlight without leaf protection (total defoliation), very few purple but more brown or yellow pods were found. In fact, more purple spots developed on the pods of the plants with two or three leaflets. It is likely that defoliation inhibited some factor or signal transfer from the leaves that caused preferential distribution of developing pods, thus reducing purple spots.

Table 3. Effects of shading and defoliation on ratios (%) of graded pod and purple spot development of vegetable soybeans.

Entry/treatment	Graded pod	Purple pod
Main plot: Variety		
G 9053	35	0.1 b[a]
AGS 292	34	4.5 a
G 10134	34	0.8 b
Subplot: Shading		
Control	34	3.2 a
55% Shading	35	0.4 b
Subsubplot: Defoliation		
0 leaflet	29 b	0.2 b
1 leaflet	35 a	0.4 b
2 leaflets	36 a	2.3 ab
3 leaflets	38 a	4.4 a

[a]Mean separation within columns at 5% level by DMRT.

Sweet Potato Breeding

Evaluation of Promising Clones in the Preliminary Trials

Summary

Fourteen scab-resistant clones were evaluated during spring and summer 1991 as PYT-II entries. In addition, they were scored for reaction to scab disease in an artificial inoculation test. Two clones gave consistently better yields than the check clones during the two seasons. These clones also had the same, if not better, dry matter content and dry matter yields as the check clones. The scab reaction scores of the best clones were low, confirming their high level of resistance. The selected clones will be included in the set of materials for distribution.

Introduction

The evaluation of promising clones that were selected from the first year preliminary yield trial (PYT-I) was continued. These clones were specifically selected for desirable agronomic traits and resistance to sweet potato scab. They were entered in the second year PYT-II where plot dimension was twice that of PYT-I. Generally, PYT-II materials are planted in two seasons, spring and summer, to give a wider range of environment for selecting clones.

Materials and Methods

Fourteen clones (including four checks) were evaluated for yield, morphological traits, and chemical scores in PYT-II during spring and summer 1991. Tainung 66, Tainung 67, CN1489-89, and CN1510-25 were used as the check clones.

The same entries were screened for response to scab disease. Twenty-four plants per clone were artificially inoculated with the fungus and incubated in the growth chamber on 16 May 1991. I 55 and I 1189 served as the susceptible and resistant checks, respectively. All screening procedures followed the guidelines developed by plant pathologists. Scab scoring rate followed the scale: 1 = highly resistant to 6 = highly susceptible.

Results and Discussion

Two entries that performed consistently better than the checks during spring and summer are shown in Table 1. These clones had the same, if not better, dry matter content as the check cultivars. Their dry matter yields were generally higher than those of the checks, especially in spring. In summer, only clone CN 1936-13 had higher dry matter yields than the checks. As in previous years, yields in the hot, wet season were generally low. CN 1936-13 gave the highest yield of 18 t/ha during this season, more than two times better than the next best clone and check CN 1489-89.

The two best clones showed high levels of resistance to scab. In contrast to their scab infection scores of 1.4 and 1.8, the resistant check (I 1189) and the susceptible check (I 55) had scab infection scores of 1.2 and 4.2, respectively, during the test.

Table 1. Yield and other horticultural characters of best entries vs. checks in the preliminary trial (PYT-II); AVRDC, 1991 spring and summer seasons.

Entry	Mark. yield (t/ha)		Dry matter (%)		Dry matter yield (t/ha)		Starch content (%dwb)		b-carotene (%dwb		Scab rating	Flesh color
SP91	SU91	SP91	SU91	SP91	SU91	SP91	SU91	SP91	SP91	SU91		
CN1936-13	16 ab	18 a	31 d	29 d	5 a	5 a	58 cd	66 bc	2 c	1 cd	1	Y2
CN1936-13	13 a-c	7 b-d	36 ab	30 cd	5 a	2 bc	61 a-c	66 bc	2 c	1 c-e	2	Y3
CN1489-89 (ck)	13 b-d	7 b-e	34 c	32 bc	4 a-c	2 b-d	59 cd	67 b	2 c	1 c-e		Y1
TN67 (ck)	7 c-e	4 c-f	38 a	36 a	3 cd	2 b-e	64 a	72 a	1 c	2 cd		Y501

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Performance of Selected Clones In the Advanced Trials

Summary

A number of new clones at different stages of testing were evaluated for yield and other characters in 1990 and 1991. Among the AYT (Group 1 clones processing and supplementary food type) in fall 1990 trial, only one clone compared favorably with the check CN 1489-89 in yield (about 25 t/ha), dry matter content (about 33%) and starch content of about 72%. No promising clones could be identified from the orange-fleshed and feed-type groups. The two best clones among the yellow-fleshed group were only comparable at best with check CN 1489-89 in yield, and in dry matter content and yield. Some of the new clones had higher ß-carotene than CN 1489-89 and indicated resistance to sweet potato scab in a controlled inoculation experiment.

Introduction

Following the 2-year, 4-season evaluation in the preliminary yield trial stage, the best clones are normally entered in the advanced yield trial (AYT). The AYTs are carried out in three different seasons, viz. spring, summer and fall. Since sweet potato research at AVRDC was due for completion in 1991, we paid particular attention to evaluating the promising selections from the 1990 PYT-II. These clones were evaluated in 1990 fall season AYTs to evaluate their performance.

Materials and Methods

Detailed information on the AYT trials conducted in 1990/91 season are given in Table 2.

Table 2. Details of the sweet potato trials conducted in 1990–91.

Season	Trial	Group	No. of entries	Plant date	Harvest date	Duration	Design*
1990 fall	AYT	Processing/ supplementary food	14	8/31	1/28	150	RCBD;4;80 5 × 4 m²
		Orange-fleshed type	10	9/18	2/11	146	ditto
		Yellow-fleshed type	11	9/21	2/19	151	ditto
		Feed type	16	9/21	2/25	157	ditto
1991 spring	AYT	High dry matter clones	12	3/19	7/16	119	RCBD;4;80 5 × 4 m²
	PYT-II	Scab-resistant clones	14	3/20	7/17	119	RCBD;2;40 5 × 2 m²
1991 summer	AYT	High dry matter clones	12	5/14	9/11	120	RCBD;4;80 5 × 4 m²
	PYT-II	Scab-resistant clones	14	5/15	9/16	124	RCBD;2;40 5 × 2 m²

* Numbers after experimental design denote number of replicates, plants per plot and dimensions, respectively.

Four groups of selections were evaluated in 1990. The same set of clones was previously evaluated in spring and summer 1990. These consisted of the following: 14 processing/supplementary food type (Group 1); 10 orange-fleshed clones (Group 2); 11 yellow-fleshed clones (Group 3); and 16 feed type clones (Group 4).

Nine clones selected for high dry matter content from 10 entries in the fall 1990 PYT II were used in the 1991 AYT trials. Tainung 57, Tainung 66, CN 1489-89 and CN1510-25 were used as standard checks for the AYT trials. Twenty-four plants per clone of the 1991 AYT entries were also provided separately for scab reaction test. This test was conducted at the same time as the 1991 PYT II set.

Results and Discussion

The best clone from the 1990 AYT (Group 1—processing and supplementary food type) is shown in Table 3. The selected clone was only comparable to CN 1489-89 in overall performance, yielding about

the same (25 t/ha), with dry matter content of around 33%, high dry matter yield of about 8.5 t/ha and starch content of about 72%. Tainung 66 had the highest yield but this was not significantly higher than the yields of CN 1843-341 and CN 1489-89. It also had the highest ß-carotene content. However, it had the lowest dry matter content of all the entries.

Table 3. Yield and other horticultural characters of a selected clone of Group 1 (processing supplementary food type) vs. checks in the advanced yield trial; AVRDC, fall 1990.

Entry	Mark yield (t/ha)	Dry matter (%)	Dry matter yield (t/ha)	Starch content (%dwb)	ß-carotene (mg/100g)	Flesh color
CN1843-341	25 bc	34 a	8 a	71 ab	0 1f	Y5
CN1489-89 (ck)	26 a-c	33 a	9 a	73 a	0 2f	Y1
TN57 (ck)	11 f	28 de	3 f	69 b-d	0 3f	Y3O1
TN66 (ck)	27 ab	28 e	7 ab	65 f	7 a	O5Y3

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

No promising clones relative to the most appropriate checks could be identified from the AYT Groups 2 (orange-fleshed clones) and 4 (feed type clones). The two best clones among the AYT Group 3 (yellow-fleshed) clones are given in Table 4. Again, these clones only compared at best with CN 1489-89 in terms of yield, dry matter content and yield, although they had slightly higher ß-carotene (especially CN 1688-116).

Table 4. Yield and other horticultural characters of selected clones of Group 3 (yellow-fleshed clones) vs. checks in the advanced yield trial; AVRDC, fall 1990.

Entry	Mark. yield (t/ha)	Dry matter (%)	Dry matter yield (t/ha)	Starch content (%dwb)	ß-carotene (mg/100g)	Flesh color
CN1757-30	19.2a-c	30 7b	5 9bc	70 9b	1.7b-d	Y1
CN1688-116	22 6a	32 4a	7 3a	72 8a	2.0b	Y1
TN66 (ck)	18.8bc	25 3f	4 8c	63 5e	9.5a	Y5O5
CN1489-89 (ck)	20 9ab	31 1b	6 5ab	71 0b	1 1de	Y1
TN57 (ck)	17 7b-d	28 1d	5 0c	68 9cd	0 4f	Y3O3

Yields of the AYT entries (including the checks) tested in summer 1991 were invariably low. No new clone was therefore selected from this trial. The best clones from the spring planting are given in Table 5. These clones significantly outyielded CN 1489-89 but not Tainung 66. However, they had appreciably higher dry matter contents and yield than Tainung 66. ß-carotene contents of some of these high dry matter clones, e.g., CN 1888-17, were much improved over other materials. These clones also exhibited resistance to sweet potato scab as indicated in Table 5.

Table 5. Yield and other horticultural characters of selections vs. check cultivars in the advanced yield trial; AVRDC, spring 1991.

Entry	Mark. yield (t/ha)	Dry matter (%)	Dry matter yield (t/ha)	Starch content (%dwb)	ß-carotene (mg/100g)	Scab rate	Flesh color
CN1912-200	18 ab	30 ef	5 bc	61 b-d	1 de	2	Y2O1
CN1899-34	13 b-d	33 cd	4 b-e	63 bc	2 c-e	2	Y1
CN1888-17	11 cd	33 cd	4 de	58 de	6 b	2	O3Y3
CN1489-89 (ck)	9 d	32 de	3 e	58 de	1 c-e		Y1
TN66 (ck)	21 a	24 h	5 b-d	50 f	11 a		O5

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

Inheritance Studies and Breeding for Resistance to the Scab Disease Caused by *Sphaceloma batatas* Saw

Summary

One of the most important diseases of sweet potato is scab, caused by the fungus *Sphaceloma batatas*. Host plant resistance to scab has therefore been one of the main objectives of the Center's breeding program since 1985. In this experiment, the inheritance of resistance to sweet potato scab was studied among three populations. Heritability (h^2) values for resistance varied among different populations. When the population (A) was generated by polycrosses among randomly chosen parent cultivars from the AVRDC germplasm, h^2 was 0.4 ± 0.2 indicating a fairly adequate gene frequency which would allow individual plant selection for the trait. A higher h^2 of 0.7 ± 0.2 was obtained when the population (B) was generated by polycrosses among parent cultivars that were selected for scab resistance. The higher gene frequency for scab resistance in this population contributed to a higher genetic component for the character. In contrast, the h^2 value from its reciprocal (or the regression of offspring on male parents) was 0.5 ± 0.4, indicating no maternal or extrachromosomal inheritance. Results from this experiment suggest that incorporating high levels of scab resistance could be readily accomplished especially if the parental stocks are properly selected.

Introduction

One of the main objectives of the Center's sweet potato breeding program since 1985 is to increase host-plant resistance to the scab. However, there is a paucity of genetic data on this trait. There is a need to understand the inheritance of resistance to scab so that breeding progress may be attained by applying suitable breeding procedures as guided by genetic data.

The objective of the present experiment is to study the inheritance of resistance to scab in populations generated from different mating schemes.

Materials and Methods

Generating host populations

Three populations, A, B and C, were generated for the study. Populations A and B were generated using the same polycross mating design but differed in that the 16 parents of population A were not selected for scab resistance whereas the 16 parents of population B were selected based on their range of scab reaction (highly resistant, moderately resistant, and susceptible). Population C had parents with varying levels of resistance to scab and was generated by controlled hand pollinations.

Raising of parents in pollination nurseries

Cuttings of a flowering sweet potato cultivar, American Yellow Skin, were planted as rootstocks to induce flowering of parents in the cross- pollination blocks. One month after planting, scions from various parents were grafted onto these rootstocks. For populations A and B, 16 parents were set up in a polycross field nursery using a Latin square design. For population C, hand crossings were set up as a diallel mating design. Due to insufficient seed production of some biparental crosses, the design was later modified to a nested (or hierarchical) mating design.

Raising of plants/seedlings and scab testing

Ten clones of each of the parents, resistant standard check cultivar (V 2-30 or AVRDC Acc. No. I 1175), and susceptible standard check cultivar (AVRDC Acc. No. I 55), were grown on 10 cm diameter plastic pots 14 days before the scab test. More than 150 seeds from each female parent of population A or B and from each cross of population C were sown in 10 cm diameter plastic pots 10 days before inoculation.

Populations A, B and C were inoculated separately. For population A, only 9 of the 16 parents were used in this study. For population B, all 16 parents were used, whereas for population C, only those with sufficient seeds were used.

At the time of inoculation, relatively uniform clones and progeny seedlings for each parent (or cross) were chosen and inoculated with conidia suspensions of 1 x 10^4 spores/ml using a power sprayer. Plants were placed in a growth chamber in a completely randomized design. Temperature in the chamber was maintained between 28 and 32°C, with a relative humidity of 90-100%. After 7-10 days, plants were rated for resistance using a scale of 1-6, with 1 = highly resistant (no visible symptoms) and 6 = highly susceptible (leaves, petioles and stems severely infected).

Statistical analysis of data

The disease ratings of each population were evaluated by ANOVA, followed by Duncan's Multiple Range Test. Frequency distribution tables for populations A, B and C were generated along with the family means. Transformed mean ratings of progenies were used in a regression analysis with the corresponding clonal parent means. Heritability (h^2) of scab resistance was computed using the formula of Becker (1988)[1]; $h^2 = 2b$ where b is the regression coefficient. Expected gain from selection assuming 5% of the population being retained was also calculated.

Results and Discussion

Population A

Scab resistance ratings of the resistant check cultivars V2-30 (or AVRDC Acc. No. I 1175) ranged from 1 to 4, with a mean rating of 2.2, whereas, that of the susceptible check cultivar I 55 ranged from 3 to 5, with a mean of 4.3 (Table 6). Of the nine cultivars tested, three (CN 1221-1, CN 1310-5 and I 107), had ratings that were not significantly different from that of the resistant check. Since the nine cultivars were picked randomly, it appeared that differences in levels of scab resistance existed among the AVRDC germplasm.

Table 6. Differences in scab ratings of sweet potato parent clones, unselected for scab resistance, used to generate population A.

Cultivar	No. of plant rated	Scab rating[a]	
		Range	Mean
CN 1221-1	10	1-3	1.7 a
CN 1310-5	10	1-4	2 2 ab
I 107	10	2-3	2.2 a
CN 1448-49	10	2-3	2 5 bc
I 139	10	1-4	2.7 bc
I 130	10	1-5	2.8 bc
TN 66	10	1-5	2.9 bc
TN 65	10	2-4	3 0 c
CN 1229-16	10	2-4	3.2 c
Check cultivars:			
V 2-30 (resistant check)	10	1-4	2.2 ab
I 55 (Susceptible check)	10	3-5	4.3 d
Population	90	1-5	2.6

[a]Scab rating ranged from 1 to 6, where 1 = highly resistant and 6 = highly susceptible

The frequency distribution for scab rating of the polycross progenies of population A is discussed below (Table 7). The variances among the progenies of CN 1221-1 and CN 1229-16 were 1.1 and 1, respectively, whereas the variances of their clonal plants (i.e., derived from cuttings) were 0.5 and 0.4, respectively. The variation between the clonal plants is expected to be attributed to nongenetic causes, whereas the variation among the progeny plants is due to both genetic and nongenetic causes. Population A consisted of 1350 progenies with a mean rating of 3.60, higher than the 2.60 rating of the clonal parents. Overall, 16 plant genotypes out of a total of 1350 plant genotypes of population A (or 1.1%) were rated 1.0 or highly resistant, with at least one highly resistant genotype from each of the nine female parents.

[1]Becker, W A. 1985. Manual of Quantitative Genetics. (4th ed). Academic Enterprise, Pullman, Washington, U S A

Table 7. Frequency distribution for scab rating of sweet potato polycross progeny population (A) derived from parent cultivars unselected for scab resistance.

Pedigree	Total progeny plans	Scab rating[a]							Variance
		1	2	3	4	5	6	Mean	
CN 1221-1	150	3	31	74	23	14	5	3.1	1.1
CN 1310-5	150	1	8	43	44	37	17	4.1	1.3
I 107	150	1	27	66	36	18	2	3.3	1.0
CN 1448-49	150	2	37	63	33	10	5	3.2	1.1
I 139	150	2	15	53	48	21	11	3.7	1.2
I 130	150	1	12	49	52	24	12	3.8	1.2
TN 66	150	2	12	40	52	34	10	3.9	1.2
TN 65	150	3	24	68	30	19	6	3.4	1.2
CN 1229-16	150	1	9	44	55	36	5	3.9	1.0
Population[2]	1350	16	175	500	373	213	73	3.6	
Clonal plants:									
V 2-30 (Resistant check)	10	1	7	1	1	0	0	2.2	0.6
I 55 (Susceptible check)	10	0	0	1	5	4	0	4.3	0.5
CN 1221-1	10	4	5	1	0	0	0	1.7	0.5
CN 1229-16	10	0	1	6	3	0	0	3.2	0.4

[a]Scab rating ranged from 1 to 6, where 1 = highly resistant and 6 = highly susceptible.
[b]Distribution of progeny population was not normal since Univariate Procedure (SAS) showed skewness = 0.28; kurtosis = -0.37; and test W: normal = 0.89, with Prob. < W = 0 01.

The heritability value of the scab resistance in population A was $h^2 = 0.4 \pm 0.2$ (Table 6). An h^2 value of 0.20 is considered by some as the minimum heritability value in which individual plant selection is likely to be effective. A value of 0.4 indicates a fairly sizable frequency of genes for scab resistance, in turn indicating that larger variation occurred among the progenies due to genetic and nongenetic factors.

Population B

Eight cultivars had mean ratings significantly higher than that of the resistant check V2-30 (Table 8). The most susceptible among the 16 parents was I 1114, with a mean rating of 3.70 but was significantly less than the rating of 4.2 for the susceptible check.

Twenty-nine of 2327 progenies were rated highly resistant (Table 9), whereas 411 were resistant. Progeny families of the female parent I 216, I 112, I 835, and I 934 had some genotypes rated as highly resistant. The progeny families without a single highly resistant genotype came from the female parents I 1182, CN1747-88, I 890 and I 345. Except for these, the distribution of scab resistance among progeny families does not differ markedly. The mean scab rating of the progeny families ranged from 2.89 (tending toward resistance) for the progeny family of the female parent I 112 to 4 (tending toward susceptibility) for the progeny family of the female parent I 345.

For population B, the h^2 value of scab resistance was 0.72 ± 0.14 (Table 10). This heritability value is much higher than that of population A, reflecting the preponderance of the genes for scab resistance in this population arising from selection of parents for scab resistance. Since this is the first stage of selection, the high heritability of the trait reflects the progress in selection based simply on the phenotypic values of individual plants.

In the study using handcrosses, there appears to be no significant role of maternal inheritance for scab resistance.

Monitoring the Progress in Scab Resistance Breeding

Monitoring the changes in the Center's sweet potato populations bred for scab resistance yielded the data given in Table 11. At the start of the scab resistance program in 1986, all the progeny families tended toward susceptible classes with a population mean scab rating of 5.5 and with variances within each family ranging from 0.12 to 0.6. None of the progenies was rated 2 or better for scab resistance. By 1988, a slight

Table 8. Differences in scab ratings of sweet potato parent clones, selected for their scab resistance ratings used to generate population B.

Cultivars	No. of plants rated	Scab rating[1] Range	Mean
I 216	9	1–2	2 a
I 112	10	1–3	2 ab
I 835	8	1–3	2 ab
CN 1836–163	10	1–3	2 ab
I 1182	10	1–3	2 abc
I 933	9	2–3	2 abc
I 932	10	1–4	2 bc
I 949	10	1–3	2 bc
CN 1747–88	10	2–3	3 cd
I 1189	7	2–4	3 cde
I 890	10	2–4	3 de
I 934	9	2–3	3 de
I 613	7	2–4	3 de
I 1174	10	2–5	3 de
I 345	9	2–6	3 de
I 1114	10	2–5	4 e
Check cultivars:			
V 2–30 (resistant check)	8	2–4	3 de
I 55 (susceptible check)	6	3–5	4 ef

[1]Scab ratings ranged from 1 to 6 where 1 = highly resistant and 6 = highly susceptible.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 9. Frequency distribution for scab rating of sweet potato polycross progeny population (B) derived from parent cultivars selected for scab resistance ratings.

Pedigree	Total progeny plants	Scab ratings[1] 1	2	3	4	5	6	Mean	Variance
I 216	145	5	29	56	40	[illegible]	6	2.9	1.2
I 112	143	4	43	69	21	[illegible]	2	2.9	0.8
I 835	147	6	41	69	22	[illegible]	1	2.9	0 9
CN 1836-163	142	2	35	69	23	[illegible]	[illegible]	3.1	0.9
I 1182	143	0	25	61	40	[illegible]	[illegible]	3.4	1.0
I 933	145	1	30	65	33	[illegible]	[illegible]	3.2	0.9
I 932	147	1	31	78	26	[illegible]	[illegible]	3.1	0.8
I 949	[illegible]45	2	28	77	31	[illegible]	[illegible]	3.2	0.8
CN 1747-88	145	0	20	68	38	[illegible]	3	3.4	0.9
I 1189	145	1	16	49	32	26	19	3.9	1.5
I 890	142	0	30	76	32	3	1	3.1	0.6
I 934	147	4	25	86	22	8	2	3.1	0.8
I 613	148	1	20	58	38	17	14	3.6	1.4
I 1174	149	1	15	64	50	14	5	3.5	0.9
I 345	150	0	9	44	51	31	15	4.0	1.2
I 1114	141	1	14	49	42	23	12	3.8	1.3
Population[2]	2327	29	411	1038	341	212	96	3.3	
Clonal plants:									
I 216	9	2	7	0	0	0	0	1.8	0.2
I 1114	10	0	1	3	4	2	0	3.7	0.9
V 2-30 (resistant check)	8	0	5	2	1	0	0	2.6	1.1
I 55 (susceptible check)	6	0	0	1	3	2	0	4.2	0.6

[1]Scab rating ranged from 1 to 6, where 1 = highly resistant and 6 = highly susceptible.
Distribution of progeny population was not normal since Univariate procedure (SAS) showed skewness = 0.59; kurtosis = 0.22 and test @: normal = 0.26 and Prob. > W = < 0.01.

Table 10. Heritability[a] of scab resistance in three sets of populations and the standard error of the heritabilities.

Population	Heritability, h^2	Standard error
Population A	0.4	0.2
Population B	0 7	0.1
Population C:		
Offspring - female parent	0.5	0.3
Offspring - male parent	0.5	0.4

[a]The heritability values for Populations A and B were calculated as $h^2 = 2b$ where b = regression between the mean scab ratings of the progenies and the mean scab ratings of the female parents (male parents unidentifiable). In population C, where both female and male parents were identifiable, regression analyses were carried out for both (a) offspring with female parent and (b) offspring with male parents

Table 11. Frequency distribution for scab resistance of progenies of sweet potato female parents in the applied breeding program for scab resistance improvement in 1986, 1988, 1989 and 1990.

Year	Pedigree	Total	Scab rating[a]							Variance
			1	2	3	4	5	6	Mean	
1986	CN1028-15	28	0	0	1	2	13	12	5.3	0.6
	G16	43	0	0	1	3	4	35	5.7	0.5
	GI13	39	0	0	1	1	5	32	5.7	0.4
	I306	37	0	0	6	4	10	17	5.0	5.3
	GI19	29	0	0	0	0	4	25	5 9	0.1
		176	**0**	**0**	**9**	**10**	**36**	**121**	**5.5**	**0.7**
1988	CN 1831-42	36	0	1	8	11	5	11	4.5	1.5
	CN 1827-5	49	0	1	10	18	6	14	4.5	1.4
	CN 1828-46	42	0	0	13	12	6	11	4.4	1.4
	I948	46	0	3	12	17	9	5	4.0	1.2
	I1186	44	0	0	11	17	7	9	4.3	1.2
	I1189	34	0	1	6	8	11	8	4.6	1.3
	I1175	48	0	4	11	12	15	6	4,2	1.4
		299	**0**	**10**	**71**	**95**	**59**	**64**	**4.3**	**1.3**
1989	CN 1489-89	16	0	0	5	5	4	2	4.2	1.1
	CN 1732-4	46	0	0	9	20	12	q5	4.3	0.8
	CN 1747-20	33	0	1	15	9	4	4	3.9	1.2
	CN 1817-226	46	1	3	17	15	5	5	3.8	1.3
	CN 1822-127	46	1	1	16	14	11	3	3.9	1.2
	CN 1656-101	43	0	2	7	11	13	10	4.5	1.4
	CN 1525-11	37	0	3	7	13	13	1	4.1	1.0
	TN 67	34	0	0	4	9	16	5	4.7	0.8
	TN 57	30	0	2	4	11	11	2	4.2	1.0
	I949	31	0	2	15	10	4	0	3.5	0.7
	CN 1618-461	39	0	0	5	7	26	1	4.6	0.6
	CN 1661-62	12	0	0	0	7	3	2	4.6	0.6
		413	**2**	**14**	**104**	**134**	**122**	**40**	**4.1**	**1.1**
1990	CN 1836-163	24	0	8	7	6	3	0	3.2	1.1
	CN 1618-461	42	1	2	21	8	10	0	3.6	1.0
	CN 1525-11	20	0	1	2	9	8	0	4.2	1.6
	CN 1832-77	41	2	3	11	15	6	4	3.8	1.5
	CN 1489-89	43	1	1	7	16	10	8	4.3	1.4
	CN 1747-88	11	0	0	3	3	2	3	4.5	1.5
	CN 1656-37	29	0	0	10	4	10	5	4.3	1.3
	CN 1688-116	37	0	0	16	7	8	6	4.1	1.3
	CN 1661-15	36	0	0	7	9	13	7	4.6	1.1
	CN 1790-42	18	0	0	3	4	4	7	4.8	1.3
		341	**5**	**19**	**101**	**92**	**79**	**45**	**4.0**	**1.4**

[a]Scab rating ranged from 1 to 6 where 1 = highly resistant and 6 = highly susceptible.

shift in the frequency distribution was observed such that 10 progeny plants were rated 2. Although none was yet rated 1, the population mean scab rating was already 4.3, a relatively better resistance level than that of 1985. Also, plant variation in the scab resistance was increased compared to that of 1985 which ranged from 1.2 to 1.5. Slight improvement in scab resistance was observed in 1989 when the frequency distribution showed two progeny plants rating 1 and 14 plants rating 2. These progenies had a population mean scab rating of 4.2 with the variance somewhat slightly reduced and having a range of 0.6 to 1.4. By 1990, resistance was much slighter; five plants rated 1 and 19 plants rated 2. However, at this time population mean was already levelling off at 4.1 from that of 1989. The variance also was levelling off with a range of 0.7 to 1.6. It is possible that the program has now reached the beginning of a plateau phase in the improvement for scab resistance (Fig. 1). The genetic data from the experiments reported here could serve as a guide in planning breeding procedures.

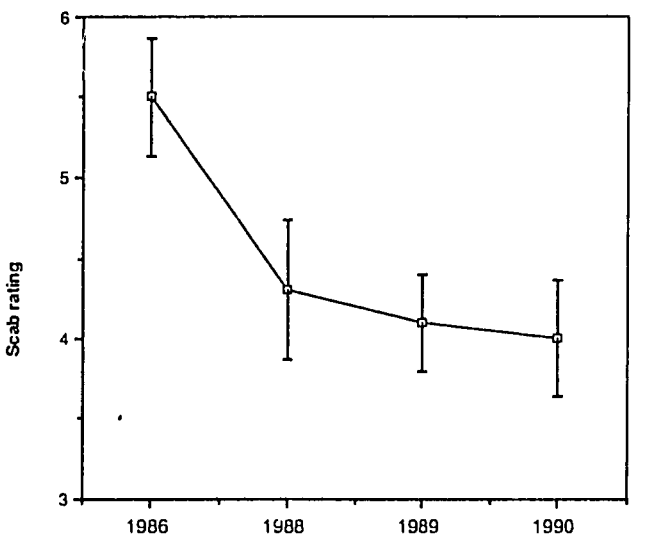


Fig. 1. Changes in the mean and standard deviation of scab rating of sweet potato populations bred for scab resistance.

International Cooperation

Both sweet potato true seeds and virus-free plantlets in test tubes were distributed in 1991. A total of 77 clones in 154 tubes were distributed to the United States, Seychelles, Mauritius, Surinam and Lesotho. A total of 2300 true seeds were sent to cooperators in Bhutan and Zambia.

To facilitate the utilization by national partners of the true seed populations developed at AVRDC, an international cooperator's guide sheet entitled "Handling and selecting improved clones from true seed populations of sweet potato" was recently published. This guide will assist the national programs to access, evaluate and select outstanding clones from genetically diverse true seed populations for their specific agroclimatic, socioeconomic and technological conditions. This approach gives cooperators a better chance of finding highly adapted genotypes which could be released to the sweet potato farmers.

Sweet Potato Entomology

Screening of BC_1F_1 Progeny of Cross Between *I. batatas* and *I. trifida* for Resistance to Sweetpotato Weevil in Vines

Summary

Seven backcross progenies from the cross between *I. batatas* and *I. trifida* and three susceptible checks were screened for resistance in vines to the sweetpotato weevil, *Cylas formicarius* (F.), in the field. The number of weevils (larvae + pupae + adults) found in a 30-cm segment of crown as well as the number of weevil-damaged crowns were recorded. Although there was no statistically significant difference in the number of weevils in the crowns, two clones, CM 1869-13 and CN 1872-8, had the least number of weevils. CN 1872-8 had the lowest number of plants damaged by the weevil. This entry also gave the highest yield in last year's screening trial and appears to be promising in future insect resistance improvement program.

Introduction

Sweetpotato weevil (SPW), *Cylas formicarius* (F.) (Coleoptera: Curculionidae) is the most destructive pest of sweet potato in the tropics and subtropics. Because of its concealed feeding habit and life cycle, this insect is difficult to control economically by conventional means, i.e. insecticide applied by farmers. AVRDC's research, therefore, aimed to develop an integrated pest management (IPM) program based on breeding of SPW-resistant cultivars. AVRDC failed to find any reliable source of resistance amongst 1200 accessions. AVRDC breeders, therefore, crossed *Ipomoea trifida*, a wild relative of sweet potato with *I. batatas* to improve agronomic characters of *I. batatas*. Selected progenies were back-crossed to *I. batatas* to improve yield and quality. Seven promising entries that had certain levels of resistance to SPW in roots were screened for resistance to SPW in vines.

Materials and Methods

Each of the seven selected backcross entries and three susceptible checks were planted in four randomly selected 5 × 1 m plots. Twenty-five vine cuttings were planted in each plot. Four weeks after transplanting large numbers of laboratory-reared weevils were released uniformly over the entire area. Five weeks after weevil release all the plants were uprooted, the crowns cut open and the number of SPW larvae, pupae and adults found inside recorded. The number of weevil-damaged and healthy plants was also recorded. The data on insect count and percentage of plants damaged were analyzed by ANOVA followed by Duncan's multiple range test to compare the SPW infestation of various entries.

Results and Discussion

Results of the SPW infestation of the crowns are summarized in Table 1. All entries were damaged by the weevil. Although there were no significant differences in the number of weevils in the crowns, two entries, CN1869-13 and CN1872-8, had the lowest number of weevils. CN1872-8 had the lowest number of plants damaged by the weevil. This entry also gave the highest yield in the 1990 screening trial. CN1872-8 seemed to have the potential to control weevil in vines. Reduction of SPW infestation in vines before root formation will reduce the weevil inoculum and thereby reduce the damage to the roots when they develop.

Table 1. Infestation of crowns of selected *I. batatas* × *I. trifida* backcrosses by sweetpotato weevil[a].

Progeny	No. weevils[b]/10 crowns	Damaged crowns (%)
CN1861-2	1 48	42
CN1864-56	1 59	32
CN1867-15	1 35	30
CN1869 6	2 33	42
CN1869-13	0 51	46
CN1872-6	1 61	36
CN1872-8	0 70	20
CN1872-9	1 07	52
CN1510-25	1.04	44
TN66	1.28	41

[a]Planting date: 18 June 1990, observation date: 31 August 1990. Data are means of four replicates. Means in each column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test Plot size: 5 × 1 m
[b]Larvae + pupae + adults

Confirmation of Sweetpotato Weevil Resistance In Vines of Sweet Potato

Summary

Six sweet potato clones which were least damaged in vines in tests conducted during early 1990 were screened for resistance to sweetpotato weevil, *Cylas formicarius* (F.), in vines to confirm the resistance. The six promising and four susceptible clones were planted in the field which was inoculated with laboratory-bred weevils to initiate infestation. Two sweet potato accessions, I 123 and I 959, and four progenies from *I. batatas* × I. *trifida* crosses were the least damaged in all three weevil-infestation evaluations carried out during the season. These results confirm observations of tests conducted in early 1990. These clones are considered to be moderately to highly resistant to the sweetpotato weevil.

Introduction

Larvae of the sweetpotato weevil (SPW), *Cylas formicarius* (F.) (Coleoptera: Curculionidae), feed inside sweet potato roots and stems. When tuberous roots are not yet developed or are inaccessible, the adult weevil lays eggs in sweet potato vines. The eggs then develop into larvae which larvae feed inside the vines. These larvae develop into pupae which, in turn emerge from the vines as adults. These adults then search for roots for oviposition and cause damage to the roots. Since it is not possible to find a sweet potato accession with genetic resistance in tuberous roots, AVRDC has initiated screening of sweet potato germplasm to identify sources of resistance to SPW in vines. Preliminary screening in 1989 and second screening in early 1990 identified two sweet potato accessions and four *I. batatas* × *I. trifida* progenies with high levels of resistance to SPW. In this experiment in late 1990 screening was repeated to confirm the resistance so that the resistant sources can be utilized for breeding purposes.

Materials and Methods

A parcel of land was worked into 1-m wide raised beds. These beds were further divided into 40 plots, each consisting of three adjacent 5-m long beds. Vine cuttings of six promising resistant and four susceptible entries were planted individually (one accession per plot) in three rows in each of four randomly selected plots, each plot being one replicate. The crop was maintained using standard cultural practices, except that no insecticide was applied. One month after planting, a large number of laboratory-reared SPW adults were released uniformly over the planted area to initiate weevil infestation. At 3, 5 and 7 weeks after weevil release, all the plants in the first, second and third row, respectively, were uprooted from each plot. A 30-cm portion of the crown was cut open and the numbers of SPW larvae, pupae and adults found inside were recorded, along with the number of plants showing visible weevil damage in the crown. The insect count data were analyzed using ANOVA and the means were compared with Duncan's multiple range test.

Results and Discussion

The results of the SPW infestation of sweet potato germplasm are summarized in Table 2. Two sweet potato accessions, I 123 and I 959, and four progenies from *I. batatas* × *I. trifida* crosses, WT 81, WT 230, WT 352 and WT 5780, were consistently less damaged than the three sweet potato accessions, and one *I batatas* × *I. trifida* cross progeny which was included as the susceptible check. The two sweet potato accessions, I 123 and I 959, have relatively thicker stems than the WT progeny, but they showed similar levels of damage. These results confirm those from a similar screening in early 1990 (1990 AVRDC Progress Report). These six entries were considered as resistant and promising for breeding SPW resistance in vines. There was a highly significant positive correlation between the number of weevils in the crowns and the percent damaged plants at each of the three observations: r^2 0.765; r^2 0.820; r^2 0.702.

Table 2. Infestation of sweetpotato weevil in the vines of selected sweet potato germplasm, AVRDC autumn 1990[a].

Entry	No weevil larvae+pupae+adults per plant		
	First observation 22 Nov 1990	Second observation 7 Dec 1990	Third observation 21 Dec 1990
WT81	0 05 cd	0 13 d	0 20 d
WT230	0 01 d	0 21 d	0 35 d
WT352	0 09 cd	0 36 d	0 39 d
WT578	0 11 cd	0 38 d	0 22 d
I959	0 16 cd	0 43 d	0 83 d
I123	0.53 c	1 35 cd	1 31 cd
WT532	0.43 cd	1 78 c	2 52 bc
I1062	1 36 b	3 11 b	4 53 a
I1082	1 13 b	3 00 b	4 88 a
I118	3 16 a	4 97 a	3 97 ab

[a]Planting date 18 Sept 1990, Data are means (±SE) of four replicates Means in each column followed by the same letter are not significantly different at 5% probability level according to Duncan's multiple range test Plot size 5 m × 1 m

Role of Types of Cuttings and Weevil Source on the Infestation by Sweetpotato Weevil

Summary

A field experiment was conducted to find out whether use of tender stem cuttings, which are normally not preferred by the adult sweetpotato weevil, *Cylas formicarius* (F.), for oviposition, and removing weevil infestation source from the surroundings can have adequate control of the weevil in sweet potato. Open plots where insects can migrate from all directions and plots surrounded by an 1 1-m wide trench of constant standing water were planted to either tender vine cuttings (30-m distal part) or old growth cuttings (60-cm distal part). The infestation of weevil was monitored twice a month throughout the season by uprooting 12 plants and recording the number of insects found in the crown. At harvest root yield and the number of weevils in roots were determined. In open plots planted to old cuttings there was rapid increase in weevil infestation. In enclosed plot the infestation increased only slowly. In open plot planted to fresh growth cuttings there was steady increase in weevil infestation but when the fresh growth cuttings were planted in enclosed plots there was hardly any weevil damage. The root yields in plots planted to fresh growth cuttings and weevil infestation significantly decreased. These results confirm last year's findings that the use of fresh growth cuttings and preventing weevil migration from the surroundings gives effective control of the weevil.

Introduction

Sweetpotato weevil (SPW), *Cylas formicarius* (F.) (Coleoptera: Curculionidae), is the most destructive pest of sweet potato in most tropical and subtropical areas. The larvae feed inside roots rendering even slightly damaged roots unfit for human consumption. Although SPW possess wings, it is a weak flier. It

spreads from field to field via weevil-infested cuttings used for planting a new crop or by adults crawling from infested sweet potato fields or morning glory plants (*Ipomoea* sp.) to the newly planted crop. The insect lays eggs in vines in the absence of roots. Older portions of the vine, rather than younger tender parts, are preferred for egg-laying. In this experiment the use of fresh growth cuttings in preventing migration of weevils from the surrounding area was investigated. This experiment was also meant to confirm results of two previous experiments.

Materials and Methods

A parcel of land was rototilled and worked into 1-m wide beds. The beds were further divided into 16, 10 m × 10 m plots arranged in a square. A distance of 10 m was maintained between any two adjacent plots. Each of the eight plots in one-half of the experimental field was confined on all sides by a 13-m wide trench which was kept flooded throughout the season. This arrangement isolated individual plots from the surrounding area to prevent migration of the weevil. These plots were designated as "enclosed" plots. Empty areas between the plots in the other half of the experimental field, which had the remaining eight plots, were kept uncultivated. The empty area was occasionally rototilled to keep it relatively weed-free. Each plot in this half was thus subject to invasion of SPW from the surrounding area. These plots were designated as "open" plots.

Sweet potato (cultivar Tainung 57) vine cuttings from the weevil-infested field were used as a planting material. A distal 30-cm shoot (fresh growth cutting) was planted in each of four enclosed and four open plots, each plot being one replicate of treatment ("enclosed" vs. "open"). A distal 60-cm shoot (old growth cutting) was planted in the remaining four enclosed and four open plots.

All standard cultural practices were used except that no insecticide was applied. Once every 2 weeks 12 plants from each plot were uprooted, the crowns cut open and the number of SPW larvae, pupae and adults found inside recorded. The number of plants with visible weevil damage in the crown was also recorded. At harvest, root yield was recorded. Five kilogram roots was sampled from each plot for weevil infestation and evaluation. Each root was cut open and thinly sliced, and the number of SPW larvae, pupae and adults found inside was recorded. The yield and insect count data were analyzed by ANOVA and the test of least significant difference (LSD) was used to compare the treatment means.

Results and Discussion

Results of the monitoring of infestation of SPW of sweet potato plants (crowns) are summarized in Figure 1. The old cuttings planted in the enclosed plots and the open plot had practically identical weevil numbers during the first three observations. However, the weevil number increased rapidly in open plots (A) compared to the enclosed plots (B). The rapid increase in weevil population in open plots is obviously due to the immigration of weevils from the surrounding area in addition to the native weevils carried in the vines. The steady but much slower increase in weevil number in enclosed plots planted with old vine cuttings (B) is believed to be due to the native weevils emerging from the old cuttings. Since the inoculum is small, the infestation is low.

There was a continuous increase in weevil infestation of sweet potato planted with fresh growth cuttings in the open field (C). This increase is obviously due to the migration of weevils from the surrounding area, since there were very few weevils in the cuttings as evidenced by practically no increase in the weevil population in sweet potato planted with new growth cuttings in enclosed plots (D). The increase in the number of weevils in the open plot planted to new growth cuttings is not as rapid as when planted with old growth cuttings (A) because very few weevils were carried in the fresh growth cuttings. There was little or no weevil infestation in enclosed plots planted with new growth cuttings. This was also reflected in minimal damage to the root by the weevil (Table 3). Yield was also significantly higher in plots protected from weevil infestation.

It is thus possible to harvest a weevil-free crop if one uses fresh growth cuttings and cleans the surroundings of all possible weevil sources.

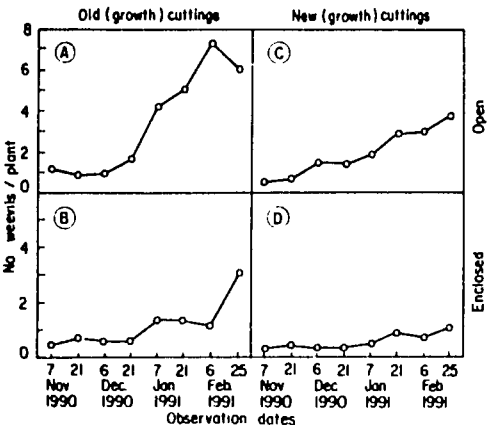


Fig. 1. Infestation of sweetpotato weevil in crowns of sweet potato planted from fresh or old growth cuttings in enclosed weevil-proof and open areas. Planting date, 5 October 1990.

Table 3. Yield and weevil infestation of roots planted with new growth or old growth cuttings in enclosed or open plots[a]

Cutting type	Plot condition	Yield kg/plot	No. weevils[b] /kg root
New growth	enclosed	49.4	2.5
	open	28.3	8.8
Old growth	enclosed	34 6	3.9
	open	13.4	20.1
LSD 5%		14.0	11.4
1%		20 4	16.6

[a]Plot size: 10 m × 10 m. Cultivar. Tainung 57. Planting date: 5 October 1990. Harvest date: 11 March 1991. Data are means of four replicates except in "New growth-enclosed" plots where only three replicates were used.
[b]Larvae + pupae + adults.

Effect of Sweetpotato Weevil Infestation of Crown on Yield

Summary

Two field experiments were conducted: one in spring 1990 and the other in autumn 1990 to study the effect of infestation of sweet potato crowns by the sweetpotato weevil, *Cylas formicarius* (F.), during the season on the yield of sweet potato roots. Carbofuran liquid formulation was applied to crowns at various intervals to create varying levels of weevil infestation. Insect infestation on crowns was monitored once every two weeks and root yield was determined at harvest. Except for the observation taken at 16 weeks after planting in autumn 1990 crop, when a significant negative correlation was observed between the number of weevils in crown and the root yield, there was no correlation between weevil infestation of crown and root yield in both years.

Introduction

Sweetpotato weevil (SPW), *Cylas formicarius* (F.) (Coleoptera: Curculionidae), is the most destructive insect pest of sweet potato both in the field and in storage. In the field, adults lay eggs in the root when the roots are accessible, or in the crown when roots are either not yet developed or are inaccessible. Although

in most cases the root development does not begin until 6–8 weeks after planting, the insects are seen laying eggs in the vines soon after planting, especially the older portion of the vine. The larvae feed inside the crown, and adults that emerge act as an important source of infestation in roots that develop later.

Although there is little doubt that the weevils infesting crowns serve as a source of infestation of roots, it is not certain whether weevils feeding in crowns reduce root yield. At AVRDC no correlation between crown damage and yield was found in infested crowns at harvest. However, in some experiments, there are indications that such damage can reduce root yield if infestation occurs early. In one 1990 experiment on SPW infestation, a significant negative correlation was found between SPW damage to crown 1, 2 and 3 months after planting and root yield. A detailed investigation (two experiments) was then conducted in spring and autumn 1990.

Materials and Methods

A parcel of land was rototilled and worked into 1-m wide beds. The beds were further divided into eight 5-m × 10-m plots. A distance of 1 m was maintained between two adjacent plots. About 250 tender stem cuttings of sweet potato cultivar Tainung 57 were planted in each plot. Standard cultural practices were followed, including fertilizer application, weeding and irrigation as needed.

Starting one week after planting, 0.04% a.i. carbofuran was sprayed on the 10–15-cm aboveground portion of crowns only. The 1st plot was sprayed once every 5 days; 2nd, every 10 days; 3rd, every 15 days; 4th every 20 days; 5th, every 25 days, 6th, every 30 days; and 7th, every 35 days. The 8th plot was the untreated check. The purpose of treating plants with insecticides at various intervals was to create varying levels of SPW infestation. This would establish a correlation between yield and the weevil infestation.

This experiment was done twice, once each in spring and autumn 1990. In both cases the experiment was planted in the vicinity, 5–10 m from sweet potato planting, which was damaged by the weevil. This was done to facilitate natural infestation of the new crop with weevil from the old crop.

Starting 2 weeks after planting, and once every 2 weeks thereafter, 15 plants from each plot were uprooted. Each plant was cut open and the number of SPW larvae, pupae and adults found inside was recorded. In the spring experiment only, the leaf area of each sampled plant and weight of leaves, stems and roots after drying these plant parts at 110°C for 72 hours were also recorded. At harvest, 22 weeks after planting, root yield was recorded. Some 5 kg roots were cut open and the number of SPW larvae, pupae and adults feeding in each were recorded.

The yield, biweekly insect monitoring, leaf area and dry weight data were analyzed to study the correlation between the yield and number of weevils in the crown, leaf area, and plant dry weight.

Results and Discussion

The results of the correlation between number of insects in the crowns at various times during the season and root yield at harvest are summarized in Figure 2. Sweetpotato weevil infestation in both seasons began 8–10 weeks after planting in untreated plots or plots treated less frequently with insecticides. There was no correlation between sweet potato yield and the weevil infestation of any observation interval in spring. In autumn a significant negative correlation was found between SPW infestation and yield in observations taken only at 16 weeks after planting. No correlation was found between leaf area and insect infestation or dry weight and insect infestation. The leaf area and dry weight data were extremely variable from one observation to the next. There was, however, significant correlation between the number of SPW in crowns from 8 weeks onwards and the number of SPW in root at harvest, but only in the autumn. No such correlation was found in the spring crop.

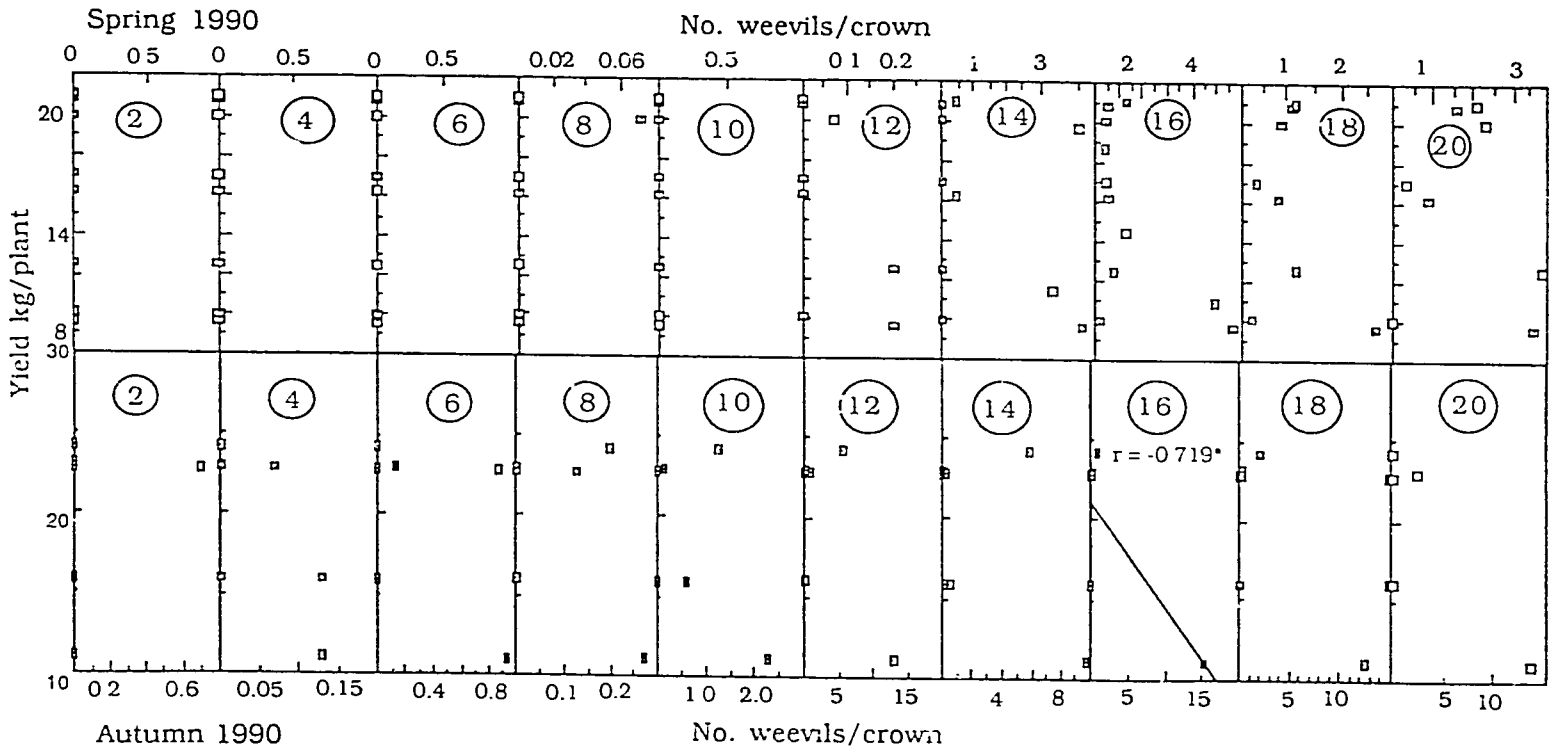


Fig 2. Correlation between sweetpotato weevil infestation of crown and yield in field tests conducted in spring and autumn 1990. Encircled numbers represent weeks after planting when observations were taken.

Sweet Potato Pathology

Cultural Studies on *Sphaceloma batatas* and the Identification of Resistance to Sweet Potato Scab

Summary

Sweet potato scab limits the production of sweet potato in some regions of the world. Past studies at AVRDC have concentrated on utilizing host plant resistance to control scab. Screening for resistance depends on the production of inoculum of the fungus. Different temperatures and pH values were tested to determine optimum conditions for sporulation. The optimum temperature for sporulation of *Sphaceloma batatas* was 24°C followed by 28°C. On carrot agar medium, a pH of 6 was the most suitable for abundant sporulation. To determine the optimum length of time that inoculated plants need to be incubated under high humidity, an experiment was conducted by removing inoculated plants from a growth room at 100% humidity daily for 8 days. Disease severity was highest when plants were incubated at high humidity for 7 days. To find more sources of resistance, a total of 1191 accessions were screened, with 275 accessions initially being rated as less susceptible. These were retested and eight accessions were identified as highly resistant and 25 accessions as resistant. These accessions may provide good sources of resistant stock for future use in plant breeding programs.

Introduction

Sweet potato scab, caused by the fungus *Sphaceloma batatas*, is one of the most important diseases of sweet potato in certain geographical locations. The pathogen may cause total loss of tuberous root yield as it infects foliage and stems which may cause dieback of the plant.

S. batatas grows slowly and produces very few conidia in culture on most common media like potato dextrose agar. Inoculum in the form of conidia is most suitable for inoculating plants either under field or controlled conditions. Besides nutrient requirements for sporulation, the effect of temperature and pH is also important for optimum inoculum production.

Host resistance is one approach to controlling scab, and for the past 5 years has been a major focus at AVRDC. Screening for resistance initially was conducted under field conditions, but the cost of labor and finding fields with high levels of inoculum was not always feasible. The objectives of this study were to develop procedures to increase conidia production, determine what environmental conditions are most suitable for screening at seedling stage, and to identify resistant sources.

Materials and Methods

Cultural studies. To study the effect of temperature on sporulation, a 9-mm diameter carrot agar disk from a 1-week old culture of the fungus was smeared on sterile carrot agar medium to propagate the fungus. A total of 84 plates were smeared. Twelve plates, each representing three samples in four replications, were incubated from 12 to 36°C at 4°C intervals. After 10 days a 0.9-cm diameter disk was transferred to a test tube containing 5 ml of sterilized water. The tube was shaken for 10 sec and a drop of spore suspension was placed on a hymacytometer to determine the conidial concentration.

To test the effect of pH on sporulation, carrot agar medium was prepared as follows: carrot slices were put into 200 ml of distilled water for 1 hour, then boiled for 5 min. This suspension was added to 800 ml of distilled water and 20 g of agar powder, then autoclaved. When the temperature of the medium was decreased to 50°C, drops of NaOH or HCl were added to the medium to adjust the pH value from 3 to 10

in increments of one pH unit. Plates were inoculated as described previously with 12 plates representing three samples in four replications for each pH treatment, and were incubated at 25°C.

Plant inoculations. Cuttings of accessions I55, I6, V2-30, and I-1189 were arranged as in a randomized complete block design with four replications. There were six cuttings planted in 6-cm diameter pots for each accession. One week after transplanting, a suspension of 1×10^6 conidia/ml at 1.5 kg/cm^2 was sprayed on the cuttings before moving them to a growth room (26±2°C, 98–100% RH). After inoculating cuttings, the length of the incubation period was studied using the number of incubation days as treatments: 1 = plants incubated up to 11 days after inoculation (DAI), 2 = 1 DAI, 3 = 2 DAI, 4 = 3 DAI, 5 = 4 DAI, 6 = 5 DAI, 7 = 6 DAI, and 8 = 7 DAI. After incubation, cuttings were moved to the greenhouse. Twelve days after inoculation, disease was assessed based on the following scale: 1 ≤ 3% surface infection, 2 = 3–10%, 3 = 10–25%, 4 = 25–30%, 5 ≥ 50%, 6 = death. Data from rating samples of the six cuttings per replication were averaged before ANOVA. Means were separated by LSD test.

A total of 1191 accessions were divided into three sets to screen for resistance. Four check lines: I1189 (resistant), I6 (moderately resistant), CN1108-13 (moderately susceptible) and I55 (susceptible) were included in all three sets. Cutting preparation, inoculations, and assessments were done as previously described. A total of 275 accessions based on lower disease ratings from one of the three sets were screened.

Results and Discussion

Cultural studies. Sporulation was significantly greater at 24°C than at other temperatures. No sporulation occurred at 36 and 12°C. Conidia production was 2.7 at 16°C, 4.8 conidia/ml at 20°C , 9.3 conidia/ml at 24°C, 6.8 conidia/ml at 28°C, and 4.2 conidia/ml at 32°C. A pH value of 6 was most suitable for abundant sporulation, followed by pH values of 5 and 7. Values of pH 9, 3, and 10 were not suitable for sporulation. Sporulations per square centimeter were as follows: 0.17 at pH 3, 4.8 at pH 4, 6.3 at pH 5, 3.2 at pH 6, 6.0 at pH 7, 4.6 at pH 8, 1.2 at pH 9, and 0.03 at pH 10.

Plant inoculations. Disease severity was highest when host material was kept for 7 days, followed by 6, 5, 4, and 11 days at high humidity after inoculation. Incubations of 1, 2, 3 days significantly reduced severity. Disease severity based on days of incubation was: 2.6 at 1 and 2 days, 3.0 at 3, 4, and 5 days, 3.2 at 6 days, and 2.9 at 7 days.

Screening for scab resistance. Two hundred and seventy-five out of 1191 accessions were less susceptible combined over three sets. These were retested and eight accessions were identified as highly resistant, 125 as resistant, 129 moderately resistant, 68 moderately susceptible, 34 susceptible, and 7 highly susceptible. The highly resistant and resistant accessions may provide good sources of resistant stock for future use in plant breeding programs (Table 1).

Table 1. Sweet potato accessions that were rated as highly resistant and resistant to scab over two evaluations.[a]

Accession no.	Variety	Disease reaction[b]	Accession no	Variety	Disease reaction
I 135	HM-616	HR	I517	Yeeira	R
I 390	Cu Marata	HR	I 540	Mung	R
I 457	Greike	HR	I 570	Wakum	R
I 483	Laez	HR	I 571	Ysungaperian	R
I 507	Sokol	HR	I 585	Minip	R
I 578	Simbu	HR	I 702	Tul-Tulum-26	R
I 587	Simbu	HR	I 716	Unknown 78	R
I 1031	Black Leaf	HR	I 718	Seka 109	R
I 450	Manta	R	I 731	Marpepu 150	R
I 452	Rimbom	R	I 747	Balusaina 162	R
I 455	Lae 13	R	I 757	Wapi 134	R
I 464	Yura	R	I 862	Ysuningi	R
I 487	Markham 1	R	I 883	082 (Wamakawama)	R
I 501	NG 5461	R	I 927	Laloki 2	R
I 505	Hagesafu	R	I 931	Laloki 4	R
I 506	Yaira	R	I 1189	Hawaii	R
I 516	Damiambo	R			

[a]Selected from an initial screening of 1191 accessions and a rescreening of 271 accessions.
[b]Mean of the disease scale of six seedlings and three replications rated as HR = highly resistant (> 3% infected area), R = moderately resistant (3–10% infected area).

Sweet Potato Physiology

Performance of Flooding-Tolerant Sweet Potato Clones

Summary

Eight relatively flooding-tolerant sweet potato clones were evaluated in three seasons to confirm their flooding tolerance. Storage root yield was lowest in the May planting. This low root yield was likely due to high temperature and excessive rainfall. Among the clones, improved CN 1028-15, CN 1448-49 and CN 1489-89 clones had higher storage root yields than the other clones. CN 1448-49 and CN 1489-89 had higher dry matter and starch content in the storage root than CN 1028-15. Both CN 1448-49 and CN 1489-89 have more reliable performance during the rainy season.

These eight sweet potato clones were further tested for flooding tolerance using leaf cuttings as well as whole plants under soil-moisture controlled conditions. Results showed that field moisture capacity, maintained at more than 60%, reduced storage root formation. The reduction could be attributed to reduced harvest index. These two yield evaluations confirmed the relative flooding tolerance of CN 1448-49 and CN 1489-89.

Introduction

Excess soil moisture, especially at the critical stage of storage root initiation, is one of the major factors limiting the productivity of sweet potato in the hot, humid tropics. To overcome this constraint, improvement and selection of clones for their ability to produce storage roots under excessive soil moisture conditions have been conducted at AVRDC. Using leaf cutting method eight improved clones and accessions that possess some levels of flooding tolerance were previously identified. The purpose of this study was to confirm the results obtained in experiments using the leaf-cutting method with whole plants under field and soil-moisture controlled conditions, and to investigate some of the physiological responses of these clones under flooding conditions.

Materials and Methods

Field planting. Stem cuttings of CN 1028-15, CN 1108-13, CN 1232-9, CN 1448-49, CN 1489-89, CN 1517-139, Tainung 66 and Tainung New 31 were planted in the field on 25 July 1990, 21 September 1990 and 17 May 1991, respectively. An RCBD with four replications was employed. Each plot contained three 700-cm long rows spaced 100 cm between rows and 25 cm between plants. Mean maximum/minimum air temperatures for the July, September and May plantings were 30.2/22.0°C, 27.0/17.5°C and 31.8/23.9°C, respectively, and mean maximum/minimum soil temperatures were 29.7/27.5°C, 27.2/24.7°C and 32.3/29.7°C, respectively. Field capacities for plantings ranged from 29 to 64% for July, 13 to 35% for September, and 32 to 79% for May, and total precipitation during the entire growing periods were 871.5, 18.3, and 1432.5 mm.

Three plants were randomly sampled from each plot at 30-day intervals. Canopy light penetrations were also measured monthly. Sampled plants were studied for leaf area index, root development, dry matter of shoot and root, storage root yield, and chemical components of storage roots.

Leaf-cutting evaluation. Leaves with petioles were detached from the entries and transplanted to PE tubes (inside diameter 17 cm, height 40 cm) with soil-sand-compost mixture on 17 July and 12 October 1990. Leaf cuttings were grown under greenhouse conditions. Field capacities at 30–50, 50–70 and 60–80% were imposed 1 week after transplanting until the end of the experiment. Mean maximum/minimum

air temperatures during the entire growing periods were 33.6/25.1°C for July and 31.6/18.3°C for October, respectively, and mean maximum/minimum soil temperatures were 31.6/26.4°C (July) and 26.9/17.0°C (October). A split-plot design with four replicates, and eight tubes/replication was employed. Soil moisture treatments were main plots, and clones subplots.

Leaf cuttings were sampled at 2-week intervals for the July planting, and 3-week intervals for the October planting. Leaf cuttings were assessed for plant survival, leaf area, chlorophyll content, fresh and dry weights of different plant parts, oxygen activity of the root system, and carbohydrates in the storage root.

Pot planting. Stem cuttings of the entries were transplanted to PE containers (60 × 42 × 30 cm) filled with growing media on 10 July and 19 October 1991. Plants were grown under screenhouse conditions. Soil moisture was maintained at 30–50 and 60–80% of field capacity. Mean maximum/minimum air temperatures were 31.7/22.9°C, and 25.4/15.7°C, and mean maximum/minimum soil temperatures were 29.0/21.2°C, and 26.9/15.4°C. A split-plot design with four replicates and four plants/replicate was used. Plants were harvested 120 days after transplanting, and assessed for leaf area, fresh and dry weights of different plant parts, storage root number and yield, and nutritional components of the storage root.

Results and Discussion

When data were combined over entries, planting in September had the highest storage root yield and harvest index, despite lowest total dry matter production (Table 1). This could be attributed to the decreasing temperature throughout the growing period and absence of heavy rainfall. On the contrary, the planting in May had the least storage root yields and harvest index, but the highest total dry matter production, likely due to increasing temperature and heavy rainfall. Furthermore, storage roots from the May planting had the lowest soluble sugars and starch. Likewise, photo-assimilates that were produced in the plants of the May planting were diverted for top growth. Thus, it can be concluded that high precipitation unfavorably affects storage root formation but not the overall total dry matter production.

Table 1. Means of content analysis, yield and yield component of eight sweet potato clones grown in the field.

Planting/entry	Fresh storage root (kg/m^2)	Total dry wt (kg/m^2)	Harvest index (%)	Dry matter (%)	Sugar (%)	Starch (%)
July–Nov	1 3 a[a]	0.7 b	51 b	27.6	13.5 b	68.8 a
Sept –Jan	1 4 a	0 5 c	70 a	27.7	15 2 a	66.8 a
May–Sept	0.9 b	1.0 a	24 c	27.1	12.5 c	61.4 b
CN 1028-15	1.6 a	0 8 b-d	52 bc	23.6 d	17.9 a	60.0 e
CN 1108-13	1 3 b	0.6 e	56 ab	26.1 c	13.8 c	66.7 bc
CN 1232-9	1.2 b	0.8 bc	44 de	25.7 c	12.4 d	65.7 c
CN 1448-49	1.64 a	1.0 a	62 a	33 3 a	10.7 f	71.0 a
CN 1489-89	1.4 ab	0.9 ab	51 bc	31.0 b	11.3 ef	69.9 a
CN 1517-139	0.7 c	0 6 de	39 e	30.6 b	11.7 de	67.9 b
TN 66	1 1 b	0 6 e	49 cd	25.7 c	14.9 b	62.1 d
TN New 31	0 8 c	0 7 c-e	33 f	22.5 d	19.2 a	61.7 d

[a]Mean separation within columns by DMRT 5% level

When the data from the different plantings were combined, CN 1028-15, CN 1448-49 and CN 1489-89 had the highest storage root yields due to high dry matter production and harvest index (Table 1). The differences in maximum and minimum values in the harvest index were greater than in total dry matter production. Results suggested that enhanced dry matter production and harvest index are two important determinants for high yield potential of sweet potato. However, enhanced harvest index seemed more critical than increased dry matter production among the eight clones examined.

Although CN 1028-15 had comparable storage root yields with CN 1448-49 and CN 1489-89, its dry matter and starch contents in the storage root were lowest among these three high yielders. This could be due to its inefficiency in converting soluble sugars to starch and other carbohydrates in the storage root; CN 1028-15 was one of the two entries that had the highest soluble sugars in the storage root.

When leaf cuttings were grown under controlled soil-moisture conditions, their storage root yields, survival rates and harvest index tended to decrease with field capacity maintained at 60–80%. Oxidizing capacities of fibrous roots of leaf cuttings, on the other hand, increased with field capacity maintained at 60–80%. The physiology of increased oxidizing capacity with soil moisture is not clear, but this increased oxidizing capacity may play a role in flooding tolerance. Among eight clones tested with the leaf-cutting method, both CN 1448-49 and CN 1489-89 produced higher storage roots than the other clones.

When whole plants were grown under controlled soil-moisture conditions, again storage root yields and harvest indices were reduced when field capacities were maintained at 60–80% (Fig. 1). The extent of reduction in total dry matter was not as great as storage root yields and harvest indices. CN 1028-15, CN 1448-49 and CN 1489-89 produced higher storage roots than the other clones.

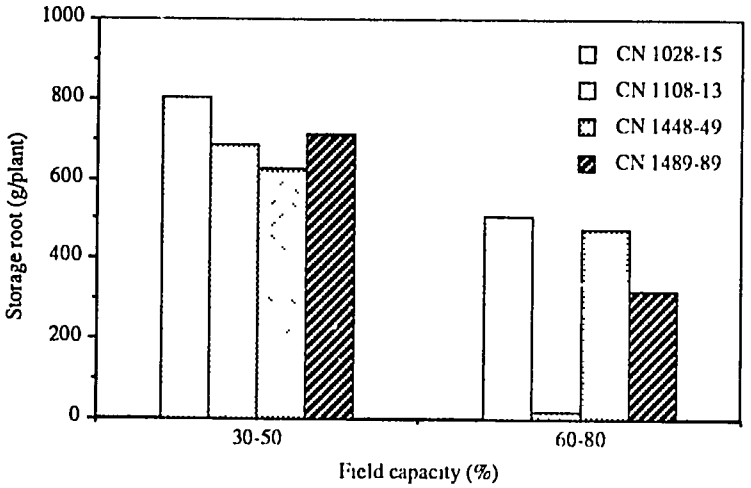


Fig. 1. Storage root yields of three sweet potato clones under controlled soil-moisture conditions for 120 days. Means of two trials.

Based on these studies, it was concluded that the partition of assimilates to storage root was the major determinant for the varietal differences in storage root yield under field capacities higher than 60–80%. Furthermore, based on yield and quality of storage roots, both CN 1448-49 and CN 1489-89 appeared to be relatively reliable for growing during seasons of excessive rainfall.

Sweet Potato Virology

Sweet Potato Virus/MLO Resistance and Virus Indexing

Summary

Witches' broom caused by MLO is a serious disease in Southeast Asia and the South Pacific, where it causes substantial yield losses. Screening for resistance under natural epiphytotic conditions and by grafting was initiated. Twenty-one lines were found to be symptomless after two consecutive field screenings of 5 months duration each. They were subjected to a confirmatory field and graft screening. Two lines I-422 and I-1436 were confirmed as having low % witches' broom incidence (< 20%) both in the field and by grafting.

The virus elimination and virus indexing method which was developed in 1986, was applied to 86 additional accessions, comprising elite AVRDC breeding lines and collections from Southeast Asia, the Pacific, and Puerto Rico. Meristem survival ranged from 40 (Papua New Guinea lines) to 90% (AVRDC breeding lines). A total of 66 virus-free lines were obtained. Some viruses, such as sweet potato yellow dwarf virus, previously only reported from Taiwan, have been detected by DAS-ELISA in lines from China, Japan, and the South Pacific. Similarly, MMV, which has only been reported from the African continent, was detected in samples from Malaysia and Japan.

By immunosorbent electronmicroscopy, a recently newly characterized virus, sweet potato sunken vein virus, was found in samples from Thailand, Solomon Islands and Taiwan.

Introduction

Sweet potato, being a vegetatively propagated crop, is known to harbor many viruses and also mycoplasma-like organisms (MLO). Witches' broom (WB), a serious disease caused by a leafhopper-transmitted MLO, affects sweet potato in Southeast Asia and the Pacific Islands. Yield losses of 100% are not uncommon in cases of severe infection. Resistance so far has not been found in cultivated or in wild species. Screening for resistance to witches' broom was initiated under natural epiphytotic conditions in Penghu Island, where both the vector and the MLO are endemic, and by grafting to witches' broom-infected sweet potato. In two consecutive previous field screenings, only 21 of the 466 lines screened were symptomless. These lines were subjected to a confirmation screening under natural field conditions and by grafting.

At least six well characterized viruses are known to occur on sweet potato. AVRDC, as an international center, has the responsibility to ensure that all sweet potato materials received for use in its own crop improvement program and those intended for international distribution are free of viruses and other pathogens, particularly MLO. Such a scheme, involving meristeming followed by 2 ELISA tests and 2 cycles of graft indexing, was established in 1986. Since the sweet potato program at AVRDC is being phased out, only those germplasm collections AVRDC is obligated to clean up as mandated by IBPGR, the last 2 sets of AVRDC elite breeding lines and outstanding AVRDC accessions were subjected to the virus elimination and virus indexing procedure in 1991.

Resistance to Witches' Broom

Materials and Methods

Field screening. Twenty-three lines (I90, 91, 109, 115, 116, 422, 423, 903, 938, 971, 975, 978, 998, 1068, 1377, 1385, 1389, 1436, 1396, 1424, 1425, 1429, 1437), previously found symptomless and one line observed to be tolerant (Chin Men 16) in last year's field screening at Penghu Island, were tested.

Each line was planted on 1 × 3 m plots with 10 plants per plot. Cuttings, 40-cm long, were used for planting. A spreader row of the highly susceptible line I-1385-2 was planted at every fifth row. The trial was replicated twice. Insecticides were not applied. Five visual assessments were made at monthly intervals after planting.

Screening by grafting. The same sweet potato lines mentioned above were used. Ten 30-cm long cuttings of each of the sweet potato lines to be tested were rooted in soil and wedge-grafted with individual 8-10 cm long WB-infected sweet potato cuttings. The WB-infected cuttings were originally collected from a farmer's field in Penghu Island and tested virus-free. The grafted plants were maintained in an insect-proof screenhouse and observed for 6 months for symptom development.

Results and Discussion

Field screening. All 23 lines screened were symptomless up to 3 months after planting to the field. At that time the susceptible check already showed 40% WB incidence. At 4 months, WB symptoms could be observed in six lines; I-91, I-423, I-998, I-1385, I-1424 and Chin Men 16, which had 10, 10, 25, 17, 10 and 10% WB incidence, respectively compared to 42% of the check. At the last assessment taken at 6 months after planting, WB incidence ranged from 5% (I-1437, I-1436) to 53% (I-1385) compared to 78% in the susceptible check (Table 1).

Table 1. Witches' broom (WB) incidence in field screening and in graft screening.

Line	% WB incidence[1]		Line	% WB incidence[a]	
	graft[2]	field[3]		graft[b]	field[c]
I-90	60	26	I-1068	80	21
I-91	100	38	I-1377	90	28
I-109	100	26	I-1385	100	53
I-115	100	10	I-1389	100	12
I-116	80	10	I-1396	90	35
I-422	20	16	I-1424	100	22
I-423	80	47	I-1425	90	33
I-903	100	11	I-1429	90	24
I-938	100	40	I-1436	0	5
I-971	100	46	I-1437	90	5
I-975	100	14	Chin Men 16	100	65
I-978	100	31	I-1385-2 (CK)	100	78
I-998	100	44			

[a]After 6 months.
[b]Average % infected plants out of 2 × 10 plants grafted.
[c]Average % infected plants out of 2 × 10 plants planted to the field

Screening by grafting. In 2 lines (I-975, I-1396) witches' broom symptoms appeared as early as I month after grafting. At 3 months after grafting only 2 lines (I-422 and I-1436) were without symptoms. Line I-1436 remained symptomless up to 6 months after grafting, at which time incidence in most other lines ranged from 60 to 100%. Line I-422 showed only 20% WB incidence at 6 months after grafting (Table 1). The combined results of the field screening and graft screening are shown in Table 1.

As expected, occurrence of infection in grafting was very severe, and infection in most lines reached 100% after 6 months, even though the same lines showed a low percentage of infection in the field. The field screening and graft screening results do not correspond well in most cases. For example, the two lines (I1436 and I 1437) with the lowest infection (both 5%) in the field showed different results in grafting: Line I-1436 was not infected by grafting, whereas line I-1437 showed 90% infection after grafting. However, there were clear differences in the time it took before symptoms began to appear in these grafted plants. For example in plants of the line I-903 symptoms began to appear 4 months after grafting and in line I-422 only 5 months after grafting. These two lines also showed a low percentage of infection in the field: 11% (line I-903) and 16% (line I-422). Line I-1436 will be tested again to confirm its good performance in field screening and graft tests.

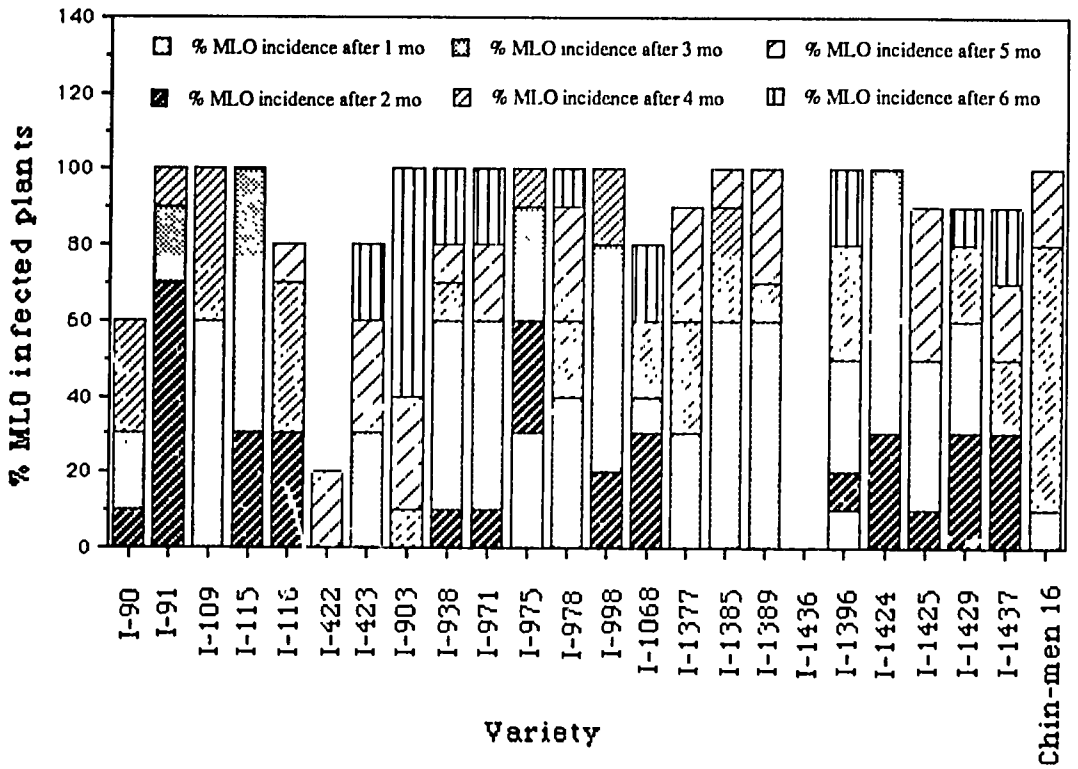


Fig. 1. Rate of MLO infection after grafting in 24 sweet potato lines.

Virus Elimination and Virus Indexing

Materials and Methods

Virus elimination and virus indexing. Eighty-six lines including seven AVRDC elite breeding lines, 23 priority AVRDC accessions, and germplasm from Thailand (10 lines), China (2 lines), the USA (1 line), Papua New Guinea (3 lines), Puerto Rico (1 line), Cook Islands (1 line), Niue Islands (3 lines), Solomon Islands (21 lines), Malaysia (10 lines), and Japan (4 lines) were subjected to the virus elimination and indexing scheme during 1990-1991. The method followed was that described in the 1989 and 1990 Annual Reports.

Detection of new viruses. Sixty-three meristem-derived lines were previously found to contain virus as evidenced by strong symptoms in one or two graft indexing steps. These plants reacted in ELISA with none of the 5 viruses which are routinely tested (SPFMV, MMV, YDV, LV, SPV II). It was suspected that they contain new viruses or viruses which have not yet been well characterized. For all samples, leaf-dip preparations were made which were viewed in the electronmicroscope. All samples were additionally tested by immunosorbent-electronmicroscopy (ISEM) for the presence of two newly characterized viruses: sweet potato sunken vein closterovirus (SPSSV) and lettuce infectious yellows virus (LIYV). Antisera were provided by Dr. H. J. Vetten, BBA.

Results and Discussion

Virus elimination and indexing. Of the total of 86 lines which passed through the above scheme, 66 virus-free lines have been obtained (Table 2). Meristem survival ranged from 40% (Papua New Guinea lines) to 90% (AVRDC lines). Average meristem survival was 65%. In the first ELISA test conducted on young tissue cultured plantlets for FMV, LV, YDV, SPVII and SPMMV, an average of 18% virus-infected plants could be detected. In the following first graft indexing, 38% of plants were detected which were still virus-infected. This high number reflected in part the infection of sweet potato plants with unknown viruses for which antisera were not available for inclusion in the first ELISA test. This clearly shows that relying only on the ELISA test for indexing is not sufficient.

Table 2. Summary of 1990–1991 virus elimination and virus indexing.

Country	Description	Received	No. of lines received	No of lines rooted	No. of virus -free lines before 1991	No. of virus -free lines 1991
Thailand	Germplasm collection	Nov '86	100	91	81	5
Solomon Islands	Collection	Dec. '87	102	56	35	16
Papua New Guinea	Elite line	Sep. '87	17	16	13	3
Taiwan	AVRDC Breeding lines 4th	June '89	16	16	15	1
Taiwan	AVRDC Breeding lines 5th	Feb '90	6	6	0	6
China III		Dec '88	11	11	9	
Cook Islands	Germplasm coll	Apr. '89	11	5	4	1
Niue	Germplasm coll	Sep. '89	6	6	3	3
Japan I	Elite lines	Sep '89	8	8	4	2
Malaysia	Germplasm coll.	May '89	20	20	9	5
USA	Elite lines	Dec. '88	66	66	65	1
Puerto Rico	Elite lines	June '87	15	9	8	1
Taiwan	AVRDC GRSU Acc.	Jan. '90	24	24	0	21

Sweet potato yellow dwarf virus, which has only been reported from Taiwan so far, has been detected by ELISA in lines originating from China, Solomon Islands, and Japan. Similarly MMV, which so far has only been reported from the African continent, was detected in samples from Malaysia and Japan. Some of the lines also seem to contain viruses which could not be identified by ELISA and probably represent new viruses.

Detection of new viruses. None of the 63 samples reacted in ISEM with antiserum to lettuce infectious yellows virus (LIYV). In 11 samples (originating from Thailand, Solomon Islands, and AVRDC) virus particles were trapped and decorated in ISEM with antiserum to sweet potato sunken vein virus. In three of the samples (from Thailand and Taiwan) geminivirus particles were clearly visible in the electronmicroscope. In 2 samples (originating from AVRDC) a potyvirus was found which may represent a new virus, since it does not serologically react with antisera to any of the known sweet potato potyviruses.

This clearly shows the importance of the graft indexing step, which can readily detect new or not well characterized viruses for which antisera are not yet available.

Tomato Breeding

Breeding for Bacterial Wilt Resistance: Number of Backcrosses To Recover Adequate Resistance

Summary

A genetic experiment was conducted to approximate the number of backcrosses that could serve as a guideline in the breeding program to develop bacterial wilt-resistant tropical lines with good horticultural characters. Comparisons of the levels of BW resistance among a random sample of F_5 backcross-inbred lines from three backcross generations of two crosses indicated that two backcrosses may be sufficient to recover a good level of the BW resistance among the progenies. A resistant fraction of 20–30 % in the BC_2 generation of the two crosses studied would have been selectable given a theoretical selection limit of one standard deviation or more above the population mean (or a survival rate from BW inoculations of ≥ 85% and ≥ 91% in CLN690 and CLN735, respectively). A cursory analysis of the distributions of BW reaction among backcross-inbred lines showed marked multimodalities and discontinuities in both crosses, indicating that BW resistance possibly belongs to the class of quasi-quantitative characters that are controlled by a few major factors with relatively large effects on the trait but whose expressions are modified by minor genes. Such a genetic system adequately explains the observations in this experiment that high levels of BW resistance could be easily captured in the early backcross generations—a phenomenon not conceivable in a true polygenic system. Given these, there is an excellent prospect to develop BW-resistant tropical lines which also carry other desirable traits, e.g. improved fruit size, heat tolerance, etc., by limiting the number of backcrosses to two at most and then selecting novel gene combinations that would otherwise not be possible to find in a full backcross scheme.

Introduction

Bacterial wilt, caused by *Pseudomonas solanacearum*, is possibly the most destructive disease of tomatoes and other solanaceous plant species in the tropics. The Center's tomato improvement program has traditionally given high priority to breeding resistant lines for the tropical tomato growers. A total of 68 BW-resistant tropical lines has been officially released in 28 countries as of 1990.

BW resistance has been reported to be associated with small fruits (Acosta et al. 1964)[1]. Indeed, the early tropical lines bred at the Center invariably produced small fruits averaging only 30 g/fruit. Later attempts to increase fruit size through changes in breeding strategies met with moderate success—fruit sizes were improved to about 65–70 g/fruit in more advanced lines. However, conspicuous loss of resistance did occur in many lines as selection for large fruit size was intensively practiced, thereby limiting the latitude for selecting other desirable characters in the program.

The number of desirable traits possessed by tropical lines also steadily increased with progressive breeding. Pyramiding these traits in a single genotype at the highest possible levels of expression, especially for complex characters such as bacterial wilt resistance, may require the use of suitable breeding techniques such as the backcross method. Yet, the fruit sizes of tropical lines that would normally serve as recurrent parents in such backcross programs are mostly small and thus are not desirable enough to fully recoup into new backcross derivatives. The number of backcrosses should be as few as possible to allow novel combinations of genes, e.g. improved fruit size, to be preserved in breeding yet enough to allow the recovery of good BW resistance levels.

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[1]Acosta, J. C., Gilbert, J. C. and Quinion, V. L. 1964. "Heritability of bacterial wilt resistance in tomato." Proc. Am. Soc. Hort. Sci. 84: 455-461.

This experiment was conducted to approximate the minimum number of backcrosses that could be adopted as a guideline in breeding tropical lines which combine BW resistance with other desirable genes of interest.

Materials and Methods

Randomly selected F_5 backcross-inbred lines of three backcross generations (BC_1, BC_2 and BC_3) of two crosses (CLN690 and CLN735) were used in this experiment. CLN690 came from the cross of tropical line CL5915-93 with BL284 (cv. Cavalier, a large-fruited variety from Peto Seed Company), whereas CLN735 was derived from the crosses of tropical line CLN65-349 with BL284. The tropical stocks in both cases served as the recurrent parents.

The experiment followed a split-split plot arrangement of factors in a randomized complete block design. A total of 20 backcross-inbred lines from each backcross family were combined with four check cultivars to comprise 24 sub-subplots. The check cultivars consisted of the following: resistant and susceptible parents; resistant check L285; susceptible check L390. The three backcross generations served as subplots whereas the two cross combinations served as the main plots. Each individual plot comprised 24 seedlings. The experiment was replicated twice.

The first planting in the BW nursery was done in May 1991. This experiment was destroyed by heavy rains. Consequently, the study was repeated in late summer 1991 using seedling pot inoculations. Sowing was done on 19 August 1991. Each individual pot was inoculated with 20-ml bacterial suspension at an inoculum density of 10^8 bacterial cells/ml on 19 September. Inoculated seedlings were kept inside a warm plastic house. Weekly wilt reading started on 26 September and was completed on 17 October. Individual survival rate (%) data of the unit plots were transformed into arcsin($\sqrt{\%}$) prior to statistical analysis.

Results and Discussion

The BW reaction of the crosses and their backcross generations is given in Table 1. The reactions of parents indicate that they are well contrasted and therefore striking segregation should be expected.

The BW resistance levels of the two crosses were practically similar across the backcross generations. In contrast, the BW resistance level changed significantly as backcrosses to the resistant parents were made although the increase from BC_2 to BC_3 was insignificant. This seems to indicate that making a third backcross does not offer any real advantage in increasing the general population mean for BW resistance.

The comparative statistics from frequency distribution analyses of the BC populations for each cross are given in Table 2. Cross CLN690 showed a dramatic increase in the level of resistance from BC_1 to BC_2 but followed by a slight decrease in BC_3. This was accompanied by the expected decay of variability with progressive backcrosses. In contrast, CLN735 started off with a high level of BW resistance in BC_1 followed by small changes in further backcrosses. Variability was surprisingly unchanged from backcross to backcross and can be explained if the recurrent parent itself is heterozygous for the trait. Available data on the parent, CLN65-349, a breeding line that has undergone more than 10 generations of selfing, does not currently support this view, but this line will be subjected to further analysis.

If we as[illegible] that only progenies whose BW reading are equal to or greater than the population mean + 1 standar[illegible] (Note: this theoretical limit in the distribution curve is equal to 85% BW survival rate in CLN69[illegible] [illegible]1% in CLN735) are to be selected from each backcross generation, a selectable fraction of 30% is already attainable in CLN690 by BC_2 generation. In contrast, there is a steady increase in selectable proportions with progressive backcrossing in CLN735. In the BC_2, this fraction is already 20% of the population, a figure that may be considered already workable in the breeding program. The hypothesis that two backcrosses may be sufficient to recover good levels of BW resistance in a backcross breeding program is further corroborated.

The frequency histograms for BW readings of BCF_5 lines from the three backcross generations of CLN690 are shown in Figure 1. Multimodality and discontinuity of distribution are evident in all generations. Such behavior often suggests traits that are quasiquantitative in nature, i.e. controlled by several genetic factors with relatively major effects on the trait but the expressions of which are further altered by an undefined number of minor genes or modifiers. A similar trend was present in the cross CLN735, although a distinct fraction of the susceptible classes that is markedly set apart from the upper

Table 1. Bacterial wilt reaction of F_5 backcross-inbred lines averaged over crosses and backcross generations; AVRDC, summer 1991.

Family	Survival rate (%)
Cross	
CLN 690	64.1 a
CLN 735	64 6 a
Backcross generation	
BC1	59.6 b
BC2	66.6 a
BC3	66.8 a
Resistant & susceptible parents	
Resistant parent (CLN 690)	79.1
Susceptible parent (CLN 690)	4.9
Resistant check (CLN735)	87.2
Susceptible check (CLN735)	1.4

Table 2. Comparative statistics for bacterial wilt resistance of F_5 backcross-inbred lines from two populations; AVRDC, summer 1991.

Cross	Generation	Mean survival rate (%)	Standard deviation	Selectable progenies[a] (%)
CLN 690	BC_1	55.4	16.9	25
	BC_2	77.5	6.5	30
	BC_3	72.3	7.3	25
CLN 735	BC_1	71.4	11.3	15
	BC_2	65.8	11.3	20
	BC_3	70.8	13.4	25

[a]Selection limit theoretically set at ≥ mean +1 standard deviation for purposes of comparison, corresponding to minima of 85% and 91% survival rate for CLN 690 and CLN 735, respectively.

"resistant" fraction remained after three backcrosses. This persistent susceptible class is the main reason for the variability of CLN735 which still remained substantial despite three successive backcrosses.

Partial Seediness Among Parthenocarpic Lines: Fruit Size and Fruit Set Behavior

Summary

Six BC_1F_3 lines with varying seediness from each of two crosses between parthenocarpic and normal-seeded parents were studied in summer 1991 for fruit setting potential, fruit size, yield and other important traits. The parthenocarpic lines were generally earlier, with better fruit set and higher early yields relative to the normal, seedy lines. However, they produced smaller fruits, grew relatively weaker and had lower total and marketable yields compared to the seedy lines. The partially seeded types were not promising as they showed lower fruit set, had fewer large fruits and yielded lower than either the seedless or the seedy genotypes. Contrary to an earlier hypothesis, it appears from the initial results that there are no conspicuous benefits in selecting for partial seediness among parthenocarpic genotypes.

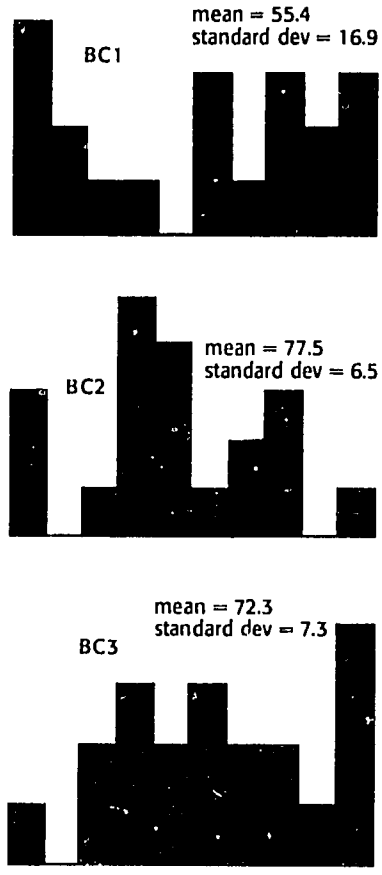

Fig. 1. Frequency histograms of BW resistance among random F_5 backcross-inbred lines from population CLN690.

Introduction

Fruit set under hot and humid conditions of the Center's heat-tolerant germplasm has been considered adequate. This is attested to by the fact that as many as 68 heat-tolerant tropical lines have been officially released to tomato growers in 28 countries around the world. However, these lines do not set fruit very well under hot, dry conditions which are often met in the fringes of the tropics. Moreover, while the present level of heat tolerance is already usable, unexplored germplasm might be able to augment the fruit set under high temperature stress of current tropical lines, making them potentially more productive.

A single recessive gene, pat-2, for facultative parthenocarpy was reported to enhance fruit setting of tomato under extreme temperatures. This gene has since been investigated by AVRDC plant breeders as a potentially useful addition to the tropical lines to increase their fruit set in the hot season. A breeding line, CL5675, which combines heat tolerance and parthenocarpic fruit set, was subsequently developed. Hot season trials of AVRDC tropical breeding lines during the last 3 years has shown this line to have the best fruit setting ability. However, its fruits tend to be small, perhaps owing to the lack of seeds of large-fruited varieties. It has been postulated that selection for pat lines that are partially seedy could solve the problem of fruit development (AVRDC, 1983, unpublished data) while at the same time maintaining the potential for high fruit set under high temperatures.

This experiment was conducted to initially test the above hypothesis and to determine if it could be a valuable breeding objective in further improving the heat tolerance level of tropical lines.

Materials and Methods

Six BC_1F_3 lines varying in seediness expression (seedless, partly seeded and seedy) were selected from each of two crosses (CLN1107 and CLN1116) between parthenocarpic and seedy parents. CL1107 was derived from the cross between CLN 698BC_1F_2-358-4-13 and CL 5675BC_1F_2-1-2-2-7, whereas CLN1116 came from the cross between CLN 475-265-4-19 and CL 5675BC_1F_2-1-2-2-7. CL 5675BC_1F_2-1-2-2-7 is the parthenocarpic parent that also carries genes for heat tolerance.

The above treatments were laid out on a split-split plot arrangement, with crosses as the main plot, seediness class as the subplot and lines within each seediness class as the sub-subplot. This experiment was replicated three times. The experimental materials were sown on 25 April 1991 and transplanted to the field on 23 May. However, this planting was destroyed by heavy rains. The experiment was resown on 10 July and transplanted to the field on 6 August. Each plot consisted of two rows, each 4.8 m long, with rows and plants within the rows spaced 1.5 and 0.4 m apart, respectively. Data on yield, fruit characters, maturity and other important traits were collected for statistical analyses.

Results and Discussion

The two crosses differed significantly in a few major characters, viz. flowering date, days to maturity, fruit set, fruit size and early total and marketable yields. Lines derived from CLN1116 were significantly earlier (61 vs 71 days), had higher fruit setting ability (50.4 vs 32.6%), bigger fruit size (31 vs 24 g) and higher early yields (6.7 vs 1.9 t/ha) than those from CLN1107. This cross will be subjected to further selection to develop parthenocarpic tropical lines with better fruit set and fruit size.

When the various seediness categories were compared, significant differences were noted in many traits (Table 3). The seedless parthenocarpic genotypes compared to the normal seeded lines tended to be: earlier, generally less vigorous, have higher fruit set, smaller fruit size, lower total and marketable yield but higher early yields. The partially seeded types that were of great interest as a potential solution to the main problem associated with seedlessness (particularly the small fruit size) were not promising due to the following limitations: lower fruit set, fewer large fruits although the mean fruit size was improved over that of the seedless genotypes, and lower yields than either the seedless or the seedy genotypes. However, the partially seeded types did show advantages of improved vigor and higher soluble solids over the seedless and seeded lines. From these initial results, it appears that it may not be worthwhile to select for partial seediness among parthenocarpic genotypes as it does not give any overwhelming benefits as postulated earlier.

Table 3. Yield and other horticultural characters[a] of full-sib F_3 lines derived from seeded x parthenocarpic crosses; AVRDC, summer 1991.

Category	DF	Maturity (DAT)	Large fruit (kg/plant)	Large fruit (No.)	Brix°	Early total yield (t/ha)	Early MY (t/ha)
Seedless	18 b	65 c	0.6 a	31 a	4.7 b	8.4 a	7.9 a
Partial	18 b	70 b	0.4 b	19 b	5.2 a	3.2 b	2.7 b
Seeded	19 a	72 a	0.8 a	31 a	4.8 b	2.6 b	2.2 b

[a]DAT = days after transplanting, MY = marketable yield.

Breeding for Root-knot Nematode Resistance: Performance of Resistant and Susceptible Isolines and their Hybrids

Summary

The general performance of three possible genotypic states for the **Mi** gene which controls nematode resistance in tomatoes was compared using BC_5F_7 isogenic lines and their hybrids. Results indicated that other than a few traits which showed significant differences, the isogenic lines were practically similar in all aspects of yield, fruit traits, fruit setting ability and quality. Developing lines that are homozygous for nematode resistance does not, therefore, bring in unfavorable traits associated with the **Mi** gene. Based on this first experiment, it appears that apprehensions about the unfavorable effects of the **Mi** gene in homozygous state do not have a firm basis.

Introduction

In the course of breeding nematode-resistant tropical lines, resistant lines (carrying the **Mi** gene in homozygous state) were found to be weaker, to have more open vines, fewer fruits and lower yield than the susceptible lines. A similar experience has been shared by numerous plant breeders from private seed companies but it is a dilemma that they regularly avoid with hybrid development. The undesirable traits that are supposed to be associated with homozygosity for nematode resistance have not been corroborated, however, in carefully designed genetic experiments.

Since the Center-bred tropical fresh market lines will have to carry the **Mi** gene in homozygous state (except for a few of the fresh market and processing hybrids), the above cursory observations must be corroborated by experimental proof. Based on the results, appropriate breeding strategies may be devised accordingly.

This study was conducted to determine if indeed there are undesirable traits associated with homozygosity for nematode resistance.

Materials and Methods

Genetic materials used in this experiment were F_7 inbred-backcross lines derived from the two crosses CLN690 and CLN691. CLN690 was a cross between tropical line CL 5915-93D_4-1-0 and Cavalier, a firm, large-fruited fresh market hybrid. CLN691, on the other hand, came from the cross between another tropical line CL 5915-223D_4-2-1-0 and Cavalier. Both tropical stocks served as the corresponding recurrent parents in the backcross program.

In deriving the F_6 lines from the BC_5F_1 generation, only the heterozygous plants of each successive selfed generation were kept to guarantee as close a filial relationship as possible among the resulting isolines. The heterozygous BC_5F_5 plants of each cross were then selfed and the progenies tested for nematode resistance to classify them for homozygosity for the **Mi** gene. Both F_5 types were then selfed to produce homozygous resistant and susceptible lines. At the same time, they were crossed with each other to develop the heterozygous F_1s. These three genotypes comprised a set. A total of three such sets or isoline groups from two crosses were developed for the experiment.

The experiment was laid out in a split plot arrangement in randomized complete block design. The three isoline groups served as main plots where as the three gene configurations (homozygous susceptible, homozygous resistant and heterozygous resistant) comprised the subplots. The experiment was replicated three times.

The materials were sown on 25 March 1991 and transplanted to the field on 25 April. A second planting to confirm the results of the first experiment was sown on 5 September and transplanted on 3 October. Each unit plot consisted of two beds, each 4 m long, with rows 1.5 m apart and plants within the row, 40 cm apart. Data on yield, fruit characters, fruit set, pollen viability and quality were taken for statistical analyses.

Results and Discussion

Only the results from the first planting were available at this time. With the exception of significant differences in fruit size, the isoline groups derived from the two crosses were practically comparable in the major attributes measured in the experiment.

Only days to flowering and pollen viability differed appreciably when the comparisons were made among the **Mi** genotypes (Table 4). Both nematode-resistant genotypes tended to flower slightly later (although this difference is only 1 day) and had significantly higher pollen viability than the susceptible genotype. Yield, fruit characters such as size, and fruit quality such as soluble solids content, pH, and

Table 4. Comparisons among the three gene configurations for Mi gene.

Genotype	Days to flower	Fruit set (%)	Fruit wt/ plant	Fruit size (g)	Total yield (t/ha)	Pollen viability (%)	Brix°
NRM (Mi/Mi)	9 a	38	1.7	48	29	65 a	4.6
F_1 (Mi/+)	9 a	37	1.6	46	27	64 a	4.8
NSP (+/+)	8 b	37	1.5	47	24	53 b	4.8

acidity were practically similar regardless of genotypic state of the **Mi** gene. These observations are contradictory to the cursory observations that homozygous resistant lines tended to be associated with undesirable characters.

Screening for Bacterial Wilt Resistance Among Breeding Lines

Summary

BW-resistant breeding lines continue to be observed among the various screening trials conducted in 1991. A number of these promising tropical lines will be distributed to our national partners for further testing. Some of the genetic materials that hold great promise are the large-fruited CRA series stocks from the Center's elite BW stocks. These materials will be evaluated in 1992 in Southeast Asia to observe their resistance to the BW inoculum in the region. The best ones will be shared with interested national programs and at the same time included in the active collection for the Center's breeding purposes or as components of a yet to be designed recurrently selected BW resistant populations. The large-fruited fresh market entries that showed comparable resistance as the resistant checks will be distributed to interested national programs for further testing and adoption.

Introduction

Bacterial wilt continued to receive high priority in the Center's tomato program. In 1991, we screened for resistance a number of tropical breeding lines, fresh market hybrids and advanced firm-fruited breeding lines. In addition, we subjected our elite germplasm stocks to a comprehensive analysis of their BW resistance under the same set of testing conditions. Previous data from these elite stocks came from separate tests in different years.

Materials and Methods

The materials that were screened for bacterial wilt resistance in 1991 are given below. Many of the materials included in these tests are being reconfirmed for resistance. All field tests in summer 1991 failed because of heavy rains. Consequently, the tests were resown and BW screening through soil inoculation method (by 20 ml inoculum of 10^8 cell/ml concentration) was adopted. The inoculated seedlings were kept inside the plastic houses. Mean temperature inside these houses during the above test (except in the last two trials) was already fairly low—about 20°C. Wilt readings usually started a week after inoculation and completed 3 weeks later except the last group. A total of one reading was made every week.

Type of materials	Total lines	Sown	Inoculated	Recorded
Indeterminate tropical lines	24	9/2/91	9/26/91	10/3–10/17/91
Determinate tropical lines	33	9/2/91	9/26/91	10/3–10/17/91
Elite BW-resistant stocks	47	9/2/91	9/26/91	10/3–10/17/91
Fresh market hybrids	26	9/17/91	10/9/91	10/16–10/29/91
Firm-fruited lines	34	9/17/91	10/15/91	10/22–10/29/91

Results and Discussion

The most resistant indeterminate tropical lines are given in Table 5. The two best breeding lines compared very well against the most resistant accession, L285 and against two resistant check lines. Of the total of 24 lines tested, 17 lines showed resistance comparable to the resistant checks.

Among the determinate tropical lines, the best four lines had as good if not better resistance as the best check line CL143 (Table 6). L285, supposedly the most resistant accession in the Center's tomato collection, did not do well in this test although its survival rate was not statistically lower than the best lines and checks. A total of 19 lines out of 33 screened had survival rates comparable to L285.

The survival rate of lines among the firm-fruited group was below 50%. However, even the resistant checks had lower survival rates (range of 33–50%). Among the total 34 lines tested, 32 lines compared well

Table 5. Bacterial wilt resistance[a] of promising indeterminate tropical breeding lines vs. checks; AVRDC, summer 1991.

Entries	SR (%)	RRL	RRB_1	RRB_2
L 285 (res. check)	81 a-c	100	93	91
CLN 65-349D_5-2-0 (res. check B_1)	87 ab	107	100	97
CL 143-0-10-3-0-1-10 (res. check B_2)	90 a	110	103	100
CL 591E 206D_4-2-2-0-4	95 a	117	109	106
CLN 657BC_1F_2-285-0-17-0	90 a	110	103	100
L 390 (sus. check)	12 e	15	14	13
Mean of all entries	67	-	-	-
CV %	18	-	-	-

[a]SR = survival rate, RRL = relative survival rate compared to L285; RRB1 = relative survival rate vs. res. check B1; RRB2 = relative survival rate vs. res. check B2

Table 6. Bacterial wilt resistance of the promising determinate tropical breeding lines vs. checks; AVRDC, summer 1991.

Entries	SR (%)	RRL	RRB_1	RRB_2
L 285 (res. check)	56 a-j	100	79	60
CLN 65-349D_5-2-0 (res. check B_1)	72 a-h	127	100	76
CL 143-0-10-3-0-1-10 (res. check B_2)	94 a	166	131	100
CL 5915-223D_4-2-1-0	94 a	166	131	99
CL 1131-0-0-43-4-12	92 ab	163	128	98
CL 2729-0-2-1-12-0	90 a-c	159	125	96
CL 5915-93D_4-1-0-C-1	90 a-d	159	125	96
L 390 (sus. check)	10 k	18	15	11
Mean of all entries	54			
CV %	23			

against the resistant checks. The coefficient of variability in this experiment is abnormally high leading to insignificant differences among entries even though their magnitudes were appreciable. Most of the lines in this group have been selected for large fruits and excellent firmness and the best ones will be further selected for distribution or for further use in breeding.

The bacterial wilt resistances of the large-fruited fresh market hybrids were comparable, if not better, to those of the resistant checks. The best ones had survival rates of 46–52% compared to 33% for L285. In general, the BW infection rates in this experiment were very high. Of the 26 hybrids screened, 26 hybrids were as resistant if not more resistant than the checks.

The best BW-resistant stocks out of the total of 49 tested are given in Table 7. Of the 47 accessions evaluated, 29 showed survival rates comparable to the resistant check L285. Among these stocks, the CRA

Table 7. Bacterial wilt resistance of the best elite stocks vs checks; AVRDC, summer 1991.

Entry	Varietal name	SR (%)	RRL
L 285 (res. check)	Chang #1	85 a-g	100
BL 177	CL 114-5-5-0-0 x 1-12 L.V #16	98 a	115
BL 340	CRA 84-69	96 ab	112
BL 333	CRA 84-58-1	94 a-c	110
BL 162	LS 89	94 a-c	109
BL 353	MT 8	92 a-d	107
BL 342	CRA 84-79	92 a-d	107
BL 314	CRA 84-6-5	92 a-d	106
BL 323-20	CRA 84-26-3-20	92 a-d	106
L 390 (sus. check)	Nan-Tzu (Apple type)	9 j	11
Mean of all entries		73	
CV %		14	

series appears to be promising because of their relatively large fruit sizes. The best stocks in this group will be included in the 1992 BW test of AVNET to see if their resistances will hold against the BW inoculum in Southeast Asia.

Performance of Fresh Market Tomato Entries

Summary

Three trials were conducted during 1990–91 to select new, large-fruited and disease-resistant fresh-market entries. These trials allowed the selection of new entries with the following features: yields that were comparable to those of the best FMTT checks; fruit sizes comparable to the FMTT checks but often significantly lower than that of KY 301 with the exception of a few entries; better firmness in most cases; better crack resistance in most cases; and, apparently better resistance to bacterial wilt. However, the new entries tended to have lower soluble solid readings than the checks. The best new entries will be advanced to the next trial phases, as the case may be.

Introduction

Evaluation of the new fresh market entries for yield and other important horticultural attributes was continued. These predominantly hybrid materials bear large fruits and better quality for fresh consumption than the small-fruited tropical lines. However, the level of heat tolerance and BW resistance among them may not be as good as those of the tropical lines. AVRDC is continually looking for exceptional materials that combine heat tolerance, BW resistance, large fruits and good fruit quality.

Materials and Methods

Three trials were conducted during fall to spring 1990–91. Trials conducted during the hot, wet season were destroyed by heavy rains and are not reported here.

Information on the kind of materials, type of trials, sowing and planting dates are given below.

Type of trial	No. of entries	Sown	Transplanted	Harvested
Observational	43	12/30/90	1/15/91	4/19–5/10/91
Preliminary	24	8/14/90	9/19/90	11/27/90–1/2/91
Advanced	10	9/25/90	10/23/90	1/14–2/21/91

The observational trial (OYT) was unreplicated and had more entries than the other trials. On the other hand, the preliminary trial (PYT) was evaluated in a randomized complete block design with two replications. Unit plots of the OYT and PYT consisted of a double-row bed, each 4.0 m long and spaced 60 cm apart within the bed. Plants within the row were 40 cm apart.

The advanced trial was also planted in a randomized complete block design with three replications. Each unit plot comprised two double-row beds, each 4 m long and spaced 60 cm apart within the bed. Plants within the row were spaced 40 cm apart. Data on yield, fruit characters, quality and other important attributes were gathered.

Results and Discussion

The best new materials selected from the unreplicated OYT yielded 65–74 t/ha. Prominent features of the entries selected for further tests are better crack resistance than the checks and some had fruit size comparable to KY 301. Yield levels of the new entries appear to be lower than that of FMTT 33 but no statistical test could be carried out. All new materials carry ToMV resistance. Some also have adequate levels of heat tolerance and BW resistance.

Among the PYT entries, the best ones that compared favorably in yield with the best checks FMTT 22 and FMTT 138, are listed in Table 8. The most striking features of the best selections compared to the checks were as follows: comparable if not better yields than the best checks; fruit sizes comparable to

Table 8. Yield and other horticultural characters of the best ToMV-resistant fresh market hybrids vs.check cultivars in the preliminary yield trial; AVRDC, fall 1990.

Entries	MY (t/ha)	Fruit size (g)	Firmness at red-ripe stage (kg/0 5 cm)	Brix°	Cracking[a]	Vine[b] cover	Uniformity[b] of fruits in cluster	BW[c] (%)
FMTT 268	92.6 a	132 b-d	1.6 bc	4.4 de	2 R	G	G	21
FMTT 267	91.2 ab	130 b-d	1.7 a-c	4.5 de	0	F	F	48
FMTT 278	87.1 a-c	131 b-d	1 8 a-c	4.8 cd	2 R	F	F	-
FMTT 276	86.8 a-c	159 a	1.8 a-c	4.3 e	2 R	G	G	40
FMTT 22 (ck)	85.4 a-c	119 b-d	1.1 de	5 2 ab	1 R	G	G	6
FMTT 138 (ck)	77.5 a-c	72 e	0 8 e	4.5 de	0	G	G	22
KY 301 (ck)	28.8 d	144 ab	0.8 e	5.5 a	4 R/C	G	G	4
Mean of all entries	78.5	127	1 6	4.6				
CV (%)	11.3	8 2	10.7	3.6				

[a]R = radial crack; C = concentric crack; Rating = 0-4 (0 = none, 1 = very slight; 2 = slight; 3 = moderate; 4 = severe)
[b]F = fair; G = good
[c]BW (%) = survival rate in BW test at seedling stage using soil inoculation method

FMTT 22 and KY 301 (entry FMTT 276 showed larger fruit size than other selections); better crack resistance than KY 301 but no better than the FMTT checks except for entry FMTT 267; better fruit firmness at full ripe stage and possibly better bacterial wilt resistance than the checks. The main disadvantage of the new materials is the lower soluble solids content compared to the checks. The best entries of this trial will be evaluated in the advanced trials in 1992.

Entries in the advanced yield test yielded higher than those in the other fresh market trials (Table 9). The lowest yielder was KY 301, largely owing to its extreme susceptibility to foliage diseases especially ToMV, black leafmold, etc. The best entries ranged in yield from 111–115 t/ha; in contrast, KY 301 yielded only 70 t/ha. Except for FMTT 282, the entries generally produced smaller fruits than KY 301 but comparable to those of FMTT 22. Some entries had firmer fruits than KY 301. All were better than KY 301 in crack resistance. The best entries appeared to have better BW resistance than KY 301 and FMTT 22. As in the PYT, the new entries seemed to have lower soluble solids reading than the checks, however.

Table 9. Yield and other horticultural characters of the best ToMV-resistant fresh market hybrids vs.check cultivars in the advanced yield trial; AVRDC, fall 1990–spring 1991.

Entries	MY (t/ha)	Fruit size (g)	Firmness at breaker stage (kg/0 5 cm)	Brix°	Cracking[a]	Vine[b] cover	BW[c] (%)
FMTT 304	115.0 a	131 d	3 4 b-d	4 7 c	0	E	30
FMTT 282	112.9 a	153 ab	3 8 a	4.8 bc	0	G	40
FMTT 311	110.9 a	136 b-d	3.7 ab	4 7 c	2 R	G	50
FMTT 22 (ck)	109.9 a	134 cd	3.3 cd	5.1 ab	1 R	E	6
KY 301 (ck)	69.5 c	162 a	3.1 d	5.2 a	3 R	[illegible]	4
CV (%)	13.9	4.4	4.2	3.5			
Mean of all entries	101.2	144.7	3.5	4.8			

[a]R = radial crack; C = concentric crack; Rating = 0-4 (0 = none; 1 = very slight; 2 = slight, 3 = moderate; 4 = severe)
[b]F = fair; G = good
[c]BW (%) = survival rate in BW test at seedling stage using soil inoculation method

Performance of Processing Tomato Entries

Summary

Three observational and one advanced trial of processing tomato lines and hybrids were conducted in 1990–91 to select entries with good yield, disease resistance, good fruit traits such as firmness and crack resistance, and adequate quality for processing (good color and acceptable soluble solids content). Two

lines from OYT-I, five hybrids from OYT-II and six lines from OYT-III were selected for further evaluation. General features of the best selected entries compared to the respective checks include: high yield, improved fruit size, good fruit firmness, better soluble solids content, good crack resistance, good vine compactness and cover, and good concentration of maturity. Some selections have jointless pedicel. Most selections from different trials are already resistant to tomato mosaic virus and rootknot nematode. Most are yet to be tested for resistance to bacterial wilt.

Introduction

Selection for processing tomato lines and hybrids with good yield, some level of heat tolerance, disease resistance (particularly ToMV, rootknot nematode and bacterial wilt), good horticultural traits such as fruit firmness, crack resistance, etc., and adequate quality for processing (good color, acceptable brix and acidity) was continued. In addition, particular attention was focused on materials that had concentrated fruit set and carrying special traits such as jointless pedicel.

Materials and Methods

The types of processing tomato trials conducted, number of entries tested and the corresponding sowing and transplanting dates are given below:

Type of trial	No of entries	Sown	Transplanted	Harvested
Observational I	39	9/10/90	10/8/90	1/14–2/4/91
Observational II	174	9/10/90	10/8/90	1/14–2/4/91
Observational III	24	9/10/90	10/8/90	1/14–2/4/91
Advanced	14	9/10/90	10/8/90	1/11–2/1/91

The observational trials were made up of single-row, unreplicated plots and designed mainly for general selection of lines deserving further consideration from among a large number of materials. Each plot was a single 4 m long bed, 1.5 m apart from the adjacent beds, with plants within the row spaced 40 cm apart.

The advanced trial was planted in a randomized complete block design with three replications. Each plot comprised four 4 m long beds spaced 1.5 m apart. Within-row spacing between plants was 40 cm as in the other trials.

Results and Discussion

Two lines were selected from OYT I with comparable yields as the high-yielding check PT 4121, but with excellent firmness (reading of 2.3 kg/0.5 cm fruit surface) compared to 1.6 for the firmest check), good color and good pericarp thickness. These selections also had jointless pedicel which is preferred in mechanical fruit harvesting.

Six hybrids were selected from OYT II for further testing. Special features of the selections from this group compared to the checks (TK 18, UC 82 and PT 4225) include: high yield; firmness; good soluble solids content; good fruit color; firm fruits; good to excellent vine cover; good pericarp thickness and jointless pedicel in some selections. The new hybrids had only fair to good concentration of maturity, however.

Five lines were taken from OYT III for further testing. Special features of the selections from this group compared to the checks include: bigger fruit size (mostly above 90 g/fruit vs. 70–80 g for the hybrid checks); better firmness; good to excellent concentration of maturity; and, comparable vine cover, vine compactness, fruit color and soluble solids content. The hybrid checks had better crack resistance; however, and one PT 4121 appeared to outyield the new selections.

No significant differences were noted between the best yielding entries and checks, except when they were compared with check TK 18 (Table 10). In general, the best entries compared favorably well with the best performing checks (PT 4121 and Peto 86) in yield, fruit size, soluble solids, firmness, and vine cover and compactness. Some entries had better crack resistance and concentration of maturity than the checks. Two had comparable pericarp thickness as Peto 86.

Table 10. Yield and other horticultural characters of the best ToMV and nematode-resistant processing tomato hybrids vs checks in the advanced yield trial; AVRDC, fall 1990.

Entry	MY (t/ha)	Fruit size (g)	Brix°	Firmness (kg/0 5 cm)	Cracking[a]	Vine[b] cover	Compact vine	Wall[c] thickness	Concentrated[b] set
PT 4439	100 5 a	85 cd	4.8 ab	1.6	0	G	F	2	F
PT 4433	90.3 ab	75 de	4.6 a-d	1.7	0	G	G	4	G-E
PT 4455	84.1 ab	86 cd	4.9 a	1 7	2R	G	G	2	G-E
PT 4446	81.2 ab	85 cd	4 9 a	1.8	0	G	G	4	G
PT 4121 (ck)	89.5 ab	93 bc	4 4 a-d	1.7	2 R/C	G	F	3	F-G
Peto 86 (ck)	79.7 ab	84 cd	4 2 b-d	1 8	1R	E	E	4	G
TK 18 (ck)	67.3 b	126 a	4 2 b-d	1 6	0	G .	F	2	P

[a]C= concentric crack; R = radial crack; rating = 0 4 (0 = none, 1 = very slight; 2 = slight, 3 = moderate; 4 = severe)
[b]F = fair; G = good; E = excellent
[c]Rating scale of 1-4: 1 = thin, 2 = moderately thick, 3 = thick, 4 = very thick

Performance of Tropical Cherry Tomato Lines

Summary

Four trials of specialty type cherry lines were carried out in 1990–91. The observational and preliminary trials planted in summer 1991 were damaged by heavy rains and flooding—only cursory observations of performance could be gathered from these trials. A few conspicuously good selections with better yield and fruit setting ability relative to the checks were taken. More reliable results were obtained from the advanced trials (I and II) planted towards the fall 1990–91. Various selections from these trials will be advanced to the next testing phase and/or distributed to our national cooperators for further selection.

The best entries in AYT I outyielded the commercial hybrid Sugar Pearl but not the cherry hybrid checks from the program. They had excellent fruit set (about 90%/cluster), almost ideal fruit weight of 15 g/fruit, good to excellent uniformity of size and maturation of fruits in the cluster, and had better fruit firmness and crack resistance than the checks. None of the selected entries compared well with Sugar Pearl in soluble solids content but this could have been due to the low yield of Sugar Pearl. Soluble solids and yield are generally inversely related.

In AYT II, the selected entries again outyielded Sugar Pearl but not the cherry hybrid checks from the Center's program. Fruit set of all the entries was also excellent in this trial, about 90%/cluster. Selected entries had about the ideal fruit size of 15 g/fruit, and had better firmness and crack resistance than the checks. Uniformity of fruits (size and maturation within the cluster) of the selections ranged from good to excellent. Selections (especially CHT 266) compared very well with the checks in soluble solids content.

Introduction

Cherry tomato was viewed as a specialty item during the hot season. New materials coming out of the program were evaluated in 1990–91 for heat tolerance and improved quality during hot season.

Materials and Methods

Four trials were conducted in 1990–91. Information on the kind of materials evaluated, type of trials, sowing and planting dates is given below:

Type of trial	No of entries	Sown	Transplanted	Harvested
Observational*	65	5/7/91	6/4/91	8/5/91
Preliminary*	32	5/7/91	5/30/91	8/5/91
Advanced I	14	9/25/90	10/23/90	1/11–2/20/91
Advanced II	22	9/25/90	10/23/90	1/11–2/20/91

* Severely damaged by heavy rains and flooding

The observational trial was made up of single-row, unreplicated plots, and had more entries than the replicated trials. Each plot was a single 4-m long bed, 1.5-m apart from the adjacent beds, with plants within the row spaced 40-cm apart.

The preliminary trial was replicated twice in a randomized complete block design. Unit plot consisted of two beds, each 4-m long, spaced 1.5-m from adjacent beds and with within-row spacing of 40 cm.

The advanced trials were planted in a randomized complete block design with three replications. Unit plot comprised of two double-row beds, each 4.0-m long, with rows spaced 60-cm apart within the bed. Plants within the row were 40-cm apart.

Results and Discussion

Heavy rainfall and flooding which occurred twice on 21–23 June and 28–30 July, 1991 affected the outcome of the observational and preliminary trials.

Three entries, CHT 432, CHT 442 and CHT 440, yielded 7–9 t/ha with mean fruit weights of 12–15 g/fruit, and fruit setting per cluster of 29–38%. In contrast, the check entries CHT 264 and Season Red yielded only 0.4-0.5 t/ha, respectively, with mean fruit set of only 12%.

The PYT entries were severely damaged by flooding and had much lower yields than the OYT entries. One entry, CHT 33-7C-2-0-1, had yield and fruit setting ability comparable to the parthenocarpic CL5675, currently the best setting breeding line. All entries in the PYT had very small fruits, another indication that the flooding damage was severe.

The performance of the cherry tomato entries in the two advanced trials that were planted in the late summer were exceedingly better than in the summer trials (Table 11 and 12). The best entries in the AYT-I significantly outyielded the commercial hybrid Sugar Pearl, but not the cherry hybrid checks (CHT 104 and CHT 105) from the Center's program. In general, fruit setting of all entries was very high, about 90%/cluster. The fruits of the selected entries were smaller but closer to the ideal size of 15 g/fruit and with better firmness, color and crack resistance than those of the checks (especially compared to Sugar Pearl). CHT 283 had the fewest fruits per cluster yet had the highest yield. The best entries had good to excellent uniformity of fruits (size and maturation) per cluster. None of the best performing entries had soluble solids comparable to Sugar Pearl; on the other hand, this could have been due to their higher yields.

Table 11. Yield and other horticultural characters of the best cherry tomato entries vs check cultivars in the advanced yield trial (I); AVRDC, fall 1990.

Entries	MY (t/ha)	Fruit set (%)	Fruit size (g)	Brix°	Acid (%)	Color (a/b)	Firmness[a]	Fruits/ cluster	Uniformity of fruits/ cluster[b]	Cracking[c]
CHT 283	94 a	94 a	15 cd	6.5 cd	0.5 bc	2.1 b	MF	5	G	0
CHT 265	87 ab	92 a-c	11 d	6.5 d	0.5 bc	2.2 b	F	12–18	E	0
CHT 264	82 a-c	91 a-d	12 d	6.7 b-d	0.5 bc	2.1 b	F	13–16	E	0
CHT 261	80 a-c	88 a-d	12 d	6 5 cd	0.5 bc	2.2 b	MF	10–14	G	0
CHT 105 (ck)	80 a-c	93 ab	25 ab	6.5 d	0.5 b	2.1 b	MS	10–12	F	2R
CHT 104 (ck)	72 b-e	91 a-d	21 b	6.9 b	0.5 bc	2.2 ab	MS	8–12	G	0
Sugar Pearl (ck)	43 f	90 a-d	26 a	7.7 a	0.6 a	1.9 c	MS	8–12	F	4R
CV (%)	10	4	9.7	2.5	3 9	3.7	-			
Mean of all entries	68	89	16.5	6.6	0.5	2.1	-			

[a]Ms = moderately soft; MF = moderately firm; F = firm
[b]P = poor; F = fair; G = good, E = excellent
[c]R = radial cracking; C = concentrate cracking; rating = 0-4 (0 = none; 1 = very slight; 2 = slight; 3 = moderate; and 4 = severe)

The best entries in AYT II are given in Table 12. The selected entries outyielded Sugar Pearl but not the cherry hybrid checks from the Center's program. Again, fruit set of all entries was generally excellent, about 90%/cluster. Fruits of the selected entries were smaller but about the ideal size of 15 g/fruit, and had better firmness and crack resistance than the checks. Fruit color of the selections was also better compared to that of Sugar Pearl. Uniformity of the fruits in the cluster (size and maturation) of the selections ranged from good to excellent. In this trial, the selections (especially CHT 266) compared very well with the checks in soluble solids content.

Table 12. Yield and other horticultural characters of the best cherry tomato entries vs. checks in the advanced yield trial (II); AVRDC, fall 1990.

Entries	MY (t/ha)	Fruit set (%)	Fruit size (g)	Brix[c]	Acid (%)	Color (a/b)	Firmness[a]	Fruits/ cluster	Uniformity of fruits/ cluster[b]	Cracking[c]
CHT 266	57 bc	88 a-e	15 b-d	8 2 ab	0.4 b-d	2.2 a	MF	10–18	G	1R
CHT 284	55 b-d	88 a-e	15 b-d	7.2 cd	0 4 cd	2.2 a	MF	12–20	E	0
CHT 290	55 b-d	92 a-c	14 b-d	7.2 cd	0.5 b-d	2.1 a	F	12	E	0
CHT 104 (ck)	62 ab	92 a-c	22 a	7.1 cd	0.5 b-d	2.1 a	S	8–12	E	2R
CHT 105 (ck)	69 a	93 a	23 a	6.9 d	0.5 d	2.2 a	S	12–16	E	2R
Sugar Pearl (ck)	37 f	92 ab	18 b	7.8 ac	0.6 a	1.7 d	MS	10–13	F	4R
CV (%)	8	5	9.6	4.0	6.6	4.2	-			
Mean of all entries	50	87	15.4	7.6	0.5	2.1	-			

[a]Ms = moderately soft; MF = moderately firm, F = firm
[b]P = poor; F = fair; G = good; E = excellent
[c]R = radial cracking; C = concentrate cracking; rating = 0-4 (0 = none; 1 = very slight; 2 = slight; 3 = moderate; and 4 = severe)

International Cooperation

Seed Distribution

A total of 2928 seed packets were distributed to 110 cooperators in 52 countries. Feedback from 22 cooperators on trials has been received. AVRDC lines continued to show outstanding performance in a number of countries. Completed trials and other information from cooperators are presented below.

Cultivar Releases

CL 5915-223 was officially released as No. 12 in Ho Chi Minh City, Vietnam. In previous tests, this breeding line performed well and was considered the best variety for off-season (hot and wet) production.

The Alafua series of lines, viz. Alafua Large (CL 5915-206D4-2-2), Alafua Early (CL 2729-0-2-1-12-0) and Alafua Winner (CL 5915-93D4-1-0), released in Western Samoa in 1988 were recently reported to have been released and recommended this year for production in the other Pacific countries of Solomon Islands and Vanuatu.

The above releases bring the total number of AVRDC tomato lines released by the national programs to 68 lines in 30 countries since 1978.

Collaborative Trials

Feedback in 1991 from various trials is reported below by country, in alphabetical order.

American Samoa. The horticulturist at American Samoa Community College, Land Grant Programs, American Samoa Government, Ms. W. H. Kuo, reported a 1990 trial of 13 AVRDC fresh market lines and hybrids vs. commercial check cultivars from Known-You Seed Co., namely Kingkong, Season Red, Red Cloud Vanguard and Sugar Pearl. With the exception of one line which was completely susceptible to bacterial wilt, the AVRDC lines yielded from 19 to 56 t/ha and had wilt infection rates of 0–16%. In contrast, the commercial checks had 0–13 t/ha yield and wilt infection rates of 6–100%. The best entry was FMTT138 which yielded 56 t/ha, with a wilting rate of 12%, mean fruit size of 83 g/fruit, and an early maturity period of 60 days. In contrast, the best check was Kingkong which yielded 13 t/ha, had a wilt infection rate of 6%, fruit size of 95 g/fruit and maturity of 75 days.

Argentina. Our cooperator at Agrotecnica Trebol, S.R.L. tested six AVRDC fresh-market tomato lines against local check Platense in a 1987–88 trial. All entries significantly outyielded Platense, with a yield range of 72–93 t/ha. In contrast, Platense yielded 70 t/ha. Highest yielding line was CL5915-2-5. The main disadvantage of the AVRDC line was its small fruit size. Platense had a mean fruit weight of 122 g

compared to only 75 g for the largest-fruited line. AVRDC lines matured in 102–110 days and were significantly earlier than Platense which matured in 120 days.

Australia. Dr. A. M. Hibberd of the Department of Primary Industries, South Queensland, tested seven AVRDC processing tomatoes for resistance to bacterial canker caused by *Clavibacter michiganense* ssp. *michiganense*. PT 4225 compared favorably with the most resistant check, H 2990, in a stem-rating test. Based on the severity test of leaflets, none compared with H 2990.

Brazil. Mr. Nei Peixoto of Emgopa of Estacao Experimental de Anápolis compared five AVRDC processing tomato hybrids with Petomech, Rossol and two UC checks, UC82 and UC204, in a 1990 trial. Only PT 4172 compared favorably with Petomech, the best entry, in yield and soluble solids content. Petomech yielded 58 t/ha whereas PT 4172 yielded 42 t/ha. Yield difference was statistically insignificant.

Brunei. Mr. Ramon Santiago of Sinaut Agricultural Training Center reported three trials, one each of AVRDC's determinate and indeterminate tropical lines, and one trial under protected cultivation of the large-fruited hybrids in 1990. Among the determinate lines, CLN466BC1F2-45-34-9-9 produced the best yield of 21 t/ha. This line also had the lowest wilting (due to bacterial wilt) rate (%) and the largest fruits (67 g/fruit) among the selections. CL6046BC3F2-51-1-1-15-10 yielded the highest (21 t/ha) among the indeterminate lines. However, bacterial wilt infection among this group was relatively high. This line was 25% infected compared to commercial hybrid Kingkong which was 40% infected. Among the large-fruited fresh market cultivars tested under the hydroponics culture, YR815 yielded the best with 16 t/ha in a nonreplicated test. FMTT 3 yielded 11 t/ha but had twice as large a fruit as YR815.

Colombia. Dr. J. J. Vasquez of the Instituto Colombiano Agropecuario, Centro Nacional de Investigacion tested 22 AVRDC tropical lines from 1988-90 in several sets of trials. Checks were Peto 98, Early Daro, Humaya F_1 and Napoli VF. CL6046B3F2-1-1-15-1 gave a yield comparable to the checks in the 1989 trial at Atlantico, yielding 54 t/ha with a soluble solids reading of 6.1 Brix. The best yielding check, Early Daro, yielded 65 t/ha with a Brix value of 4.8. However, its fruits are small (25 g/fruit). In the 1988 trial at Palmira (Cauca Valley), three AVRDC lines yielded 20 t/ha or more. CL5915-2-5 yielded the best with 22 t/ha. In contrast, the best check Humaya F_1 yielded only 13 t/ha. In the 1989 trial at Palmira (Cauca Valley), the best yielder was CL5915-206-2-2, yielding 12 t/ha; best check yield was that of Napoli VF with 17 t/ha. Soluble solid readings were comparable among all entries. In the 1990 trials at the same location, best yielder was CL5915-223 with 10 t/ha against that of 11 t/ha for Napoli VF with 11 t/ha. Again, soluble solids were comparable among entries.

Egypt. Dr. A. M. M. Mohamed tested six of AVRDC's fresh market hybrids in a 1991 trial in Cairo. The best entry was FMTT138 which yielded 39 t/ha and with the highest fruit setting score of 5. In addition, Dr. Mohamed reported the high yield of four processing hybrids, and four fresh-market and processing lines in the summer.

Ethiopia. Ten trials of AVRDC tomato lines from 1985 to 1988 by the Agricultural Research Center at Nazret showed that none of these lines outyielded the local check Roma VF during the regular tomato-growing season. In the first set of trials on determinate lines, CL1131-7-2 had the best yield (14 t/ha) and in 2-year trials yielded 12 t/ha. In contrast, local check Roma VF yielded only 3 t/ha in the 1985–86 trial and 13 t/ha in the 1987–88 trial. CL1131 gave a yield comparable to Roma VF in the dry season 1987–88 trial. In the second set, CL5915-136 gave the highest yield of 14 and 5 t/ha during the rainy seasons of 1985-86 and 1987-88, respectively. Roma VF yielded 7 and 9 t/ha in the same two years. None of the AVRDC entries outyielded Roma VF during the cool, dry season. Among the indeterminate types, CL5915-553 gave the best yields of 27 and 13 t/ha during the rainy season of 1985-86 and 1987-88, respectively. Local check, MoneyMaker, yielded 11 and 5 t/ha in these trials. No AVRDC entry compared favorably with the check during the cool, dry season.

India. Dr. Rajput of the Central Experiment Station in Wakawali reported one 1988 trial on AVRDC lines against other germplasm. In this trial, CL6046BC3F2-51 yielded the highest (33 t/ha) with a bacterial wilt infection rate of 9%. In contrast, germplasm such as Hy-37 and Selection 120 had no yield and both with wilt infection of 90%. In Bangalore, Dr. Tikoo reported that BL263 (Hawaii 7998) and CLN65-349 had more than 90% survival rate in the bacterial wilt nursery. In contrast, the susceptible check showed only 5% survival rate. However, the AVRDC accessions were reported to have small and soft fruits that cracked easily.

Kenya. Mr. M. Ngugi of Kenya Seed Company conducted two trials in 1990 on AVRDC's fresh market, processing and cherry hybrids. One trial was carried out in Kitale and the other at Kibwezi. AVRDC entries did not significantly outyield the two strains of MoneyMaker but some entries had larger fruit sizes in the Kitale trial. Three entries, FMTT 138, CHT 104 and CHT 103, significantly outyielded MoneyMaker in the Kibwezi trial, yielding 44–60 t/ha compared to 20–30 t/ha for the two strains of the check. Mr. Ngugi has retested the materials and recently asked if parent stocks of the best combinations could be shared so that the promising varieties could be released to Kenyan farmers.

Lesotho. Mr. M. Makhata of Agricultural Research Division tested four AVRDC fresh market tomatoes against two local checks (BR 54 and Eterna F_1) in 1990. FMTT 33, FMTT3 and FMTT 22 had the best yield of 53–60 t/ha with comparable fruit sizes (over 100 g/fruit) as those of the checks. The best check, BR 54, yielded 43 t/ha.

Malaysia. In Sabah, Ms. Liaw Hiew Lian of the Agricultural Research Center in Tuaran, tested nine AVRDC lines against the local variety in Kundasang highland in 1989-90. The best entry was CL1131-43 with a marketable yield of 15 t/ha. The local variety yielded 0.4 t/ha with smaller fruits (21 g/fruit) than those of most of AVRDC's tropical lines. The trial was greatly affected by severe insect damage, blossom-end rot and cracking. In a duplicate trial in the lowlands of Tuaran, CL1131-43 was again the best yielder (20 t/ha). Three other lines, CL9-1-3, CLN475-265 and CL143-10-3, had comparable marketable yields of 18–20 t/ha. Similarly, the damage from insects, blossom-end rot and cracking was severe in some lines.

Marianas. Dr. L. N. Ragus of the Northern Marianas College tested five AVRDC accessions against local hybrid check Apollo in a 1991 trial. The best line was L22 (VC 11-3-'-8) which yielded 22 t/ha with an average fruit size of 72 g/fruit. In contrast, Apollo yielded 10 t/ha with a mean fruit size of 25 g/fruit.

Panama. Mr. J. Cedeño of Nestle Panama, S.A. evaluated 13 AVRDC lines in a commercial trial for processing. For reference, hybrids PY 870, TM 103 and PT 1599 served as checks. Including CL5915-153, all checks had 100% mortality due to bacterial wilt. The most resistant line was CLN65-349-2-0 with 15% infection rate. It also gave the best yield of 55 t/ha. However, it tended to have lower soluble solids content than other entries.

Tanzania. Two trials of AVRDC lines were conducted by Mr. E. Meela of the Uyole Agricultural Centre at Uyole in 1990. The first trial of indeterminate lines was damaged by an early occurrence of blight and had a very large number of culled fruits. A similar problem existed in the trial of determinate lines. Another disease, late blight, was a major problem. AVRDC plant breeders will have to seriously contend with new tomato diseases as the Center begins to move its germplasm into Southern Africa.

Vietnam. Mme. Nguyen Thi-Duc Tu of the Center for Horticultural Technology in Hanoi reported the results of two trials (winter to spring 1990 and spring to summer 1991) of seven AVRDC tropical lines. CL 143-0-10-3 had the highest yield of 33 t/ha during the winter. In the spring to summer trial, best yield among the high-yielding entries was only 20 t/ha. The main limitation of the tropical lines is their small fruit size. Leaf curl virus infection was up to 55% in the trials.

Tomato Entomology

Screening of BC_1F_1 Population from Crosses Between *Lycopersicon pennellii* and *L. esculentum* for Resistance to Tomato Fruitworm

Summary

Three hundred BC_1F_1 plants belonging to the progeny of six crosses between tomato fruitworm (*Helicoverpa armigera* Hübner)-resistant *Lycopersicon pennellii* accession and susceptible *L. esculentum* breeding lines were screened in the field for resistance to tomato fruitworm Plants in an open field were exposed to the insect and each plant was observed for total number of fruits and fruitworm-damaged fruits. Eleven plants with the fewest insect-damaged fruits and relatively better horticultural characters were selected for further improvement. There was significant positive correlation between fruit size and percent fruit damage.

Introduction

Tomato fruitworm (TFW), *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae), is a polyphagous insect that attacks tomato and several other economically important crops in Asia. It lays eggs on the foliage where the larvae, after initial feeding on the leaves, bore into the tomato fruit. Since 1980–81, AVRDC has been breeding tomato lines for resistance to this pest. Until 1989 TFW-resistant genes from *L. hirsutum* f. *glabratum* had been used, and three breeding lines with moderate levels of resistance and medium fruit size were selected. There was a need to increase the level of resistance and fruit size to make these lines competitive with commercial cultivars. In 1989 AVRDC initiated a breeding program to incorporate the newly-found TFW resistance genes from *L. pennellii* into cultivated tomato. In 1991 BC_1F_1 progeny were screened for resistance to TFW to select a resistant progeny with desirable horticultural characters.

Materials and Methods

Seeds of 6 BC_1F_1 and 3 *L. esculentum* susceptible checks were obtained. Fifty 1-month old seedlings of each entry were transplanted in the field on 1.5-m wide beds. A distance of 3 m was maintained between two adjacent plants on each bed. One plant of breeding progeny and one of susceptible check were transplanted in alternate rows. The entire planting was surrounded by a row of TK 70, a commercial cultivar which is susceptible to TFW. The crop was grown according to customary cultural practices except that no insecticide was applied. Starting with the first flowering, an undetermined number of laboratory-reared TFW were released in the field to augment the native population to ensure a high level of infestation and to minimize escape of insects. When the fruits started maturing each plant was observed and the number of total fruits and fruitworm-damaged fruits on each plant was recorded. This was done twice when the TFW population was high. When fruits became ripe, the weights of several individual fruits were taken to determine fruit size. After the second observation, the plant breeder was invited to select plants with good horticultural characters among the least damaged ones.

Results and Discussion

The results of the TFW damage on selected promising BC_1F_1 progeny and susceptible checks are summarized in Table 1. In both observations all 11 selected BC_1 were substantially less damaged than the susceptible checks. On average, the susceptible check has far fewer fruits per plant than the BC_1F_1 progeny. The fruits of all BC_1F_1 plants were distinctly smaller than those of the susceptible checks. There was

significant positive correlation between TFW-damaged fruits and fruit size. This correlation, if sustained in subsequent backcrosses, could be disadvantageous in breeding a tomato cultivar that is both resistant to TFW and possessing large enough fruits to be competitive with commercial cultivars. The selected BC_1F_1 progenies from this test will be used for further backcrossing to improve fruit size.

Table 1. TFW infestation of selected BC_1F_1 progeny and susceptible checks[a].

Entry	First observation		Second observation		Fruit weights (g)
	Damaged fruit/ total fruit	% Damage	Damaged fruit/ total fruit	% Damage	
CLN1289-1 BC_1F_1	2/280	0.7	3/551	0.5	15
CLN1289-17 BC_1F_1	4/254	1.6	10/420	2.4	25
CLN1289-27 BC_1F_1	14/456	3 1	29/1213	2.4	10
CLN1289-28 BC_1F_1	7/601	1 2	29/1318	2.2	15
CLN1289-31 BC_1F_1	8/257	3.1	5/261	1.9	24
Average damage (all 50 plants)		*6.7*		*7.1*	
CLN1290-47 BC_1F_1	12/442	2.7	17/703	2.4	18
CLN1290-75 BC_1F_1	4/155	2.6	6/265	2.3	24
CLN1290-80 BC_1F_1	13/487	2.7	23/787	2.9	14
Average damage (all 50 plants)		*8.6*		*7.5*	
CLN1293-141 BC_1F_1	5/475	1.1	4/988	0.4	18
Average damage (all 50 plants)		*10.8*		*8.7*	
CLN1294-202 BC_1F_1	15/331	4.5	8/442	1.8	28
CLN1294-211 BC_1F_1	27/423	6.4	15/934	1.6	38
Average damage (all 50 plants)		*15.6*		*11.5*	
S1. CL5915-93-1-0-12[b]	1406/7356[c]	19 1	2123/7525[c]	28 2	36
S2: CLN65-349-2-0[b]	513/3155[c]	16.3	913/3919[c]	23.3	64
S3. CLN698BC_1F_1-358--2-11-6[b]	543/2022[c]	26.9	730/2671[c]	27.3	64
TK70[b]			1293/3782[c]	34.2	109

[a]Planting date: 8 October 1990, observation dates: first: 9-10 January 1991, second: 23-24 January 1991. The susceptible parents and susceptible check was planted one month after planting of test entries to synchronize fruiting. [b]S1, S2, and S3 are susceptible parents and TK 70 is a susceptible commercial cultivar. [c]Data are total of 50 plants; remaining data are for one plant each

Screening and Selection of *Trichogramma* Species for the Parasitization of Tomato Fruitworm Eggs

Summary

Fourteen species of trichogrammatid egg parasites were evaluated for the parasitism of eggs of tomato fruitworm, *Helicoverpa armigera* (Hübner). In laboratory tests where tomato fruitworm eggs laid on tomato foliage which were exposed to various species, *Trichogramma pretiosum* parasitized the highest number of eggs followed by *T. ostriniae*, *T. cacoeciae*, *Trichogramma* sp. from France, *Trichogrammatoidea bactrae*, *T. chilotraea* and *T. principum* in descending order. The parasitism by these species ranged from 82.3 to 95.7% of eggs. Tests are underway to evaluate the potential of *T. ostriniae* and *T. bactrae* in the control of tomato fruitworm in the field. The efficacy of two egg parasites, *Trichogramma chilonis* Ishi and *T. chilotraea* Nagaraja and Nagarkatti against the tomato fruitworm was also studied at the University of the Philippines at Los Baños (UPLB). *Trichogramma chilonis* was found more efficient than *T. chilotraea* in reducing the damage of fruitworm in tomato.

Introduction

Tomato fruitworm (TFW), *Helicoverpa armigera* (Hübner), a polyphagous insect that also attacks corn, cotton, tobacco, soybean and others, is causing increasing damage to tomato especially if the tomato is planted in the vicinity of these crops. Since these crops are economically important and are grown widely throughout Asia, tomato crops are seriously damaged by TFW throughout Asia. To control this pest on a

sustainable basis, AVRDC's research aims to develop an integrated pest management program, with host-plant resistance as the major component. While continuing research on breeding for fruitworm–resistant cultivars, other supplementary control measures to achieve optimal control of the pest on a sustainable basis are being explored. In this connection, among other research efforts, in a laboratory study, several egg parasites, mainly *Trichogramma* species, were screened to explore their suitability for the biological control of TFW. In a separate study in the Philippines, two egg parasites, *Trichogramma chilonis* Ishi and *T. chilotraceae* Nagaraja and Nagarkatti were also studied for their effectiveness against the tomato fruitworm. *Trichogramma chilonis* was more efficient than *T. chilotraea* in reducing damage of fruitworm in tomato.

Materials and Methods

Five-week old tomato seedlings (cv TK70), grown in small clay pots were used in all laboratory experiments (27 ± 3°C). Seedlings were placed overnight in a cage containing several mated tomato fruitworm females ready to lay eggs. In the morning, the seedlings were removed and the number of eggs on each plant recorded. With less than 400 eggs/plant, freshly laid eggs from a laboratory colony of tomato fruitworms were added. If the number was greater than 400 extra eggs were removed.

Each seedling was then confined in an acrylic cylinder (15 cm diameter, 30 cm height) and a card containing 1000 eggs of *Corcyra cephalonica* parasitized by one of 14 trichogrammatids (Table 2) was inserted in the cylinder. After 6 days, the number of parasitized and unparasitized tomato fruitworm eggs were recorded. Parasitized eggs turn black, and instead of tomato fruitworm larvae, trichogrammatid adults emerge. The unparasitized eggs turn pinkish, then brown and hatch into fruitworm larvae.

Table 2. Extent of parasitization of tomato fruitworm eggs by various trichogrammatids.

Trichogrammatid species/strain	Eggs parasitized (%)
Trichogramma pretiosum	95.7
Trichogramma ostriniae	94 2
Trichogramma cacoeciae	93.8
Trichogramma sp. (France)	87 1
Trichogrammatoidea bactrae	84.7
Trichogramma chilotraea	84.3
Trichogramma principum	82.2
Trichogramma evanescens	79.8
Trichogramma trijapitzini	79.1
Trichogramma dendrolimi	67.7
Trichogramma embryophagun	62.2
Trichogramma maidis	61.9
Trichogramma agrotidis	40.1
Trichogramma confusum	17.9
LSD 5%	13.2
1%	17.6

*Parasitism data are means of five replicates

Another study sponsored by AVRDC was conducted at the UPLB to determine the efficacy of two egg parasites, *Trichogramma chilonis* Ishi and *T. chilotraea* Nagaraja and Nagarkatti against TFW. The age of TFW eggs most preferred by two parasites, whether reared on eggs *C. cephalonica* or on tomato fruitworm was evaluated. Their fecundity was also determined based on the number of eggs parasitized. In addition, longevity of female adults and the influence of previous host on the number of emerging adults per egg were investigated.

Results and Discussion

The results of the parasitization of tomato fruitworm eggs by each of the 14 trichogrammatids are summarized in Table 2. *Trichogramma pretiosum* parasitized the highest number of tomato fruitworm eggs

followed by *T. ostriniae*, *T. cacoeciae*, *Trichogramma* sp. from France, *Trichogrammatoidea bactrae*, *Trichogramma chilotraea* and *Trichogramma principum* in descending order. The parasitism by these species did not differ significantly among themselves. The other seven species were less effective. Among the above seven species, *T. ostriniae* is commercially used in Taiwan and elsewhere to control Asiatic corn borer, *Ostrinia furnacalis*. *Trichogrammatoidea bactrae* gives the highest parasitization of eggs of diamondback moth and limabean pod borer. These two species seem to be suitable for commercialization as they will control more than one species, and are thus commercially attractive. The potential of these species in the control of tomato fruitworm will be explored in large-scale field tests during 1992.

In the laboratory, the two egg parasites significantly preferred the 1- to 2-day old rather than 3-day old eggs of TFW. Eggs older than 48 hours had the lowest parasitizm of both *T. chilonis* and *T. chilotraea*. This implies that younger eggs are suitable hosts for the parasitoids and that the embryonic stage of the host is the most important factor for the success of oviposition.

Trichogramma chilonis and *T. chilotraea* were equally efficient in parasitizing fruitworm eggs when reared on *C. cephalonica*. When reared on the eggs of the fruitworm itself, however, *T. chilonis* appeared to be more efficient than *T. chilotraea*. On the other hand, fecundity based on the number of eggs parasitized and longevity of the female of both parasites were statistically the same whether reared on *C. cephalonica* or on TFW. The host on which the *Trichogramma* was previously reared affected the number of emerging adults per fruitworm egg. The number of *T. chilotraea* adults emerging per egg was higher than that of *T. chilonis* when reared on the eggs of TFW but no difference was observed when reared on *C. cephalonica*.

In the field, parasitism of TFW eggs by *T. chilonis* and *T. chilotraea* varied significantly. *Trichogramma chilonis* had higher percent parasitism compared with *T. chilotraea*. Percent parasitism was not affected by the number of parasites used but varied directly with host egg density.

Trichogramma chilonis at rates of 40,000 and 80,000 parasitoids/ha significantly reduced the population of TFW larvae in both trials. *Trichogramma chilotraea* reduced larval population during the dry season trial but not during the wet season trial. These results reflect the relatively high mean parasitism of eggs of TFW. Larval damage was also reduced with these treatments resulting in higher marketable yield.

The results indicate that *T. chilonis* was more efficient than *T. chilotraea* in reducing damage of TFW in tomato. Confirmatory tests are necessary to verify the effectiveness of *T. chilonis* against the fruitworm in tomato-growing areas.

Susceptibility of Tomato Fruitworm to *Beauveria bassiana*

Summary

A suspension of 8×10^7 spores of *Beauveria bassiana* when mixed with 300 g sterilized soil proved to be infectious to the larvae/pupae of tomato fruitworm, *Helicoverpa armigera* (Hübner). At this concentration over 52% of insect larvae were infected with the fungus, and none was infected in untreated soil. Only 32.5% adults emerged from the pupae from treated soil as against 92.5% from pupae from untreated check soil. The fungus contributed to 61.8% mortality of tomato fruitworm pupae. Studies are underway to investigate survival and infectivity of the fungus in unsterilized soil.

Introduction

Tomato fruitworm (TFW), *Helicoverpa armigera* (Hübner), is a highly polyphagous insect that attacks several economically important crops such as tomato, corn, tobacco, cotton, soybean, mungbean and pigeon pea. The insect lays eggs on the leaves of tomato plants and the larvae, after initially feeding on foliage, bore into tomato fruit. It feeds inside the fruit until ready for pupation which takes place in the soil. This pest causes considerable damage to tomato if the crop is planted in the vicinity of corn or cotton, which is often the case in multiple cropping systems throughout Asia. AVRDC's research attempts to develop fruitworm-resistant tomato cultivars. However, based on the progress made so far, it may be difficult to develop a highly resistant cultivar which alone will control this pest. Other control measures, then, may be necessary to supplement the resistant cultivar to get optimum control of the tomato fruitworm. In this regard, while continuing resistance breeding research, other potential control methods which are

inexpensive, environmentally safe and sustainable are being explored. The potential use of a soil fungus *Beauveria bassiana* in the control of TFW is also being investigated.

Materials and Methods

Soil was autoclaved for 1 hour at 120°C and 6.8 kg pressure. The sterilized soil was divided into eight samples of 300 g each and placed individually in 500-ml beakers. Ten ml of *B. bassiana* suspension containing 8×10^7 spores was added into each of the four samples, each sample being a replicate. Ten ml of sterile water was added in the remaining four. The spore suspension or sterile water was mixed thoroughly with soil and allowed to settle for 24 hours.

Tomato fruitworm larvae were raised on an artificial diet (Bioserve No. 9219). Ten 6th instar larvae ready for pupation were placed in each of eight soil samples. The inoculated soil samples were then maintained at 25 ± 2°C for 1 week. During this period, the fruitworm larvae bored into the soil and pupated. After 1 week each pupa was observed and the number of both infected and healthy *B. bassiana* were recorded. The fungus-infected pupae had white fungal hyphae coming out of their cuticle. All pupae, diseased or otherwise, were placed in a petri dish lined with moist filter paper and put into a 30 × 30 × 30 cm cage. The number of adults emerging from each replicate was recorded for the next 7 days. Those pupae from which adults did not emerge were considered dead.

Results and Discussion

The results of the infection of TFW pupae by *B. bassiana* are summarized in Table 3. *Beauveria bassiana* infected over 52% of the TFW larvae/pupae. It is possible that the larvae that have relatively soft skin, compared to pupae which have sclerotized cuticle, are infected by the fungus but the infection was still at the initial stage which did not prevent larval pupation. The fungus continued to develop while the insect was undergoing pupation and after optimum incubation, the insect succumbed to the disease. *Beauveria bassiana* hyphal growth was visible on the pupae from infected samples. No such growth was found in pupae from check-soil samples. None of the fungus-infected pupae emerged into adults. In addition few uninfected pupae also failed to emerge. This failure is a normal biological phenomenon and not related to the fungus. In the check sample, 7.5% pupae also failed to emerge into adults.

Table 3. Susceptibility of tomato fruitworm larvae to *B. bassiana*.

Treatment	Infested pupae (%)[b]	Adult emergence (%)[b]
B. bassiana 8×10^7 spores[a]	52.5 ± 15.0**	32.5 ± 12.6**
Check	0.0 ± 0.0	92.5 ± 5.0

[a]8×10^7 spores in 10 ml water was added to 300 g sterilized soil. In the check only 10 ml sterile water was added to sterilized soil. [b]Data are means of four replicates. The differences in infested pupae or adult emergence between treatment and check are significant at 1% probability level of student's t test.

A concentration of 8×10^6 spore/ml is considered as moderately infectious to other insects when the spore suspension is sprayed on the larvae or nymphs. Ten ml of this suspension was used for mixing with soil. The larvae were expected to pupate within 24 hours—as is the case in a natural situation—and were not expected to be active to pass through the entire soil sample and thus come in contact with a high concentration of *B. bassiana* spores. TFW larvae are thus as susceptible to *B. bassiana* as the larvae or nymphs of certain other pest insects. The use of soil medium to spread the fungus is more appropriate because *B. bassiana* persists in the soil and tomato fruitworm larvae pupate in the soil. Application of fungal suspension to plants to control fruitworm is not practical because most of the larval period is spent concealed inside tomato fruits, and *B. bassiana* spores cannot reach the larvae.

Tomato Pathology

Cultural Studies on *Phytophthora capsici* and *P. infestans* and Inoculation on Tomato

Summary

Late blight of tomato occurs throughout the highland tropical production areas. Fungicides are routinely used to control late blight. In these experiments, two species of *Phytophthora* were morphologically compared and inoculated on detached tomato leaves protected with fungicides. *Phytophthora capsici* and *P. infestans* were isolated from foliage of field-grown tomatoes with late blight symptoms. Sporangia of *P. capsici*, isolate Pc9, varied in shape from spherical to fusiform with an average length and breadth of 53.5 µm and 37.6 µm; sporangia were papillate with an average pedicel length of 83.9 µm. The sporangia of a *P. infestans* isolate, Pi1, were ellipsoid to ovoid and semipapillate, and averaged 39.6 × 21.6 µm with short or absent pedicels. Optimum temperature for mycelial growth and zoospore germination of Pc9 ranged from 24 to 32°C. Mycelium did not grow at 8 and 36°C; however, zoospores did germinate when incubated at 4 and 40°C. Mycelium growth of isolate Pc9 was inhibited when Ridomil-MZ was incorporated into the agar medium at 1000, 800, 600, 400 and 200-fold dilutions. Zoospore germination of Pc9 was 83% without Ridomil-MZ and under 2% with 200-fold dilutions of Ridomil-MZ. Detached tomato leaves were individually inoculated with Pc9 and Pi1 before and after spraying different concentrations of Ridomil-MZ. Disease ratings were significantly different between unsprayed and sprayed leaves with lower disease ratings when Ridomil-MZ was applied. The fungicide had curative effects if applied 1-2 days after inoculation.

Materials and Methods

Maintenance of cultures. *P. capsici* (Pc9) isolated from tomato foliage in the Hsinyi area was maintained on potato dextrose agar (PDA) slants and subcultured every 3 months. For longer storage, mycelium growth on V8 agar disks were transferred to tubes containing 10 ml sterilized water. Tubes with plastic covers were incubated at 18°C.

P. infestans was isolated from infected leaves collected from the Hsinshe area. Infected leaves were placed inside 15-cm diameter dishes on top of detached tomato leaves that were cut from 30-day old seedlings grown in the greenhouse. Moist filter paper was placed on the bottom of each dish and the cut end of the petioles was surrounded by wet cotton. Under these conditions, detached tomato leaves had water-soaked lesions within 4–5 days, and sporangia were produced 10–14 days after incubation. Infected detached leaves were soaked in sterilized water and agitated to release sporangia. The sporangia suspension was sprayed on fresh detached leaves and treated as previously described. *P. infestans* was maintained on detached tomato leaves and transferred to fresh leaves every 14 days.

Morphology of sporangia. A drop of a sporangial suspension of *P. infestans* and *P. capsici* was placed on a microscope slide. The length, breadth and pedicel sizes of 20 sporangia for each species were measured with a micrometer under a compound microscope at ×200.

Growth and zoospore germination of *P. capsici*. Mycelium (2-mm)agar disks from 7-day old colonies were placed on the center of 9-cm diameter PDA plates. The inoculated plates were incubated from 12 to 32°C at 4°C intervals and the colony diameters were measured each day after inoculation. There were 10 replications for each temperature.

A drop of a zoospore suspension was placed on a 10-mm diameter WA disk which had been put on a microscope slide. The slides rested on small glass clubs inside dishes with moist filter paper below. The inoculated WA disks were incubated from 8 to 36°C at 4°C intervals and zoospore germination was counted each hour after inoculation. There were four replications for each temperature.

Effect of Ridomil-MZ on mycelial growth and zoospore germination of *P. capsici*. Mycelium (2-mm) agar disks from 7-day old colonies were placed on 9-cm diameter PDA plates 5 cm away from 2-mm diameter filter paper disks that had been soaked with 1000-, 800-, 600-, 400- and 200-fold diluted Ridomil-MZ suspensions, or soaked in sterilized water as a control. Cultures were incubated at 28°C and the zones of inhibition were measured 7 days after incubation. There were 10 replications for each diluted concentration of Ridomil-MZ.

To test zoospore germination, the treatments using Ridomil-MZ were done as described for mycelial growth. Inoculated WA disks were incubated at 28°C, and zoospore germination was recorded after 4 hours of incubation. There were six replications for each dilution concentration.

Protection of inoculated tomato leaves with Ridomil-MZ. Inoculum of *P. capsici* and *P. infestans* was sprayed on detached tomato leaves 4, 2, and 1 day before spraying Ridomil-MZ suspensions of 1000-, 800-, 600-, 400- and 200-fold dilutions, or leaves were inoculated just after Ridomil-MZ treatments. Another set of leaves not sprayed with Ridomil-MZ suspensions served as a control. Leaves inoculated with *P. infestans* and *P. capsici* were individually incubated at 20 and 28°C. Disease ratings, based on a 0-6 scale, were recorded 7 days after inoculation. There were five replications for each fungicide concentration and each species.

Detached leaves of tomato were cut from 30-day old seedlings and placed inside dishes with moist filter paper. Inoculum from both species was individually sprayed on detached tomato leaves after spraying Ridomil-MZ suspensions of 1000-, 800-, 600-, 400- and 200-fold dilutions. Leaves inoculated with *P. infestans* were incubated at 20°C while those inoculated with *P. capsici* were incubated at 28°C.

Results and Discussion

Morphology of sporangia. Sporangia length, breadth and LB ratio of *P. infestans* and *P. capsici* mostly agreed with sizes previously reported in the literature, although, the LB ratio of *P. infestans* was 1.82–1.97 µm, which was slightly larger than the 1.6–1.7 µm previously reported. Length and breadth of *P. infestans* were shorter than *P. capsici*, but LB ratio was greater (Table 1). Sporangia of *P. infestans* were more ellipsoid than *P. capsici*. *P. capsici* sporangia also were papillate and had obvious pedicels which were different from *P. infestans* sporangia that were semipapillate and without obvious pedicels. Basically, the two species were quite easy to distinguish.

Table 1. Length, breadth, length-breadth (LB) ratio, and pedicel length of sporangia of *Phytophthora infestans* grown on tomato leaves and of *P. capsici* grown on V8 agar medium.

Isolate	Sporangia (µm)			
	Length (µm)	Breadth (µm)	LB ratio	Pedicel
P. infestans (Pi1)	39 6[a]	21 6	1 84	-[b]
P. infestans (Pi2)	37 7	20 6	1 82	-
P. infestans (Pi3)	38 1	19 4	1.97	-
P. capsici (Pc9)	53 5	37 6	1.44	83.9

[a]Means based on 25 sporangia.
[b]No obvious pedicels observed

Growth and zoospore germination of *P. capsici*. Growth of *P. capsici* ranged from 12–32°C (Fig. 1). No growth was recorded at 8 and 36°C. The optimum temperature for growth was 24–32°C. Zoospores germinated between 8 and 36°C with an optimum at 24–32°C (Fig. 2).

Effect of Ridomil-MZ on mycelial growth and zoospore germination of *P. capsici*. Ridomil-MZ effectively inhibited mycelium growth and zoospore germination of *P. capsici* (Table 2). Zoospores had

encysted and lysed before germination. As concentration increased so did the inhibition zone of mycelial growth.

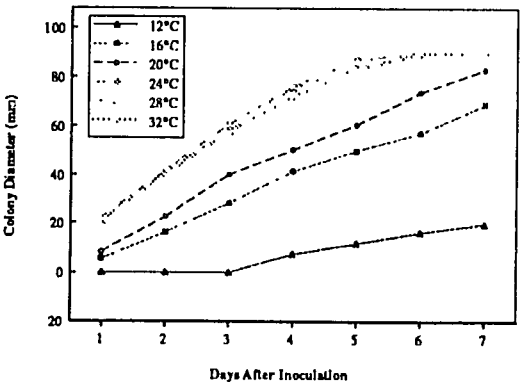

Fig. 1. Colony diameter of *Phytophthora capsici* (Pc9) grown on potato dextrose agar at six temperatures.

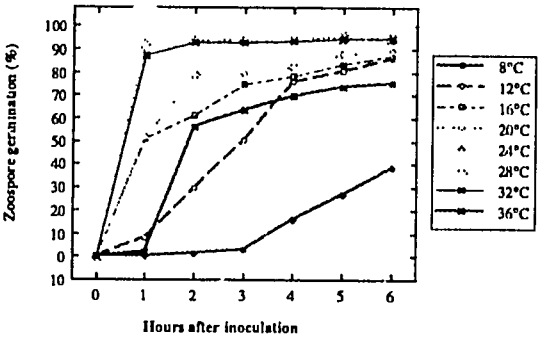

Fig. 2. Zoospore germination of Phytophthora capsici (Pc9) at eight temperatures.

Table 2. Zone of inhibition of mycelium from treated filter disks and the germination of *Phytophthora capsici* (Pc9) sporangia exposed to different concentrations of Ridomil-MZ[a].

Diluted concentration of Ridomil-MZ	Inhibition zone (mm)	Germination (%)
0	0 a[b]	83.3 a
1000	9.3 b	2.3 b
800	11.3 c	2.6 b
600	13.0 d	2.8 b
400	13.3 d	3.3 b
200	18.2 e	2.3 b

[a]Means based on 10 plates per concentration (replication) on potato dextrose agar 5 days after inoculation.
[b]Means with the same letter in the same column are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.
[c]Means based on six replications of 200 zoospores per concentration on water agar disks after 4 hours of incubation.

Protection of inoculated tomato leaves with Ridomil-MZ. Disease severity values decreased for both species when Ridomil-MZ was applied (Table 3). Without Ridomil-MZ, the disease severity was 4.2 and 6.0 for *P. infestans* and *P. capsici*, respectively. Disease severity with any concentration of Ridomil

Table 3. Disease severity of detached tomato leaves inoculated with sporangia of *Phytophthora infestans* (Pi1) and zoospores of *P. capsici* (Pc9) after treating with Ridomil-MZ[a].

Diluted concentration of Ridomil-MZ	*P. infestans*	*P. capsici*
0	4.2[b]a[c]	6.0[c]a
1000	0.6 b	2.0 b
800	0.4 b	1.0 bc
600	0 b	1.6 b
400	0 b	1.0 bc
200	0 b	0 c

[a]Based on 0-6 assessment scale.
[b]Means based on five leaves at each concentration and of each inoculum.
[c]Means with the same letter in the same column are not significantly different ($P = 0.05$) according to Duncan's new multiple range test

was below 2.0. The curative effect of Ridomil was most effective when applied to leaves 1–2 days after inoculation (Table 4). There was little effect when applied 4 days after inoculation.

Table 4. Disease severity of detached tomato leaves inoculated with sporangia of *Phytophthora infestans* (Pi1) before treating with Ridomil-MZ[a].

Diluted concentration of Ridomil-MZ	4 days before Ridomil-MZ spray	2 days before Ridomil-MZ spray	1 day before Ridomil-MZ spray
0	(2.2)[b] 6.0 a[c]	(0) 6.0 a	(1.0) 5.6 a
1000	(2.2) 5.8 a	(0) 3.0 b	(1.0) 2.8 b
800	(2.2) 5.8 a	(0) 3.2 b	(1.0) 3.4 b
600	(2.2) 5.6 ab	(0) 2.6 bc	(1.0) 2.8 b
400	(2.4) 5.0 b	(0) 2.2 bc	(1.0) 2.4 b
200	(2.4) 5.4 ab	(0) 1.8 c	(1.0) 2.4 b

[a]Based on 0–6 assessment scale.
[b]Parenthesized means were severity ratings before Ridomil-MZ spray
[c]Means with the same letter in the same column are not significantly different ($P = 0.05$) according to Duncan's new multiple range test

In this study, the two species (*P. capsici* and *P. infestans*) were readily distinguished by morphological characteristics. *P. capsici* had a broad temperature range for mycelial growth and zoospore germination. The use of Ridomil-MZ was effective in controlling the disease, but it had little curative action if applied too late.

Virulence of *Pseudomonas solanacearum* and Screening Tomatoes for Resistance to Bacterial Wilt

Summary

Bacterial wilt is a major constraint to production of tomatoes in the tropics. In this study, strains of the bacterium were compared using different inoculation techniques to various tomato lines. Twelve strains of *Pseudomonas solanacearum* were inoculated by stabbing infested toothpicks into leaf axils or by drenching soil with inoculum on four tomato lines. Strains varied in their virulence as lines differed in the incidence of wilt. Strain Ps04 caused 38% wilt averaged over all lines when soil-drenched, whereas Ps40 caused only 1% wilt. Toothpick-stabbing caused more plants to wilt than soil-drenching. Tomato L285 had the fewest wilted plants against most of the strains; however, there was a significant interaction between lines and strains. Using 30-day old tomato plants, four methods of inoculation caused different levels of wilt. Leaf-clipping and stem inoculations caused more wilt than soil-drenching. On a susceptible line (L390), all inoculation methods caused over 90% wilt whereas L285 had 23% wilt when soil was drenched, but had 80% wilt when plants were clipped with infested scissors. In another experiment, 30 commercial or breeding lines were inoculated either by toothpick-stabbing or by soil-drenching. Lines that were known to be susceptible in field tests (previous reports) were also susceptible using both methods. Most of the resistant and moderately resistant lines were susceptible in at least one of the inoculation methods. In a test designed to evaluate tomatoes and wild relatives of tomato, several entries had less than 20% wilt when plants were inoculated by soil-drenching.

Introduction

Tomato is the most commercially important vegetable crop throughout the world. It is used for fresh market and processing. Bacterial wilt, caused by *Pseudomonas solanacearum*, infects plants through the roots and causes drooping of the lower leaves followed by wilting of the entire plant. The disease has been reported to cause complete crop loss in tropical regions. In Taiwan, the disease was reported to cause 29% loss in fresh market hybrid tomatoes. The disease is widespread in the hot tropics and subtropics. Low-temperature strains have also been reported.

Screening tomato lines to assess bacterial wilt resistance continues in many countries. However, cultivars selected for resistance in one geographic area may show little or no resistance when grown in other areas. It is likely that the selection of resistant lines only against local strains is not effective for developing resistance to many strains that occur over a wide geographic area. AVRDC has mainly used field screening to evaluate resistance which generally requires much labor and field space and also is dependent on predominant strains, population levels of the pathogen in the soil, and on environmental conditions during the selection period. In the greenhouse, it is possible to control some of these conditions to a considerable extent, and it also allows for more repeatable results throughout the year.

The objectives of these experiments were to detect variation in virulence of strains of *P. solanacearum* based on several inoculation techniques and to screen tomatoes for resistance to bacterial wilt.

Materials and Methods

Virulence of strains. Twelve strains of *P. solanacearum* collected from seven different host plants were removed from distilled water, spread on 523 medium, and incubated for 24 hours at 32°C. Seeds of L285 (resistant), BL341 (resistant), CL143 (CL143-0-10-3-0-1-10, resistant), and L390 (susceptible) were directly sown in soil into 9-cm plastic pots in the pipehouse, and inoculated when 30 days old either by toothpick-stabbing or soil-drenching. Toothpick ends were rubbed on colonies and inserted into stems at the axil of the third fully expanded leaf from the top of plants. Toothpicks were left in this position throughout the experiment. Soil was drenched with 30 ml/pot of a bacterial suspension adjusted to about 10^8 cfu/ml. After inoculation, plants were placed in a heated greenhouse at 30°C. Ten plants of each variety were inoculated with each of the strains in two replications. Wilt was assessed every other day beginning at 3 days and continuing to 15 days after inoculation. Wilt was rated using the following scale: 1 = no symptom, 2 = inoculated leaf wilted, 3 = two or three leaves wilted, 4 = four or more leaves wilted, and 5 = plant dead. Plants were also rated based on percentage wilt. Data were analyzed by ANOVA and means separated by LSD.

Inoculation methods. Inoculations using infected toothpicks, leaf clipping by infected scissors, and soil-drenching with and without wounding roots were evaluated on lines L285, CL143, and L390. Toothpick-stabbing was done as previously described. Leaves of plants were clipped with a pair of scissors dipped in a bacterial suspension of 10^8 cfu/ml. Soil was drenched by pouring 30 ml of inoculum around the base of the seedling using 10^7, 10^8, and 10^9 cfu/ml. Each treatment had 10 plants and three replications arranged in a randomized complete block design. Data on the number of plants wilted were recorded 7 and 14 days after inoculation.

Evaluation of 30 lines. Seeds were sown as described above and inoculated either by soil drenching or toothpick-stabbing. There were 10 plants per treatment with two replications arranged in a randomized complete block design. Data were recorded as previously described.

Evaluation of cultivated and other *Lycopersicon* species. Seeds of wild *Lycopersicon* species, selected entries from Bulgaria and the Philippines, and check lines L285, L390, and CL143 were sown in 9-cm diameter pots on 1 February 1991. Ten plants of each entry were inoculated by either toothpick-stabbing or by soil-drenching as previously described. Plants were rated at regular intervals to record wilt. Data were analyzed as previously described.

Results and Discussion

Virulence of strains. All 12 strains caused wilt on at least one of the four lines. In general, tomato strains were more virulent compared to strains from other hosts except the pepper strain which ranked third in virulence overall (Table 5). On the average, strain Ps04 caused the most wilt (38%) when plants were inoculated by soil-drenching, while Ps60 resulted in the highest wilt incidence (60%) when toothpick-inoculated (Table 6). On the average, for all strains, toothpick-stabbing caused 34% wilt which was significantly greater than the 22% for soil drenching (Table 6); however, the disease index as well as the percentage wilt did not significantly differ on susceptible lines between the two methods of inoculation. L390 was most susceptible with 52 and 50% wilting over all strains and inoculation methods, respectively. L285 was most resistant with 5 and 19% wilt for drenching and toothpick, respectively. The other two lines

were intermediate. The progress of wilt and the disease index of the four lines were similar and L285 had the lowest ratings. Strain Ps04 was the most virulent and the disease progress in L390 either inoculated with toothpick or by drenching was greater than in L285 (Fig. 3). In general, strains that caused low wilt in L390 also caused low wilt in the other lines. The virulence of strains varied by line and some strains like Ps4 and Ps32 showed an interaction with the lines while other strains did not (Fig. 4).

Table 5. Strains of *Pseudomonas solanacearum* isolated from various host plants in Taiwan with ranking of virulence based on average ranks of wilt using two inoculation methods and four tomato lines[a].

Strain	Host plant	Location	Rank
Ps 04	Tomato	AVRDC	1
Ps 07	Tomato	Hsinyi	5
Ps 27	Potato	Sir Tze	10
Ps 29	Eggplant	Pingtung	8
Ps 32	Tomato	Taipei	7
Ps 36	Peanut	Wu Feng	9
Ps 37	Perilla	Miaoli	11
Ps 40	Bird of Paradise	-[b]	12
Ps 43	Tomato	Sanhsing	4
Ps 51	Tomato	Taitung	6
Ps 60	Tomato	Tainan	2
Ps 71	Pepper	Linnei	3

[a]Ten plants of L285, BL341, CL143, and L390 were inoculated by toothpick-stabbing or soil-drenching in three replications.
[b]Not known.

Table 6. Mean percentage wilt and disease index of four tomato lines inoculated with 12 strains of *Pseudomonas solanacearum* by soil-drenching and toothpick-stabbing[a].

	Drenching		Toothpick	
Isolates	Wilt (%)	Disease index[b]	Wilt (%)	Disease index
Ps 04	38.0	2.4	52.9	3.0
Ps 07	24.3	1.9	35.4	2.4
Ps 27	13.7	1.5	17.5	1.7
Ps 29	32.0	2.2	18.7	1.6
Ps 32	20.7	1.7	42.0	2.5
Ps 36	17.0	1.6	22.5	1.8
Ps 37	5.9	1.2	16.8	1.9
Ps 40	1.1	1.0	0.9	1.0
Ps 43	32.1	2.2	42.1	2.7
Ps 51	23.9	1.9	47.8	2.7
Ps 60	31.0	2.2	59.3	3.3
Ps 71	29.3	2.0	51.8	2.9

[a]Ten plants of L285, BL341, CL143, and L390 were inoculated either by toothpick-stabbing or by soil-drenching in three replications.
[b]1 = no symptom, 2 = inoculated leaf wilted, 3 = two or three leaves wilted, 4 = four or more leaves wilted, and 5 = plant dead

By testing many strains of the bacterium, the virulence ranged from causing a low to high percentage of wilt even on the most resistant line (L285) when stabbed with an infested toothpick. Because the toothpick inoculation caused high levels of wilt in L285, this method may be too rigorous and results may differ from those obtained from soil drenching or under field conditions. Strains from tomato were more virulent, which seems to indicate that there may be some generic specificity with regard to strain preferences for causing wilt of tomato. It also was noted that even within strains collected from tomato, there was a degree of variability in virulence. It seems that not only the original host is important in determining virulence of strains but also the geographic origin of the strain. Because of this variation in virulence, resistance screening should be done with many strains so that selection of resistant sources would most likely have resistance to a wide range of strains.

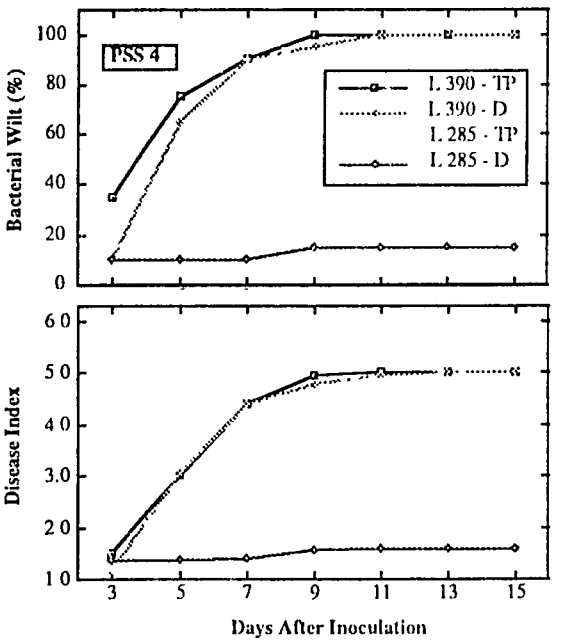

Fig. 3. Percentage wilt and disease indexes of two tomato lines inoculated using toothpick (TP) or soil drench (D) with strain Ps04 of *Pseudomonas solanacearum* over 15 days.

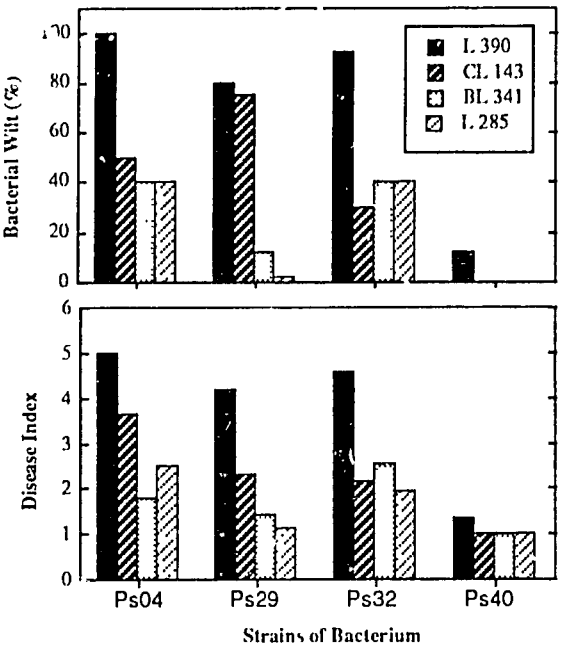

Fig. 4. Percentage wilt and disease indexes of four tomato lines inoculated with four strains of *Pseudomonas solanaearum* 15 days after inoculations.

Testing of inoculation methods. The three lines tested over four inoculation methods averaged 42, 42 and 96% wilt for L285, CL143, and L390, respectively (Table 7). Averaged over lines, leaf clipping caused significantly more wilt than the other methods which did not significantly differ from each other. There was a significant interaction between the inoculation method and host lines. L390 had more than 90% wilt regardless of the inoculation method whereas L285 had 80% wilt when plants were clipped and 23–37% for other inoculation methods. There was no significant difference between 7- and 14-day assessment of wilt or on the different concentrations used in drenching. Over all lines and methods, a concentration of 10^9, 10^8 and 10^7 cfu/ml caused 46, 44 and 38% wilt, respectively.

Table 7. Percentage wilt of three tomato lines inoculated with *Pseudomonas solanacearum* by four methods

Inoculation method[a]	L285	CL143	L390	Average
Leaf clip	80 0	78.3	100	86.1
Toothpick	36.7	55 0	95	62.2
SD + wounding	28 3	11.7	100	46 7
SD - wounding	23 3	21 7	90	45 0
Average	42 1	41.7	96	
CV[b]	45.0	48 0	10	43 0
LSD[c]	32.7	34 1	N.S.[d]	42 2

[a]Leaf clip = cutting leaves with infested scissors, toothpick = stabbing stems; SD + wounding = soil drench with root wounding; and SD - wounding = soil drench without wounding.
[b]Coefficient of variation
[c]Least significant difference
[d]Not significant.

Evaluation of 30 lines. Of the 30 lines tested, BL 341 and CL9-0-0-1-3 had the lowest wilt (25%) when inoculated by drenching (Table 8). These same lines had 50 and 100% wilt when inoculated by the

Table 8. Percentage wilt of tomato lines inoculated with *P. solanacearum* using two methods and rated 7 and 14 days after inoculation (ODI)[a].

Line	Toothpick		Soil drenching	
	7 DAI	14 DAI	7 DAI	14 DAI
CL9-0-0-1-3	75	100	10	25
BL341 (L285)	40	50	25	25
BL315	35	50	15	35
BL323	60	80	10	40
BL328	40	55	20	40
BL336	65	90	10	40
CLN475 $BGF_2$265-12-9-1	40	60	30	45
CL143-1-10-3-0-1-10	65	85	25	50
L387	80	100	30	55
BL332	70	100	30	55
BL330	60	80	35	55
BL350	20	55	50	60
BL342	40	70	30	60
BL355	55	80	10	60
CLN475 $BGF_2$265-4-19	30	70	50	65
TN-2	100	100	10	65
CLN698 $BGF_2$358-4-13	35	40	35	70
CLN65-349-0-5-2-0	20	30	45	80
CLN659 BGF_2-274-0-15-045	80	60	80	80
CLN399-2-6	55	85	15	85
TN-3	55	90	10	85
BL437	75	85	55	90
L4783	100	100	65	95
BL351	55	90	95	100
L283	100	100	60	100
TK70	100	100	75	100
W82	30	30	95	100
PETO 86	100	100	30	100
CL5915-153-3-3-0	100	100	25	100
L390	100	100	65	100
Average	61.5	80.8	37.3	68.7
CV[1]	34.0	22.0	30.0	16 0
LSD[2]	26.1	32.1	39.6	59.6

[a]Coefficient of variation.
[b]Least significant difference.

toothpick method. CLN 349-0-5 and CLN 698 BGF_2-358-4-13 had 30 and 40% wilt, respectively, which was the lowest for the toothpick method. The same lines had 80 and 70% wilt, respectively, when soil-drenched. There was a significant difference between the lines with regard to wilt after drenching (Table 8). After 7 days, an average of 37% of plants wilted while at 14 days 69% wilted. Significant differences were also apparent between lines at 7 days (62%) and at 14 days (82%) using the toothpick method. There was a significant positive correlation in wilt between the two methods, although the correlation coeffecient was quite low (r = 0.32).

Evaluation of cultivated and other *Lycopersicon* species. The overall wilt when plants were inoculated by toothpick stabbing was 72% while wilt was 54% when plants were inoculated by soil drenching. The resistant checks, L285 and CL143 respectively, had 25 and 60% wilt when toothpick-inoculated and 0 and 15% wilt when soil was drenched. A few lines like L00141, LCH267, Marikit, TmL114-42-N.H.T.P. Early, and TmL46-N-12-N Early HR had less than 20% wilt when drench-inoculated.

Stem and leaf-clipping inoculation methods are often considered to be too severe to differentiate host resistance. In these experiments, resistant lines inoculated by the toothpick method ranged from susceptible to moderately resistant and had a higher percentage of wilt than when inoculated by soil drenching. The methods used in this study clearly differentiate susceptible types but do not always differentiate the reported resistant types. It may be advisable to select resistant types using a soil drench method over several inoculum doses ranging from high to medium concentrations under controlled environmental conditions.

Tomato Physiology

Membrane Thermostabilities, Pedicel Abscissions, and DNA Polymorphisms as Markers of Heat Tolerance in Tomato

Summary

Fruit setting rate, heat injuries in anthers, pistils and leaves, and in vitro pedicel abscission of heat-tolerant CL 5915-153 and its double cross parents, and two each of the breeding lines and accessions were evaluated under hot field-growing conditions. CL 5915-153 had the highest fruit-setting rate. Both anthers and pistils of CL 5915-153 were least injured by high temperature. In vitro pedicel abscission was also low in heat-tolerant CL 5915-153 as well as heat-sensitive L 123. Results suggest that the membrane thermostability of floral parts may constitute important factors in determining heat tolerance in tomato, and the buildup of these desirable traits in CL 5915-153 could be cumulative. Furthermore, electrolyte leakage as a method of screening genotypes that perform well under high temperature conditions should focus on reproductive tissues rather than on leaf tissues.

The feasibility of detecting DNA polymorphisms based on the amplification of random DNA segments from CL 5915-153 and its double cross parents with four primers of arbitrary 17 base pair oligonucleotide sequence is also being tested. The number of fragments amplified and polymorphisms were similar among CL 5915-153 and its four parents. However, bands at 7.5 and 3.0 kb with M13 primer were observed in heat-tolerant CL 5915-153. None of these bands were observed in its parents. With KS17 primer, one band located between 6-5 kb was found in all entries except CL 949. The other bands > 7 kb were found only in CL 1131-38, CL 1131-43, and L 123. Results thus far suggest that DNA polymorphism between the progeny and its parents may represent DNA rearrangements.

Introduction

Heat tolerance of tomato depends on the ability of pollination, fertilization and fruit development under high temperature conditions. When a flower fails to be pollinated and/or fertilized, it triggers the formation of abscission zone in the pedicels. Some heat-tolerant tomatoes could produce viable pollens, and maintain viable pistils at high temperatures, and have a strong tendency to retain their pedicels with or without removal of floral organs. However, the mechanism of maintaining heat tolerance of these floral parts is still not clear. Based on the leakage of electrolytes, the leaf of heat-tolerant L 3958 (Saladette) was reported to possess a relatively high level of heat tolerance (Chen et al. 1982). Since the heat tolerance on leaf cannot be properly attributed to the fruit-setting process, the present study was conducted to compare: 1) thermostabilities of leaves, anthers and pistils, and 2) pedicel retention under in vitro conditions of a heat-tolerant breeding line and its parents grown under hot summer conditions. Both membrane thermostability and pedicel abscission have been previously suggested as physiological markers for heat-tolerance selections.

In connection with markers, DNA markers that are shown to be linked to traits of interest have wide use besides screening, such as trait introgression in breeding programs and gene cloning. DNA markers most commonly used are restriction fragment length polymorphisms (RFLP). However, detection of RFLPs by Southern blot hybridization is laborious. A simple process of polymerase chain reaction (PCR), which is based on the amplification of random genomic DNA segments with single primers of arbitrary nucleotide sequence, has been proposed and named as random amplified polymorphic DNA (RAPD). The study was also conducted to investigate the polymorphism of DNAs from CL 5915-153 and its four parents with this RAPD assay. The purpose was to examine the possible linkage between DNA polymorphism and heat tolerance in tomato.

Materials and Methods

Seedlings of a heat-tolerant breeding line CL 5915-153D_4-3-3-0 (CL 5915-153), and its parental lines, CL 1131F_5-0-0-38-4-0 (P_1, CL 1131-38), L 127 (P_2), L 387, CL 9-0-0-1-3 (P_3, CL 9), CL 949-0-8 (P_4, CL 949), and L 123, CL 1131F_5-43-8-1 (CL 1131-43) and CL 5915-206D_4-2-2-0 (CL 5915-206), were sown and transplanted to the field on 19 July and 22 August 1991, respectively. An RCBD with four replicates was used. During the growing period, plants were subjected to mean maximum/minimum temperatures of 31.9/24.8°C.

On 15 October 1991, open flowers and the third expanded leaves from the top were harvested to determine membrane thermostabilities. Floral anthers and pistils were separately collected. Leaf discs were excised with a cork borer and rinsed with at least three changes of distilled water. Ten to 12 anthers and pistils and 20 leaf discs were placed in test tubes with 10 ml of deionized water and incubated at 25°C for 20 min and then measured with conductance, thermostated at 50°C for 20 min, then cooled to 25°C before measuring conductance of electrolyte leakage, and finally boiled for 30 min, cooled to 25°C and the conductance measured again. There were four replicates for each measurement. The relative injury of the membrane was assessed from the equation of percent injury = $[(R_2-R_1)/(R_3-R_1)] \times 100\%$, where R_1 = reading with 25°C, R_2 = reading with 50°C, and R_3 = reading with boiling.

On 17 October 1991, open flowers with pedicels were collected from the field. They were sterilized in 0.1% HgCl for 5 min and washed with sterilized water three times. Flowers were cut at the base of the calyx in a laminar-flow cabinet, and the pedicel removed. The pedicels were then transferred aseptically to a modified MS medium containing 10% sucrose and 0.8% agar in petri dishes (ID 10 cm) which were placed in an incubator at 26°C. Every entry had three replicates which contained 20 pedicels each. Pedicel retention rate was determined on the basis of pedicels without discolored abscission zone after initial culturing.

The young leaves of CL 5915-153, its four parents, and two each of the breeding lines and accessions were frozen in liquid nitrogen, and then extracted for DNA. Amplification reactions were performed with about 100 ng template DNA in 100 ml reagent. Amplification was performed by PHC Programmable Dri-Block Temperature Cycler, through two programs: 1) 5 min at 94°C, 5 min at 40°C and 5 min at 72°C for 3 cycles, and 2) 1 min at 94°C, 1 min at 50°C and 1 min at 72°C for 41 cycles. Amplification products were analyzed by electrophoresis in 2% agarose gel, and detected by staining with ethidium bromide (500 ng/ml).

Results and Discussion

The heat-tolerant breeding line CL 5915-153 had the highest fruit-setting rate among nine entries investigated, whereas one of its double cross parents, CL 949, and the heat-sensitive control, L 387, had the lowest fruit setting rates under hot, field-growing conditions (Table 1). Another heat-tolerant breeding line, CL 5915-206, had a comparative fruit-setting rate with CL 5915-153, whereas three double cross parents of CL 5915-153 had intermediate levels of fruit-setting rates.

Table 1. Heat injuries of leaves, anthers and pistils, and fruit setting (%) rates of tomato grown under hot conditions.

Entry	Fruit set	Leaves	Anthers	Pistils
CL 5915-153	37 2 a[a]	33 7 cd	16 6 f	33 4 e
CL 1131-38 (P_1)	22 2 bc	44 1 b	35 2 d	49 8 bc
L 127 (P_2)	15 6 c-e	64.4 a	40 4 cd	46 9 b-d
CL 9 (P_3)	19 5 cd	42 4 bc	35 9 d	46 7 b-d
CL 949 (P_4)	9 4 ef	39 6 bc	45 2 bc	47 9 b-d
CL 1131-43	21 7 bc	29 3 d	24 2 e	42 0 de
CL 5915-206	28 8 ab	35 0 b-d	25 4 e	39 8 de
L 123	12 8 de	40 3 bc	68 9 a	64 6 a
L 387	4.9 f	40 2 bc	50 8 b	51 7 b

[a]Mean separation within columns by Duncan's multiple range test at the 5% level

It had been suggested that the tomato acquired heat tolerance because of leaf-heat acclimation(Chen et al. 1982). In this connection, leaf tissues from a heat-tolerant breeding line CL 1131-43 had the least heat injury (Table 1). Two other heat-tolerant breeding lines, CL 5915-153 and CL 5915-206, also had comparative levels of leaf tissue heat injuries with CL 1131-43. One of the double cross parents of CL 5915-153, L 127, had the highest heat injury, whereas the other three parents had intermediate levels of heat injury.

Since the poor fruit setting is the major constraint of heat stress on the tomato plant, heat acclimation in the floral organ could be more important than the leaf. Indeed, both anthers and pistils of heat-tolerant CL 5915-153 had the least heat injuries among nine entries examined. Fewer heat injuries in anthers and pistils under heat stress could be attributed to their membrane thermostabilities. Furthermore, pistils of another two breeding lines, CL 1131-43 and CL 5915-206, had comparative levels of heat injuries with CL 5915-153. Anthers and pistils of all four parents of CL 5915 had higher heat injuries than those of their heat-tolerant progeny. Since floral organs were obtained from the field-grown plants under heat-stress conditions, it is likely that heat-tolerant genotypes were improved along with the enhancement of heat-tolerant anthers and pistils. Genotypes with stable reproductive membrane are desirable, especially when one considers that heat-stress development in tomato is usually sublethal and slow. In addition, different responses to heat stress of tomato floral parts of various varieties in terms of membrane thermostabilities is a useful method to screen for heat tolerance.

The flowers which fail to pollinate and/or fertilize would eventually lead to the abscission of pedicels. Data in Table 2 indicate that both heat-tolerant CL 5915-153 and heat-sensitive L 123 had a strong tendency to prevent abscission zone formation in their pedicels after 4 days of in vitro culturing with or without ABA, a hormonal promoter of abscission. Developing ovaries usually produce auxins and gibberellins after pollination/fertilization, which lead to the prevention of pedicel abscission. Results, therefore, suggest that the potential difference in pedicel abscission may be independent from the pollination and/or fertilization process. Although low abscission potential in the pedicel would be desirable, the successful fruit set under heat stress still relies on the normal process in the floral parts. The membrane thermostability of floral parts may be important determinants of heat tolerance in tomato.

Table 2. Abscission rate (%) of pedicels without floral organs of tomato after 5 days of in vitro culturing with or without ABA (50 ng).

Entry	Control	ABA
CL 5915 153	40 0 b*	65 0 b
CL 1131-38 (P_1)	47 5 ab	85 0 ab
L 127 (P_2)	52 5 ab	82 5 ab
CL 9 (P_3)	52 5 ab	87 5 a
CL 949 (P_4)	55 0 ab	90 0 a
CL 1131-43	40 0 b	80 0 ab
CL 5915-206	45 0 ab	75 0 ab
L 123	35 0 b	60 0 b
L 387	65 0 a	92 5 a

*Mean separation within columns by Duncan's multiple range test at the 5% level

None of the four parents of CL 5915-153 did well in fruit setting rate, and in preventing heat injuries in floral parts and leaves and pedicel abscissions with their progeny. It is likely that the buildup of these desirable traits in CL 5915-153 is cumulative.

Among four short primers (17 base pairs) of arbitrary oligonucleotide tested, the annealing and extension of primer AP11 with tomato template DNA failed. However, primer SK17 successfully amplified template DNAs from four parents but failed in CL 5915-153. Template DNAs of all entries were successfully amplified with primer KS17 (Fig. 1) One band located between 6-5 kb was found in all entries except CL 949. The other bands > 7 kb were found only in CL 1131-38, CL 1131-43, and L 123. The

number of fragments amplified with primer M13 were similar among CL 5915-153 and its four parents (Fig. 2). However, CL 5915-153 showed two extra bands around 7.5 and 3.0 kb, the latter also presented in small amounts in CL 1131-38.

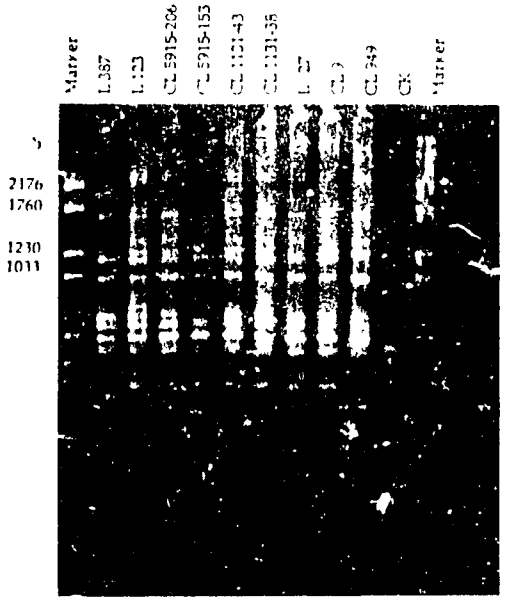

Fig. 1. Amplification of tomato DNA with KS17 primer 5'-CGAGGTCGACGGTATCG. Lines 1 to 12 (left to right): marker, L 387, L 123, CL 5915-206, CL 5915-153, CL 1131-43, CL 1131-38, L 127, CL 9, CL 949, control, and marker.

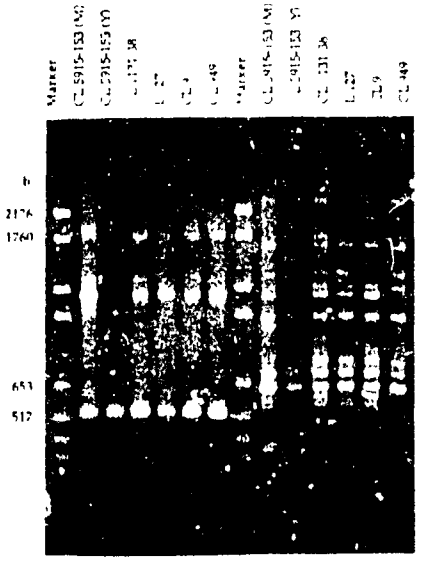

Fig. 2. Amplification of tomato DNA. Line 1, marker, lines 2 to 7 (left to right): CL 5915-153 (mature leaf), CL 5915-153 (young leaf), CL 1131-38, L 127, CL 9, and CL 949, amplified with M13 primer 5'-GTAAAACGACGGCCAGT; line 8, marker, and lines 9 to 14: CL 5915-153 (mature leaf), CL 5915-153 (young leaf), CL 1131-38, L 127, CL 9, and CL 949, amplified with KS17 primer 5'-CGAGGTCGACGGTATCG.

At present, unique bands presented in DNA polymorphisms amplified with KS17 and M13 primers are yet to be related to heat-tolerant traits of tomato, such as fruit set, membrane thermostability and pedicel abscission. However, results threw light on the potential of polymerase chain reaction with random primers to find DNA polymorphisms.

Activities and Polymorphisms of Alcohol Dehydrogenase in Tomato Roots

Summary

Seven accessions and breeding lines of flooding tolerant and sensitive tomatoes were investigated for their ADH activities and its isozymatic patterns, along with patterns of peroxidase and glutamic-oxaloacetic transaminase, under flooding/anaerobic conditions. L 123 was identified as being more flooding-tolerant than L 4650. Flooding/anaerobic stress resulted in high ADH activities in flooding-sensitive L 883; this could be attributed to ADH-2. Extra four bands of glutamic-oxaloacetic transaminase were also expressed in flooding-sensitive L 883.

Introduction

Flooding is one of the major constraints in tomato production in the tropics. Anaerobic conditions induced by flooding can cause a switch from aerobic to anaerobic metabolism with the consequent production of ethanol, which is being associated with increased alcohol dehydrogenase (ADH). Some flooding-tolerant species can switch from ethanol to malate. ADH also exists in multiple forms in some plant species and expresses differently under flooding conditions. This study aims to investigate any possible relationship between ADH activities and isozymatic patterns, along with other isozymes, with flooding tolerance of tomato plants grown under flooding/anaerobic conditions.

Materials and Methods

Seeds of L 123 (Taku-3, identified as flooding-tolerant at AVRDC), L 125 (Divisoria-2), L 387, L 883 (PI 128644, *L. peruvianum* var. *dentatum*), L 4650 (PI 406966, identified as flooding-tolerant at Purdue University), FMTT 3, and two isogenic lines of indeterminate (CL 6046 BC_5-F_1-22-6-5) and determinate (CL 6046 BC_5-F_1-22-6-9) tomatoes were sown weekly in seedling flats with rock wool from 28 May to 22 July, 1991. After germination, seedlings were transplanted to black perforated plastic pots (ID 3 cm), then fixed to polystyrene containers filled with aerating nutrient solution. The level of nutrient solution were maintained at 1 cm above the joint of root and stem by adding nutrient solution. Portions of seedling, on the other hand, were transplanted to plastic pots (ID 6 cm) that contained smoldered rice husks at one plant per pot.

There were six treatments: 4 weeks of aeration; 3 weeks of aeration, then 1 week of nonaeration; 3 weeks of nonaeration, then 1 week of aeration; 4 weeks of nonaeration; 4 weeks planted in soil; and 3 weeks planted in soil then flooded 1 week. All treatments were terminated at 4 weeks after sowing. There were three replicates/treatment and three plants/replicate.

After treatments, root tissues from three plants of each replicate were combined for fresh weight measurements, and extractions of enzymes. Root tissues were crushed and extracted with buffer (0.1 M Tris, 0.1% 2-ME, 5 mM DTT, 2% PVP-CO, 1 mM Na-EDTA, 10 mM KCl, 10 mM $MgCl_2$, $6H_2O$, 5% Glycerol), then centrifuged at 11,000 g at 4°C for 20 min. The supernatant was collected for activity of alcohol dehydrogenase (ADH). Isozymes of ADH, peroxidase (PRX) and glutamic-oxaloacetic transaminase (GOT) were analyzed on polyacrylamide gel electrophoresis (PAGE), and malate dehydrogenase (MDH) and PRX on starch gel electrophoresis.

Results and Discussion

When overall data on varieties were combined, ADH activities were shown to be highest when plants were flooded at 3 weeks after planting (Table 3). No significant differences in ADH activities were found

among nonflooding in the soil, unaerated hydroponics and aerated hydroponics. On the contrary, the flooding treatment had the lowest root fresh weight. High ADH activities in the flooding treatment could lead to the accumulation of a high ethanol concentration, which subsequently damages the tissue.

Unaerated hydroponic treatment resulted in increased root fresh weight (Table 3). This could have been due to the buildup of acclimation in the root tissue under prolonged unaerated conditions. Furthermore, tomato plants usually produced adventitious roots under anaerobic conditions, which involve stimulation of preformed root initials. The increase in root fresh weight in unaerated hydroponics could be related to the fact that more adventitious roots were formed.

Table 3. Root growth and ADH activity in hydroponic or soil-grown tomato.

Treatment	Root fresh weight (g/plant)	ADH (mm/min/g)
Aerated hydroponic	1 37 b[a]	78 9 b
Unaerated hydroponic	2 82 a	100 2 b
Nonflooded in soil	1 22 b	118 9 b
Flooded in soil	0 26 c	454 5 a

[a]Mean separation within columns by DMRT at the 5% level

L 123, a flooding-tolerant accession from a previous screening at AVRDC, had the highest root fresh weight but the lowest ADH activity with 4 weeks of continuous unaeration, or flooding for 1 week at 3 weeks after planting. Under the same condition, L 883, screened as a flooding-sensitive accession at Purdue University, had the lowest root fresh weight but the highest ADH activity. Based on root fresh weight and ADH activities, L 123 appeared to be more flooding-tolerant than L 4650, which was also identified as flooding-tolerant at Purdue University, as well as other indeterminate tomatoes, such as CL 6406 and FMTT 3. Previously L 123 and L 4650 characterized as possessing some degree of flooding tolerance, generally were found to produce more aerenchyma (greater porosity), which supply oxygen to the root system and prevent the buildup of ADH activities (Table 4).

Table 4. Root growth and ADH activity in aerated hydroponic or flooded soil-grown tomato.

Treatment/Entry	Root fresh weight (g/plant)	ADH (mm/min/g)
Unaerated hydroponic		
CL 6406 (Ind)	3 3 de[a]	78.8 b
CL 6046 (D)	3.7 ab	78.0 b
L 123	3.8 a	65.9 b
L 125	3.2 a-c	61.4 b
L 387	2.2 c	80 1 b
L 883	0.5 d	275 0 a
L 4650	3.3 ab	80 6 b
FMTT 3	2.6 bc	81.1 b
Flooding in soil		
CL 6406 (I)	0 1 de	589.0 b
CL 6046 (D)	0.1 de	430.0 bc
L 123	0.7 a	89.5 c
L 125	0 1 de	474 4 bc
L 387	0.2 cd	245.3 bc
L 883	0.0 e	1451.4 a
L 4650	0.4 b	139.8 c
FMTT 3	0.4 bc	184 2 bc

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

No distinct ADH isozymatic polymorphisms were found on the PAGE, except ADH-2 (Rf = 60) that was expressed among all varieties and treatments. Therefore, it is likely that in the present experiment, there is no involvement of ADH isozymatic patterns for differential adaptation of tomatoes to flooding or

anaerobic conditions. However, ADH-2 showed high density from the tissue that has been subjected to anaerobic or flooding stress (Fig. 3). ADH-2 appears to be inducible under anaerobic stress.

Polymorphisms of peroxidase were found on the PAGE; there were four major groups, namely PRX-1 (Rf = 87), PRX-2 (Rf = 82, 79, 76, and 74), PRX-3 (Rf = 67, 63, and 60), and PRX-4 (Rf = 47 to 19). However, no clear distinction in patterns was found among varieties and treatments (Fig. 4). Like ADH, it is likely that there is no involvement of peroxidase isozymatic patterns for differential adaptation of tomatoes to flooding or anaerobic conditions.

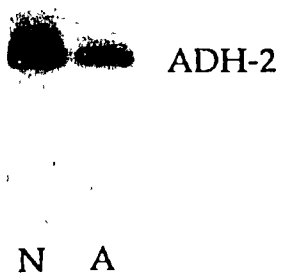

Fig. 3. ADH isozymatic patterns of tomato (L 123) root. N: nonaeration; A : aeration.

Fig. 4. Peroxidase isozymatic patterns of tomato root. N: nonaeration; A: aeration.

Two flooding-tolerant entries, L 123 and L 4650, had similar, single band of GOT at Rf = 32 on the PAGE (Fig. 5). However, flooding sensitive L 883 had four distinct bands of GOT at Rf = 39, 37, 34, and 32. Both bands at Rf = 37 and 34 in L 883 dwindled, but Rf = 39 increased under anaerobic stress. GOT is known to play a role in transamination reaction leading to the elimination of nitrogen from amino acids and the formation of keto acids for the TCA cycle; however, its role in the anaerobic response remains to be seen.

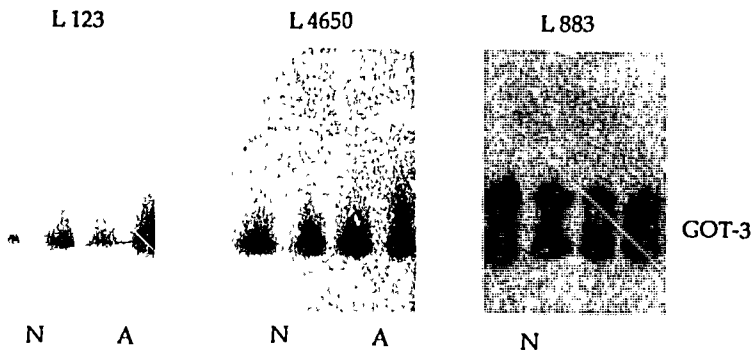

Fig. 5 . Glutamic-oxaloacetic transaminase isozymatic patterns of tomato root. N: nonaeration; A: aeration.

Tomato Virology

Cucumber Mosaic Virus and Leaf Curl Virus

Summary

The nonpersistently aphid-transmitted cucumber mosaic virus and the whitefly transmitted leaf curl virus are important viruses in the tropics and subtropics. Control by chemicals and management is not effective and good resistance sources are not yet available in the cultivated tomato. In 1990 two *Lycopersicon hirsutum* accessions were found with a high percentage of resistant plants. In a second and third screening from seeds of individual resistant plants, the resistance was confirmed in several seedlots. These lines have been passed to the AVRDC breeders. Several TLCV-resistant/tolerant populations received from INRA France have been screened by grafting, and seeds of resistant plants were returned to INRA to further advance the populations.

Lycopersicon pennellii, a source of resistance to the aphid vector of CMV, and crosses with AVRDC tropical tomato lines, were also investigated. In an aphid-feeding study lower total probe number on *L. pennellii* as found by Cornell University researchers was confirmed. However, the percentage of time probing could not be confirmed. The total probe times were lower in *L. pennellii* than in *Lycopersicon esculentum*. The time to first probe was found extremely variable but not higher in *L. pennellii*. The same lines were also tested in the field where it was observed that the rate of CMV infection was significantly higher in the *L. pennellii* × *L. esculentum* crosses than in the *L. esculentum* parent.

Introduction

Both the aphid-transmitted cucumber mosaic and the whitefly-transmitted leaf curl virus are important diseases in the tropics and subtropics, causing substantial losses in the tomato crop. CMV is a nonpersistently aphid-transmitted virus and thus very difficult to control by insecticides. Resistance in cultivated tomato is not available. Resistance in wild types is suspected but systematic screening of these for CMV resistance has never been conducted. At AVRDC systematic screening of the germplasm collection and of some lines with suspected resistance has been conducted for several years. Recently, three wild types were found with a high percentage of resistant individuals.

The wild tomato species *Lycopersicon pennellii* is considered a potential source of resistance to many arthropod pests of tomato, including aphids, spider mites, whiteflies and fruitworms. Recent studies on aphid feeding have shown an increase in preprobe time and a decrease in the number of probes and in the total time spent in probing *L. pennellii* relative to tomato[1]. This behavior, which may prove useful in developing resistance to aphid-transmitted viruses, is related to the exudation of glucose esters from type IV trichomes, which are absent in the cultivated tomato. The delay in the time to first probe is expected to be of practical significance in reducing the rate of nonpersistent virus transmission, because in many cases an aphid is only viruliferous for a few minutes after acquiring the virus.

Although leaf curl virus has been isolated from tomato in Taiwan, it is not of economic importance as it is in the Near East and certain regions of Africa and Asia, where the whitefly vector is abundant. Various control measures, including chemicals, biological control and intercropping have failed so far in providing effective control. Two research groups (one led by Dr. H. Laterrot at INRA, France, and the other

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[1] Goffreda, J. C., Mutschler, M. A., Avé., D. A., Tingey, W. M. and Steffens, J. C. 1989 J. Chem. Ecol., 15(7), 2135-2147.

by Drs. Pilowsky and Cohen at the Volcani Center, Israel) have been addressing resistance to leaf curl virus, the former using various wild types including *Lycopersicon hirsutum*, *L. peruvianum* and *L. pimpinellifolium*, and the latter using mainly *L. peruvianum*. AVRDC has been an active cooperator with Laterrot's group, screening their populations by grafting at AVRDC headquarters and in the field under natural epiphytotics by the Thailand Outreach Program in Bangkok.

The objectives of studies on CMV and LCV were to:

- Confirm the observations made by Goffreda et al.[2] on the feeding behavior of the potato aphid *Macrosiphum euphorbiae* on *L. pennellii* but using *Myzus persicae*, an important vector of viruses of pepper in Taiwan, and on crosses of *L. pennellii* with AVRDC tropical tomato lines.
- To test under field conditions the usefulness of *L. pennellii* × *L. esculentum* crosses in reducing aphid-transmitted viruses under high virus and vector pressure such as that prevailing in the tropics.
- To screen additional wild types for resistance to CMV.
- To screen Laterrot's LCV-resistant populations by grafting for resistance to the Taiwan leaf curl virus.

Resistance Screening

Materials and Methods

Screening for CMV resistance. Sixty-three lines were screened including *L. pennellii*, *S. lycopersicoides*, *S. rickii* (obtained from Dr. Rick), *L. hirsutum* and *L. peruvianum* (obtained from Laterrot, INRA France). For the first screening, 40–50 plants were inoculated with CMV isolates P and Y. For the consecutive screenings conducted on seeds of resistant plants of the first, second and third screening, the P and NT-9 isolate of CMV were used.

Plants were inoculated at the 2-leaf stage with the first virus and 2 weeks later with the second virus isolate. All plants were tested by ELISA 2 weeks after the second inoculation. ELISA negative plants were cut back above the third leaf and the new shoots were then reinoculated with a mixture of the two virus isolates. This was followed by an ELISA test 2 weeks after the inoculation. The CMV-susceptible line TK 70 was used as the check. Seeds of resistant plants were saved for confirmative screening.

Screening for leaf curl resistance. Four lines obtained from Laterrot were screened. The sandwich grafting method described in the 1986 Progress Report was followed, in which a scion of the plant to be tested was grafted onto a leaf curl-infected tomato plant. After 4 weeks, the scion was cut above the graft union and grafted to healthy *Nicotiana benthamiana*, which reacts with severe leaf curling and stunting in the presence of leaf curl virus. When *N. benthamiana* showed no symptoms, the mother plant from which the scion had been taken was saved for seed production and returned to Laterrot for further crosses.

Results and Discussion

CMV screening. The lines received from Dr. Rick had only a few seeds which were all difficult to germinate. All lines were susceptible to CMV with the exception of three lines: LA 1964 (*S. lycopersicoides*), LA 1990 (PI 255549 Mass sib) and LA 2781 (SAL 7539-7 OP) which contained some individuals in which CMV was not detected by ELISA. Unfortunately, these lines did not set fruit well under AVRDC conditions, and very few seeds were collected from individual resistant plants for confirmatory screening.

L. hirsutum seems to offer resistance to CMV, since a high number of seedlots from resistant plants of two previous screenings also proved resistant in a third screening with two different virus isolates. In contrast, the *L. peruvianum* tested, although it had a high percentage of CMV-resistant plants in the first screening, proved to be susceptible in a second and third screening. The previously observed resistance in this case may have been due to escapes.

LCV screening. Five seedlots were screened which had originated from single plants of VL 215 (*L. peruvianum* INRA selection) found resistant in a first screening by grafting at AVRDC. The resistance in

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[2] Goffreda, J. C., Mutschler, M. A., and Tingey W. M. 1988 Entomol. Exp Appl., 48, 101-107.

these five seedlots ranged from 70 to 83%. The other three lines which were screened for the first time had 43% (*L. esculentum* TY-20 F2), 53% (*L. esculentum* EC 104395) and 70% (*Pimhyrtylc*) resistant plants. Seeds of the resistant plants have been collected and returned to Laterrot for further advancement of his LCV-tolerant populations.

Evaluation of *L. pennellii* as a Potential Source of Resistance to *Myzus persicae*, the Vector of CMV

Feeding Behavior of *Myzus persicae* on *L. pennellii* and *L. pennellii* × *L. esculentum* Crosses (Laboratory Study)

Materials and Methods

Aphids (*M. persicae* Sulzer) were raised in a growth room on *N. tabacum* 'White Burley' for three generations. The growth room conditions were as follows: 26°C average temperature, 12 hours light at 5930 Lux. Alate aphids were starved for 45 min before they were transferred to the test plants. Their feeding behavior was observed for 20 min, using a magnifying lens. The following criteria were used in examining feeding behavior: time to first probe, number of probes and average duration of a probe. Probing was recognized by the antennae bent backwards along the whole length of the body. Timing was done with a hand-held stopwatch.

The following lines were used: *L. pennellii* BL 630 (a line from M. Mutschler, Cornell University through N. S. Talekar), *L. esculentum* CLN 698, CLN 5915 and CLN 65 and their F_1s. Two additional lines were included, PT 1631, the F_1 of a cross between a hairy line (2-2-2 × 1131)-15-1-0) and a normal hairy line CL1131-38-4-0 and the normal hairy parent.

Feeding behavior of aphids was monitored on three different leaves (first, second and third) of the test plants. On each leaf position 10 individual aphids were observed. There were five replications, consisting of five plants of each line to be tested. This resulted in 50 observations for each leaf position. Original data were used for comparing treatment means. To normalize the variance of the time to first probe, a logarithmic transformation was also used.

Results and Discussion

According to observations of Goffreda et al. (1989), the time to first probe was longer and the number of probes and the percentage of time probing lower in *L. pennellii* than in *L. esculentum* cv. New Yorker used in their studies. Aphid-feeding studies at AVRDC did not always agree with those of Goffreda et al. (1989). Firstly, the time to first probe was found to be highly variable, even after square root transformation (Table 1). This was evidenced by high coefficients of variation and the wide ranges in the time to first probe from 0.9 to 3.5 min in *L. pennellii*, from 0.6 to 6.0 min in *L. pennellii* × *L. esculentum* crosses and from 1.7 to 3.9 min in *L. esculentum*.

The total probe number was generally lower on *L. pennellii* than on *L. esculentum* (Table 1), which agrees with the observations of Goffreda et al. (1988). The only two exceptions were the first leaf of *L. esculentum* CLN 698 and the third leaf of *L. esculentum* CL 5915 where the total probe number was the same as on *L. pennellii*. However, on most of the F_1s the total probe time was either the same or higher than on *L. esculentum* (Table 1).

On almost all leaf positions and cross combinations tested, the percent of time probing and the total probe time was significantly higher on *L. pennellii* than on *L. esculentum*. On the F_1s the total probe time and percentage of time probing were generally between those of *L. pennellii* and those on *L. esculentum*, or similar to those on *L. esculentum* (Table 1).

Similarly, the average aphid probe duration was significantly longer in *L. pennellii* than on the other three *L. esculentum* tested (Table 1). On the F_1s the average aphid probe duration was in most cases the same as on *L. esculentum*. These findings are in contrast to those of Goffreda et al. who found that the percentage of time probing and the total probe time was lower on *L. pennellii* than on *L. esculentum*, and that the average probe duration was the same on *L. esculentum* and on *L. pennellii*.

Table 1. Aphid-feeding behavior on *L. pennellii*, *L. esculentum* and their F_1s, and on an F_1 of hairy × normal hairy *L. esculentum*.

Leaf position entry	Total probe time (sec)	Total probe no.	% of time probing	Ave. probe duration (sec)	Time to first probe (min)
First Leaf					
P_1 *L. pennellii* (BL 630)	857.5 a	8.1 b	71.5 a	111.5 a	3.5
P_2 *L. esculentum* (CLN 65)	619.1 b	9.2 ab	51.6 b	71.5 b	1.7
F_1 *Lp* × *Le* (1290)	752.1 ab	10.2 a	62.7 ab	78.9 ab	2.6
CV	18.0	16.3	18.1	33.3	90.4
Second Leaf					
P_1 *L. pennellii* (BL 630)	907.8 a	7.8 c	75.4 a	121.3 a	0.9 b
P_2 *L. esculentum* (CLN 65)	458.9 b	9.4 b	38.2 c	50.1 b	2.6 a
F_1 *Lp* × *Le* (1290)	607.3 c	11.2 a	50.6 b	54.7 b	1.3 ab
CV	5.7	11.25	5.4	14.9	69.2
Third Leaf					
P_1 *L. pennellii* (BL 630)	806.0 a	7.6 b	67.8 a	112.8 a	2.1
P_2 *L. esculentum* (CLN 65)	550.5 b	10.2 a	45.9 b	55.9 b	2.7
F_1 *Lp* × *Le* (1290)	566.2 b	10.2 a	47.2 b	56.7 b	1.0
CV	13.3	13.3	13.0	20.6	66.0
First Leaf					
P_1 *L. pennellii* (BL 630)	857.5 a	8.1 b	71.5 a	111.5 a	3.5
P_2 *L. esculentum* (CLN 698)	424.7 c	8.0 b	35.4 c	53.9 b	2.0
F_1 *Lp* × *Le* (1292)	591.1 b	10.8 a	49.3 b	57.3 b	2.6
CV	17.3	15.5	11.0	24.6	77.7
Second Leaf					
P_1 *L. pennellii* (BL 630)	907.8 a	7.8 b	75.4 a	121.3 a	0.9 b
P_2 *L. esculentum* (CLN 698)	459.0 c	8.8 a	41.6 b	57.2 b	3.9 a
F_1 *Lp* × *Le* (1292)	608.4 b	9.4 a	50.7 b	65.7 b	1.8 b
CV	14.0	8.6	15.8	14.9	43.8
Third Leaf					
P_1 *L. pennellii* (BL 630)	806.0 a	7.6 b	67.8 a	112.8 a	2.1 ab
P_2 *L. esculentum* (CLN 698)	508.8 b	10.0 a	42.4 b	50.8 b	3.5 a
F_1 *Lp* × *Le* (1292)	522.4 b	9.5 a	43.5 b	55.3 b	0.6 b
CV	16.2	9.3	16.0	18.2	64.1
First Leaf					
P_1 *L. pennellii* (BL 630)	857.5 a	8.1 b	71.5 a	111.5 a	3.5
P_2 *L. esculentum* (CL 5915)	690.5 b	9.3 ab	57.5 b	77.3 b	3.8
F_1 *Lp* × *Le* (1289)	655.2 b	10.3 a	54.6 b	65.6 b	2.7
CV	12.3	13.1	12.3	23.7	45.2
Second Leaf					
P_1 *L. pennellii* (BL 630)	909.8 a	7.8 b	75.4 a	121.3 a	0.9
P_2 *L. esculentum* (CL 5915)	653.9 b	10.2 a	54.5 b	66.9 b	3.7
F_1 *Lp* × *Le* (1289)	671.8 b	8.4 b	56.0 b	81.2 b	2.0
CV	14.0	13.7	13.8	19.1	58.6
Third Leaf					
P_1 *L. pennellii* (BL 630)	806.0 ab	7.6 a	67.8 a	121.8 ab	2.1
P_2 *L. esculentum* (CL 5915)	907.8 a	7.0 a	54.1 b	139.8 a	2.0
F_1 *Lp* × *Le* (1289)	708.5 b	8.2 a	75.7 a	91.8 b	6.0
CV	10.2	22.0	11.7	28.1	1.6
First Leaf					
P_1 *L. esculentum* 2-2-2 (hairy)	-	-	-	-	-
P_2 *L. esculentum* PT1131	659.8	10.8	54.8	65.0	6.8
F_1 (2-2-2 × 1131)-15-1-0	689.1	9.7	57.4	71.5	7.9
CV	15.9	16.7	16.2	27.2	111.0

continued

Table 1. Aphid-feeding behavior on *L. pennellii*, *L. esculentum* and their F_1s, and on an F_1 of hairy × normal hairy *L. esculentum*. (concluded)

Leaf position entry	Total probe time (sec)	Total probe no	% of time probing	Ave probe duration (sec)	Time to first probe (min)
Second Leaf					
P_1 *L. esculentum* 2-2-2 (hairy)	-	-	-	-	-
P_2 *L. esculentum* PT1131	609 0	12.0	51 0	53.7	3.1
F_1 (2-2-2 × 1131)-15-1-0	679 0	10 3	57.0	66.6	4.0
CV	18 2	16.6	18 1	27.5	82.6
Third Leaf					
P_1 *L. esculentum* 2-2-2 (hairy)	-	-	-	-	-
P_2 *L. esculentum* PT1131	650 0	13.3 a	54.0	51 2 b	3 3
F_1 (2-2-2 × 1131)-15-1-0	800.0	8.7 b	67 0	98 3 a	7.4
CV	20 0	17 4	20 0	40 0	100.5

[1]Data represent the means of 10 individual aphids and 5 replications Mean separation within columns by DMRT (P = 0 05)

No significant differences in aphid feeding behavior were observed between the F_1 of a cross between a hairy tomato and the normal hairy AVRDC line PT 1131 and the normal hairy parent.

The reasons for the discrepancy between AVRDC's and Goffreda's observations in the percentage time probing and in the average probe duration are not clearly understood. One possible explanation could be that the *L. pennellii* used in studies here was not exactly the same type as the one used in the Goffreda et al. studies and thus may not possess the same amount of type IV trichome glandular exudate. Also, the AVRDC tropical tomato lines used for the cross combinations may not necessarily behave in the same manner as the cultivar New Yorker used in Goffreda's studies with respect to aphid-feeding behavior. Furthermore, the aphid species used in experiments here may have behaved differently with respect to the trichome exudate of *L. pennellii*. It would also be conceivable that the presence of sugar esters in *L. pennellii* would deter the aphids from excessive walking on the leaves and confine them in one place where they would continue to probe. This could explain the longer probe time.

Since the laboratory study results were rather conflicting, a field test was conducted under high aphid/virus pressure to support or discredit observations in the laboratory.

Evaluation of *L. pennellii* and *L. pennellii* × *L. esculentum* Crosses Under Enhanced Epiphytotic Conditions (Field Study)

Materials and Methods

Two field tests were conducted.

Fall planting. Eight entries were tested: Three advanced tropical breeding lines—CL 5915-93D_4-1-0-12 (Le_1), CLN 65-349D_2-2-0 (Le_2), CLN 698 B_1F_2-358-2-11-8 (Le_3); three *L. esculentum* × *L. pennellii* (L.p.) crosses (the *L. pennellii* used in these crosses were brought from Cornell University by Dr. N. S. Talekar)—CLN 1289 F_1 (Le_1 × L.p.), CLN 1290 F_1 (Le_2 × L.p.), and CLN 1292 F_1 (Le_3 × L.p.); and two breeding lines from the USA—BL 438 (Floradade Long) and BL 242 (Floradade).

Plot size was 3 × 6 m, and consisted of four single rows of five plants each with a plant to plant distance of 60 cm. Distance between plots was 0.5 m. At 1.5 m distance between the end of each opposing row, one mechanically CMV-inoculated plant was planted with 10 nonviruliferous aphids placed on it, to allow for more even distribution of the virus and the vector in the experimental plots.

The beds were mulched with polyethylene mulch (black side up) and the AVRDC recommended cultural management practices were followed. A preventive fungicide, Mancozeb 1:400 was applied every 2 weeks. Insecticide was not used.

Seed was sown on 20 September 1990. The experiment was transplanted to the field 1 November 1990.

Spring planting. Sixteen entries were tested: one *L. pennellii* (BL 630-2), five advanced tropical breeding lines CL 5915 (CL 5915-93D_4-1-0-12) (Le_1), CLN 65 (CLN 65-349D_5-2-0) (Le_2), CLN 698 (CLN 698 B_1F_2-358-2-11-8) (Le_3), CLN 698a (CLN 698 B_1F_1-358-4-13) (Le_{3a}), and CLN 495 (CLN 495 B_1F_1-

265-9-0) (Le_4); five *L. esculentum* × *L. pennellii* crosses CLN 1289 (Le_1 × Lp), CLN 1290 (Le_2 × Lp), CLN 1338 (Le_3 × Lp), and CLN 1292 (Le_3 × Lp), CLN 1339 (Le_4 × Lp). The *L. pennellii* used was brought back from Cornell University by N. S. Talekar. Two lines from the US, BL 438 (Floradade long) and BL 242 (Floradade), were also included.

The same experimental layout as for the fall planting was used. Seed was sown on 5 February 1991. The experiment was transplanted to the field on 28 March.

Results and Discussion

Field trial 1 (fall 1990). In this trial only *L. esculentum* and the F_1s of *L. esculentum* × *L. pennellii* could be planted. Starting from the first assessment at 34 DAT it was noted that percentage CMV infection in the F_1 was consistently higher than in the *L. esculentum* parents (Table 2). The lowest percentage of virus infection was recorded in BL 438, the hairy Floradade (Table 2). The pooled data also clearly show that CMV infection was lowest in the hairy Floradade, followed by the AVRDC *L. esculentum* breeding lines, and Floradade (Fig. 1) and that CMV incidence in F_1s was higher than in *L. esculentum* (Fig. 1).

Table 2. Rate of CMV infection in advanced *L. esculentum* breeding lines and *L. pennellii* crosses (fall 1990).

Line	% CMV Infected plants[1]				
	5 Dec (34 DAT)	17 Dec (46 DAT)	3 Jan (63 DAT)	17 Jan (77 DAT)	27 Feb. (118 DAT)
L. esculentum					
CLN 5915 (Le_1)	0	7 cd	15 bc	20 de	57 b
CLN 65 (Le_2)	2 b	2 d	10 c	18 de	55 b
CLN 698 (Le_3)	4 b	7 cd	20 b	32 c	59 b
F_1 (*L. pennellii (Lp)* × *L. esculentum*)					
CLN 1289 F_1 (Le_1 × Lp)	4 b	12 bc	12 a	52 b	89 a
CLN 1290 F_1 (Le_2 × Lp)	15 a	25 a	25 a	57 ab	90 a
CLN 1292 F_1 (Le_3 × Lp)	10 a	24 a	24 a	64 a	94 a
BL 242 (Floradade)	10 a	14 b	14 bc	25 cd	49 b
BL 438 (Floradade hairy)	4 b	5 d	5 c	10 c	17 c
CV	55.3	26 2	24 5	17 5	9.7

[1]Out of 20 plants tested by ELISA.
[2]Data are the means of four replications. Mean separation within columns by DMRT (P = 0 05)

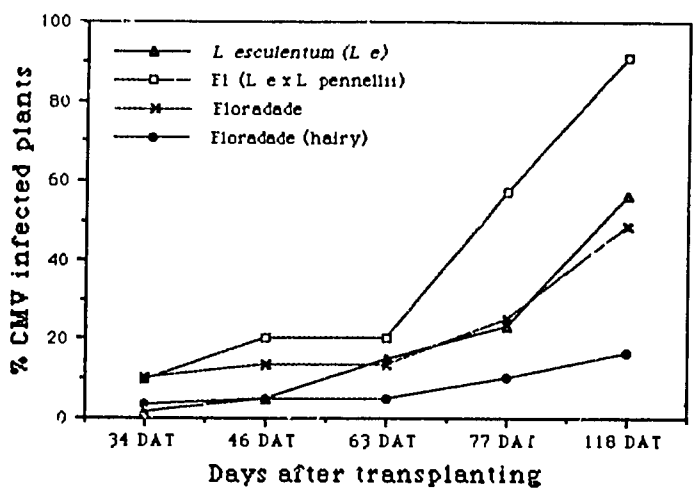

Fig. 1. Rate of CMV infection in *L. esculentum* breeding lines, *L. esculentum* × *L. pennellii* crosses and two introductions from the USA (pooled data) (fall planting).

Field trial 2 (spring 1991). As can be seen from the rate of CMV infection, disease and vector pressure was lower in this trial than in the fall trial (Table 3). At 77 DAT the average infection of F_1 with CMV was 57.2% in the fall trial as compared to 15.6% in the spring trial (Table 3). CMV infection was delayed and was lowest in *L. pennellii*. However, as in the fall experiment the F_1s of *L. esculentum* × *L. pennellii* had a significantly higher CMV incidence than the *L. esculentum* parent. The reaction of the BCF_1 was similar. Interestingly CMV incidence in BCF_1 was even higher than in F_1. Highest CMV incidence was observed in Floradade. The pooled data show again that CMV incidence in *L. e.* × *L. p.* F_1s and BCF_1s was higher than in *L. esculentum* (Fig. 2).

Table 3. Rate of CMV infection in advanced *L. esculentum* breeding lines, *L. pennellii* and crosses, planted in the field in spring 1991.

Line	% Infected plants[a]			
	29 April (32 DAT)	14 May (61 DAT)	28 May (75 DAT)	10 June (88 DAT)
L. pennellii				
BL 630-2	0 b	0 d	0 i	1 6 g
L. esculentum				
CLN 65	1 7 b	3 3 bcd	11.7 efg	13.3 f
CL 5915	0 b	0 0 d	5.0 hi	5 0 g
CLN 495	5 0 b	6 7 bc	8 3 fgh	8 3 fg
CLN 698	0 b	1.7 d	6 7 gh	8.3 fg
CLN 698a	0 b	0 0 d	3 3 hi	3 3 g
F_1 (*L. pennellii* × *L. esculentum*)				
CLN 1292	1 7 b	3 3 bcd	21 7 bc	36 7 cde
CLN 1338	0 b	8 3 b	13 3 ef	31 7 de
CLN 1289	0 b	5 0 bcd	20 0 cd	43.3 bc
CLN 1290	1.7 b	8.3 b	11 6 efg	30 0 e
CLN 1339	3 3 b	8.3 b	11 6 efg	38.3 cd
BCF_1				
CLN 1289 B_1F_1	3 3 b	5.0 bcd	33.3 a	56 7 a
CLN 1290 B_1F_1	1.7 b	5.0 bcd	15 0 de	50 ab
CLN 1292 B_1F_1	1.7 b	3 3 bcd	25 0 bc	40 c
BL 438 (Floradade hairy)	1 7 b	5 0 bcd	15.0 de	15.0 f
BL 242 (Floradade)	10 0 a	18.3 a	26 7 b	51.7 a
CV	140	65	24.4	15.6
LSD	2 0	2 4	2 5	3.0

[a]Out of 20 plants tested by ELISA
[b]Data are the means of four replications, mean separation within columns by DMRT (P = 0 05).

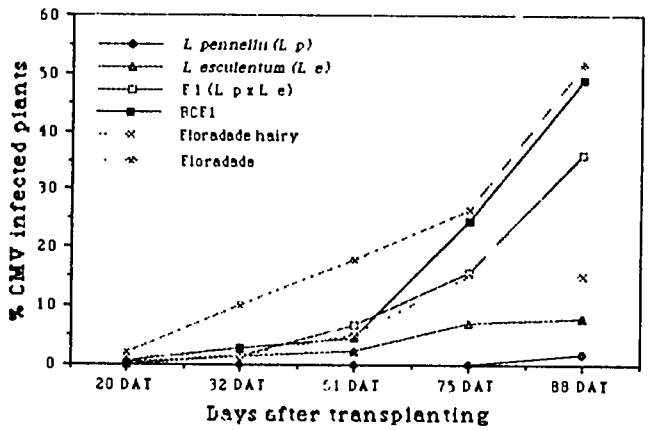

Fig. 2. Rate of CMV infection in *L. pennellii* breeding lines, *L. esculentum*, F_1s and backcrosses and in two introductions from the USA (pooled data) (spring planting).

The higher incidence of CMV in both the F_1 and BCF_1 suggests that the "indirect CMV resistance" offered by the changes in feeding behavior of the aphid vectors due to sugar esters might be controlled by nonadditive genes with overdominance for susceptibility. This hypothesis requires further study. Other factors besides changed aphid-feeding behavior such as plant morphology which influence virus transmission by aphids may also be involved. The F_1s were indeterminate and thus, higher (approximately 2m) and more bushy compared to the *L. esculentum*, which was of the determinate type and only approximately 90-100 cm high. Aphids in flight may have thus been more readily caught on the former plant type.

Genetic Resources and Seed Unit

Status of AVRDC Germplasm Collection

As of the end of November 1991, the total number of accessions in the AVRDC collection was 39,116, of which 87% belong to the Center's principal crops (Table 1). Of the total, 963 accessions were introduced in 1991. The bulk (575 accessions) were gathered from the Philippines during three collection trips carried out from March to October 1991.

The number of accessions maintained as base collection under long-term storage conditions totals 11,420 or 29% of the total (Table 1). All accessions are represented in the active collection.

Table 1. Germplasm maintained by AVRDC's GRSU, as of November 1991.

Crop	No. of accessions	Base collection
Principal crops		
Soybean	12,668	2,620
Tomato	6,390	2,037
Pepper	5,913	1,170
Mungbean	5,472	5,252
Chinese cabbage	1,502	341
Sweet potato	1,498	-
Eggplant	569	-
Allium	123	-
Subtotal	34,135	11,420
Non-principal crops		
Yard-long bean and cowpea	1,864	-
Black gram	451	-
Phaseolus bean (including Lima bean)	393	-
Pea	204	-
Lablab bean	191	-
Others	1,878	-
Subtotal	4,981	-
Total	39,116	11,420

Multiplication for Long-term Storage and Characterization of Pepper Germplasm

Summary

A total of 299 accessions was planted in fall 1990 at AVRDC, Taiwan, 100 accessions in Los Baños, Philippines, and 100 in Kamphaeng Saen, Thailand. This brings the total number of accessions that had been characterized to 1977. A total of 1257 accessions has been put in long-term storage.

Introduction

AVRDC is responsible for the global base collection of pepper. Materials received or collected are, therefore, multiplied to produce enough seeds for long-term storage. Characterization is also done to establish the identity of each accession and to provide information on genetic diversity available to scientists involved in the genetic improvement of pepper.

Materials and Methods

Plant establishment. Seeds were sown in seed flats kept inside a screenhouse. Two to three weeks after sowing, seedling characterization was carried out in the nursery. As germination percentage of some accessions was low, extra seeds were sown to increase plant number if necessary. About a month after sowing, seedlings were transplanted into insect-free screen cages which had been constructed in the field. The screen cages were not used for some accessions grown for characterization only.

Characterization. A total of 62 descriptor states which consisted of 49 qualitative characters and 13 quantitative characters; 8 seedling, 14 vegetative, 12 inflorescence, 26 fruit and 2 seed traits were used. The IBPGR descriptor for pepper was modified and followed in the characterization work. Distinct variants within an accession were identified and harvested separately to form subaccessions.

Seed extracting methods. For small fruit and high yielding accessions, extractors were used to break the fruits. Seeds were then washed out with water. For large-fruited and low-yielding accessions, the fruits were split open with a knife and the seeds extracted manually. The extracted seeds were dried and packed for storage.

Drying. Fruits were placed in a low-humidity drying chamber (15°C, 15% RH) until seed moisture content was 8%.

Packaging. Accessions that yielded more than 40 g seed/accession were prepared for long-term storage. These seeds (40 g/accession) were packed in laminated aluminum polyethylene pouches and stored at -18°C frost-free. The remainder were put in plastic jars and kept in medium-term storage (5°C, 45% RH) for distribution.

Seeds of accessions that yielded less than 40 g/accession were packed in plastic jars. These accessions will be multiplied again.

The cooperation of the National Plant Genetic Resources Laboratory (NPGRL), Institute of Plant Breeding (IPB), College of Agriculture, University of the Philippines at Los Baños (UPLB), the Tropical Vegetable Research and Development Center, Kasetsart University, and the National Gene Bank, National Research Council, Thailand, was sought in the characterization and multiplication of pepper germplasm. They followed basically the same procedure used at AVRDC with slight modification to suit local conditions.

A minimum of 20,000 seeds/accession was required for transfer to AVRDC. Characterization data were sent to AVRDC on floppy disks.

Results and Discussion

The *Capsicum* germplasm collection maintained at GRSU, totaling 5913 accessions, includes variations from all the domesticated and some wild species, i.e. *C. annuum* (2891), *C. baccatum* (335), *C. chinense* (344), *C. chacoense* (25), *C. eximium* (3), *C. frutescens* (281), *C. microcarpum* (6), *C. pubescens* (27), *C. praetermissum* (4), and unknowns (1997).

From spring crop of 1986 to spring crop of 1991, 1977 accessions (or 33%) have been characterized and 1257 accessions (or 21%) have produced enough seeds for long-term storage (Table 2).

All descriptor states were represented in the portion that has been characterized. The frequency distribution for some fruit characteristics are shown in Figures 1–3.

Table 2. Status of characterization and multiplication of pepper germplasm.

Year/season	Site	Accessions planted	Accessions characterized	Accessions multiplied[a]	
				> 40 g seeds	< 40 g seeds
1986/spring	AVRDC	105	105	63	47
1986/fall	AVRDC	116	96	23	65
1987/spring	AVRDC	98	-	224	70
1987/fall	AVRDC	250	233		
1988/spring	AVRDC	1000	624	429	144
1988/fall	AVRDC	544	-		
1989/spring	AVRDC	700	218	167	71
1989/fall	AVRDC	250	-		
1990/spring	AVRDC	150	-	273	42
1990/fall	AVRDC	299	262		
1990	Philippines	100	100	78	22
1990	Thailand	100	100	-[b]	-[b]
1991/spring	AVRDC	250	239		
Total			1977	1257	461

[a] More than 2 types were identified in some accessions.
[b] Seeds still to be received

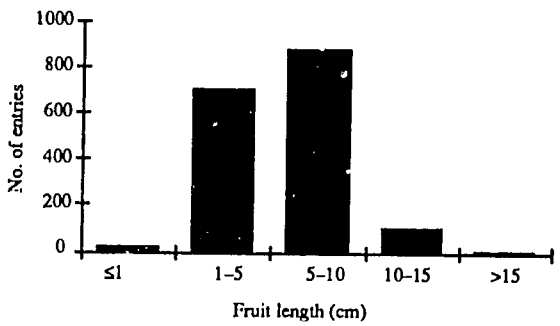

Fig. 1. Frequency distribution of fruit length in pepper.

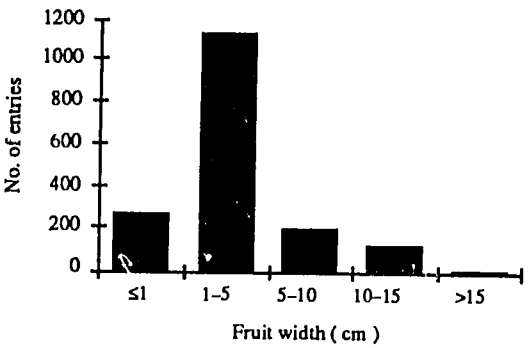

Fig. 2. Frequency distribution of fruit width in pepper.

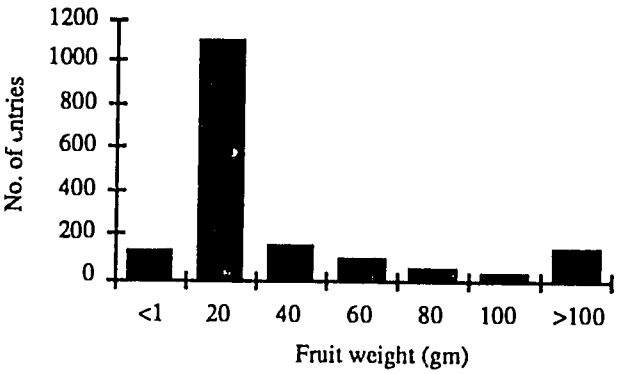

Fig. 3. Frequency distribution of fruit weight in pepper.

Multiplication and Characterization of Tomato Germplasm

Summary

A total of 2459 accessions have been regenerated and 2468 accessions recharacterized. A winter-spring crop was tried and found suitable for seed multiplication for long-term storage.

Introduction

Tomato is one of the principal crops of AVRDC. As of November 1991, the collection consisted of 6390 accessions. The high demand for tomato germplasm and the need for long-term conservation of more accessions necessitated the regeneration and recharacterization of the tomato germplasm collection.

Materials and Methods

Plantings were carried out mainly in the autumn of 1987-1990. However, a winter-spring crop was sown in January 1991. The number of accessions multiplied and characterized in one season ranged from 200 to 750 (Table 3).

Table 3. Number of tomato accessions grown in 1986–91.

Year/Season	Accessions planted	Accessions regenerated	Accessions characterized
86/Autumn	750	749	750
87/Autumn	600	593	600
88/Autumn	535	168	168
89/Autumn	250	250	250
90/Autumn	500	500	500
91/Spring	200	199	200

Fifty-four traits which mainly follow the IBPGR descriptors with additional characters considered as important by GRSU were used in characterization.

After extraction from the harvested fruit, the seeds were dried to 8% moisture content at 15°C and 15% RH. Twelve thousand seeds per accession were packed in aluminum foil bags and put in long-term storage (-18°C frost-free) as base collection. The rest of the seeds were put in plastic jars and stored in medium-term storage (5°C, 45% RH) as part of the active collection for germplasm distribution.

Results and Discussion

From 1986 to 1991, a total of 2459 accessions were regenerated and 2468 accessions were recharacterized. Most of the plantings were done in autumn. However, autumn is also the ideal time for multiplication of pepper and Chinese cabbage. Limited personnel necessitated reduction of workload during this season. A winter-spring crop with seeds sown in late January was therefore tried in 1991. Although lower yield and higher disease infection occurred at the end of the cropping season, the characterization work was still successful and seed yield was enough for the base collection and germplasm distribution.

In future, tomato multiplication will be carried out during the winter-spring cropping season with seeds sown in late January.

Distribution of Vegetable Germplasm

Summary

Various AVRDC research units requested a total of 4837 seed samples in 1991. Externally, 14,981 seed samples (including true seeds and in vitro materials) of germplasm and breeding lines were distributed to 84 countries and territories.

Introduction

To complement conservation with utilization, GRSU maintains a large active collection for distribution purposes. Most of the materials go to national breeding programs as well as the Center's own research activities.

Materials and Methods

Requests for germplasm are regularly received by AVRDC. Depending on the nature of materials required, the request is either served by GRSU or channeled to the other units of AVRDC. Import permits may be required for some countries. The required amount of seeds is taken out of the medium-term store and prepared for issuance of a phytosanitary certificate by the Tainan branch of the Bureau of Commodity Inspection and Quarantine (BCIQ).

Seed packets are dispatched by air mail or by courier in the case of in vitro materials.

Results and Discussion

External seed distribution. Recipients of AVRDC germplasm including breeding lines and in vitro materials are shown in Table 4. The distribution in 1991 exceeded that in 1990 by 4000 samples. The number of recipient countries increased by five. The major institutions that received AVRDC germplasm in 1991 are listed in Table 5.

Most of the seeds distributed outside AVRDC were breeding lines, including sets involved in variety trials (e.g. IMN, INTHOPE, ASET, AVNET).

Requests were also received for special groups of materials such as soybeans with black seed coat, representatives of different species of *Capsicum*, *Lycopersicon* and *Vigna*, and minor legumes.

GRSU also filled requests for seeds of nonprincipal crops (the highest being 128 for *Amaranthus*).

Table 4. External seed distribution of germplasm and breeding lines in 1991.

	No. of samples						
Country	Soybean	Mungbean	Tomato	Chinese cabbage	Pepper	Sweet potato	Others
Thailand	920	2,563	767	209	262	-	20
Philippines	57	277	583	36	521	4	310
India	84	140	155	5	303	-	57
Bangladesh	18	-	536	36	60	-	8
USA	16	86	116	12	353	12	18
Indonesia	262	60	124	10	128	-	16
Sri Lanka	-	100	157	124	-	-	19
Peru	-	-	-	-	-	370	-
Vietnam	73	81	96	18	30	-	-
Taiwan, ROC	2	-	30	-	30	113	83
Others	662	669	1,728	259	788	72	333
Total (84)	2,094	3,976	4,292	709	2,475	571	864

Table 5. Recipients of AVRDC vegetable germplasm in 1991.

Australia
- Queensland Government Horticulture Center

Bahamas
- Department of Agriculture
- Agricultural Technical Mission of the ROC

Bangladesh
- AVRDC/USAID/Bangladesh Project
- Bangladesh Agricultural Research Institute
- Bangladesh Agricultural University
- Homebound Business Center
- MCC Farming Systems Research

Belgium
- Insitut Superieur Industriel De L'etat

Belize
- Agricultural Technical Mission of the ROC

Bhutan
- Department of Agriculture
- Ministry of Agriculture

Botswana
- CIRAD/IRHO

Brazil
- Centro Nacional de Pesquisa de Hortalicas/EMBRAPA

(continued)

Table 5. Recipients of AVRDC vegetable germplasm in 1991.

Brazil (continued)
- EMBRAPA-CENARGEN
- Empresa de Pesquisa Agropecuaria de Minas Cerais
- Estacao Experimental de Anapolis/EMGOPA
- Universidade Federal de Santa Catarina

Brunei
- Sinaut Agricultural Training Center

Bulgaria
- Bulgarien Academy of Sciences

China
- Chinese Academy of Agricultural Sciences

Colombia
- Instituto Colombiano Agropecuario (ICA)
- Semillas Valle S. A.

Congo
- Universite Marien Ngouabi

Cook Islands
- Ministry of Agriculture

Costa Rica
- Ministerio de Agricultura y Ganaderia

Curacao
- Animal Husbandry and Fisheries

Czechoslovakia
- Research Institute for Vegetable Growing and Breeding

Denmark
- Danish Government Institute of Seed Pathology for Developing Countries

Dominica
- Agricultural Technical Mission of the Republic of China

Ecuador
- Inst. Nacional de Investigaciones Agropecuarias

Egypt
- Cairo University
- Minufiya University

England
- Rothamsted Experimental Station
- University of Reading

Ethiopia
- Institute of Agricultural Research

Fiji Islands
- Office of the President
- Sigatoka Research Station
- South Pacific Commission
- Teidamu Central Nursery

France
- CIRADLIRAT
- Clause Semences Professionnelles (CSP)
- Institut National de la Recherche Agronomique (INRA)
- Recherches Agricoles et Agroalimentaires Specialisees
- Royal Sluis

Gambia
- CUSO the Gambia

Germany
- Biologische Bundesanstalt fur Land und Forstwirtschaft
- Bundesanstalt fur Zuchtungsforschung
- Technical University Berlin
- Technische Universitat Munchen
- University of Kaiserslautern

Ghana
- Nyankpala Agricultural Experiment Station

Grenada
- Chinese Agricultural Technical Mission

Guam
- University of Guam

Holland
- D. J. Van Der Have B. V.
- Deruiter Zonen CV
- Enza Zaden De Enkhuizer Zaadhandel B. V.

Honduras
- Zamorano Escuela Agricola Panamericana

Hong Kong
- University of Hong Kong

Hungary
- Research Center for Agrobotany

India
- Andhra Pradesh Agriculture University
- Annamalai University
- Central Agriculture Research Institute
- Cotton Research Unit, C R.S
- Embassy of the Union of Soviet Socialist Republics
- Food Specialities Limited
- IARI Regional Station
- Indian Agricultural Research Institute
- Indian Institute of Horticultural Research
- Kerala Agricultural University
- National Bureau of Plant Genetic Resources
- Punjab Agricultural University
- Punjabrao Krishi Vidyapeeth
- Regional Research Station
- Tamilnadu Agricultural University
- Tamilnadu G D. Naidu Agricultural University
- The University of Agricultural Sciences Bangalore

Indonesia
- Bogor Agriculture University
- Lembang Horticultural Research Institute
- Malang Research Institute for Food Crops (MARIF)
- Project ATA 395
- Rural Management International
- Segunung Horticulture Research Station
- University of Sriwijaya-Palembang

Italy
- FAO of the UN
- National Research Council

Japan
- Applied Plant Research Laboratory
- Chiba University
- Kagome Research Institute
- Miyakawa Enterprise Inc.
- Nihon Horticultural Production Institute

(continued)

Table 5. Recipients of AVRDC vegetable germplasm in 1991.

Japan (continued)
- Sakata Seed Corporation
- Snow Brand Seed Co Ltd
- The University of Tokyo
- Tropical Agricultural Research Center

Jordan
- University of Jordan

Kenya
- Kenya Seed Company Ltd.

Korea
- Horticultural Experiment Station
- Kyungpook National University
- Rural Development Administration
- Seoul National University

Lao PDR
- Lao-IRRI Project

Lesotho
- Agricultural Research Division
- Chinese Agricultural Technical Mission

Libya
- Agricultural Research Center

Malawi
- Bvumbwe Agriculture Research Station
- Chitedze Agricultural Research Station

Malaysia
- Agricultural Research Center
- Malaysian Agricultural Research and Development Institute (MARDI)

Mauritius
- Mauritius Sugar Industry Research Institute
- The University of Mauritius

Mexico
- CRECIDATH

Morocco
- International Marketing Group

Nepal
- Lumle Agriculture Center
- Tribhuvan University

Nicaragua
- Embajada de la Republica de China

Niger
- ICRISAT - Centre Sahelien
- Niger Applied Agricultural Research Project

Nigeria
- Adelma (NIG.) Biztrades Company
- Ahmadu Bello University
- College of Education
- Farmers Library
- Federal Ministry of Science and Technology
- Ministry of Agriculture and Natural Resources
- Ministry of Agriculture and Water Resources
- NIHORT

Pakistan
- Pakistan Agricultural Research Council

Panama
- Institute de Investigacion

Papua New Guinea
- Department of Agriculture and Livestock
- Laloki Research Station

Peru
- International Potato Center (CIP)

Philippines
- AVRDC/POP
- Benguet State University
- Bohol Agricultural Promotion Center
- BPI-Los Baños National Crop Research and Development Center
- Camarines Sur State Agricultural College
- Isabela State University
- National Plant Genetic Resources Lab (NPGRL)
- University of Eastern Philippines
- University of the Philippines at Los Baños

Portugal
- Instituto de Investigacao Cientifica Tropical

Qatar
- Arab Qatari Vegetable Production Co S.A.Q.

Reunion
- Inst. de Recherches Agronomiques Tropicales et des Cultures Vivrieres
- Societe Cooperative d'Interet Collectif Agricole

Saint Vincent and the Grenadines
- Agricultural Technical Mission of the Republic of China

Saipan
- Cooperative Extension Services/ Cooperative State Research Services

Senegal
- Institute Senegalais de Recherches Agricoles

Seychelles
- Ministry of Agriculture and Fisheries

Sierra Leone
- Natural Resources and Forestry/GTZ
- Rice Research Station

Singapore
- Eastreco (Pte.) Ltd.

Solomon Islands
- Agricultural Technical Mission of the Republic of China

Sri Lanka
- CARI
- Development Alternatives, Inc.
- University of Ruhuna

Suriname
- IICA Representative in Suriname Inter-American Institute for Cooperation on Agriculture

Swaziland
- Kalanga R.D.A.
- Mahlangatja R.D A.
- University of Swaziland

Taiwan, ROC
- Academia Sinica
- Fujen Catholic University
- Hsinhwa Livestock Research Institute
- National Sun Yat-Sen University
- National Taiwan University
- Tainan DAIS
- Taiwan Agricultural Research Institute
- TARI Chiayi Substation

(continued)

Table 5. Recipients of AVRDC vegetable germplasm in 1991. *(concluded)*

Tanzania
- Horti Tengeru

Thailand
- Chainat Field Crops Research Center
- Charoen Seeds Co., Ltd.
- Chiang Mai Field Crops Research Center
- Chiang Mai University
- Chiangrai Horticultural Research Center
- Department of Agriculture
- East-West Seed Co., Ltd.
- Fang Horticultural Experiment Station
- Field Crops Research Institute
- Kasetsart University
- Khon Kaen University
- King Mongkut Institute of Technology
- Maejo Institute of Agricultural Technology
- Ministry of Agriculture and Cooperatives
- Mu Ban Suan Nuansri
- Petoseed
- Phayao Seed Center No. 8
- Sakon Nakhon Agricultural Research and Training Center
- Srisamrong Field Crops Experiment Station
- TOP/AVRDC

Tunisia
- Station d'Appui de la Medjerda
- Station Experimentale de Manouba

Uganda
- American Embassy
- FAO of the UN

USA
- Asgrow Seed Co.
- Beltsville Agricultural Research Center

USA (continued)
- College of Agriculture and Life Sciences
- Louisiana State University
- McIlhenny Company
- New Mexico State University
- North Carolina State University
- Oklahoma State University
- Petoseed Co , Inc.
- Texas A&M University
- Texas Agricultural Experiment Station
- Tsukegee University
- Universal Foods - Chili Products Division
- University of Florida, IFAS
- University of Minnesota
- University of Wisconsin
- Virginia State University
- Water Isle Botanical Garden

Vietnam
- Institute of Agriculture Science (IAS)
- National Institute of Agricultural Sciences
- Potato and Vegetable Research Center, INSA
- Seed Federation
- University of Cantho

Virgin Islands
- University of the Virgin Islands

Western Samoa
- University of the South Pacific

Zambia
- Monze College of Agriculture
- Mount Makulu Research Station
- National Irrigation Research Station

Zimbabwe
- Chiredzi Research Station

Internal seed distribution. Germplasm is used by the Center's researchers, with 5000 samples being made available in 1991. Most of the materials went to the Department of Entomology: 1000 accessions of soybean to screen for resistance to *Etiella zinckenella* and 1820 accessions of mungbean to screen for resistance to *Maruca*.

The most requested materials were C00758, a *C. frutescens* from Guatemala and C00848, a *C. frutescens* from USA for pepper, and L00634 (*L. glandulosum*), L00733 (*L. hirsutum*) and L01688 (*L. pimpinellifolium*) for tomato for the year 1991.

Viability Tests in Pepper and Tomato

Summary

Seeds of 649 accessions of pepper and 653 accessions of tomato were tested for germination rate. Percent germination for pepper ranged from 0 to 100 with 73% of the accessions having greater than 85%. For tomato, germination rate ranged from 22 to 100 with 94% having greater than 85% germination.

Low percent germination in some accessions could not be conclusively explained. However, improvement in percent germination during retest, about a year after, suggests the possibility of dormancy in some accessions.

Ward's method was used to classify pepper into groups based on germination percentage.

Initial viability was used to predict longevity in storage of pepper and tomato seeds.

Introduction

Germination testing is routinely done in a genebank to monitor seed viability. In addition, initial viability can be used to predict the storage life of the accession under a given set of environmental conditions and thus also determine when regeneration should be done.

Materials and Methods

Tomato seeds were treated with 0.2% potassium nitrate (KNO_3) and pepper seeds with 1% sodium hypochloride (NaOCl) for 10 min after which they were washed three times with distilled water. Testing was done on four replications of 50 seeds each in petridishes lined with filter paper moistened with distilled water. Seeds were wet with 0.2% potassium nitrate (KNO_3) before incubation. Test conditions were alternating 30°C (8 hours) light, 20°C (16 hours) dark.

Percentage germination was determined at 5, 7-8, 14 and 20-21 days after incubation in tomato, and 7, 9-10, 14, 20-24 days after incubation in pepper.

Results and Discussion

Tomato. A total of 653 accessions (75 from the 1987 autumn planting and 578 from the 1988 planting) were tested for percent germination. Frequency distribution for percent germination in tomato is shown in Figure 4. Initial viability for tomato was high with 94% of the 1989 harvest and 95% of the 1988 harvest having over 85% germination rate.

Germination testing was done in October 1990 for seeds of the 1988 autumn planting, and in August 1991 for the 1987 autumn planting. For the first autumn planting, accessions showing less than 85% germination were retested in October 1991 (Fig. 5). About 81% of those retested showed germination percentage >85%. The improvement in percent germination a year after suggested that a certain amount of dormancy may be present in some of the accessions tested.

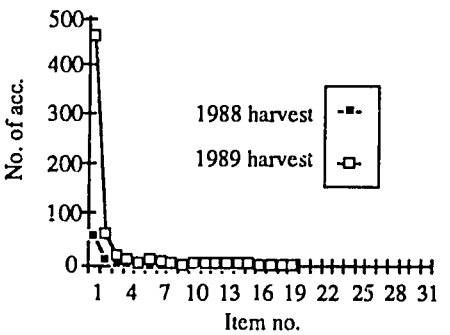

Fig. 4. Frequency distribution of percent germination in tomato.

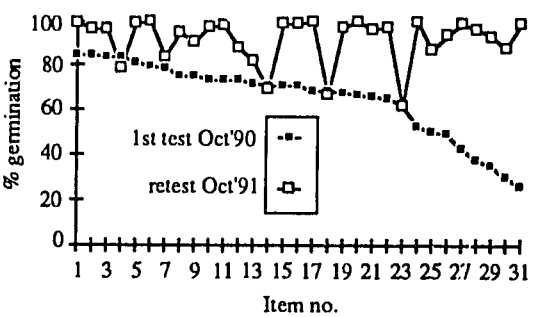

Fig. 5. Retest for percent germination in tomato.

Since viability constants for tomato were not available, the length of time it will take to bring down viability to 85% was estimated using nomographs for *Allium* and barley and getting the average of the two values. At 8% seed moisture content and 5°C storage temperature and based on the nomographs, it will take about 25 years to bring the viability of those with 96–100% germination to 85%, 10 years for those with 91–95%, and 3 years for those with 86–90% germination. Viability monitoring may be done every 10, 5 and 2 years, respectively.

Pepper. GRSU tested 649 accessions (419 from the 1988 autumn planting and 230 from the 1989 autumn planting). Initial viability for pepper was lower compared to tomato (Fig. 6). Only 70% of the 1989 harvest and 78% of the 1990 harvest showed germination percentage over 85%. Lowest percent germination was observed in accession C00302, a *C. baccatum* from Peru and in AMA 12 a *C. chinense* (1.5 and 0%, respectively).

For the 1989 harvest, retesting was done on accessions showing <85% germination (Fig. 7). Unlike in tomato, only 19% showed improved germination of > 85%.

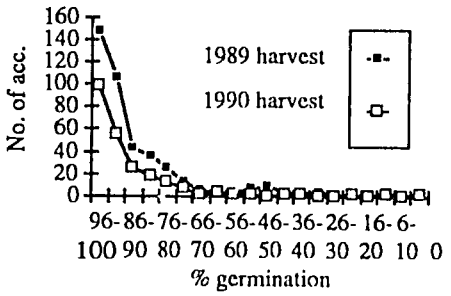

Fig. 6. Frequency distribution of percent germination in pepper.

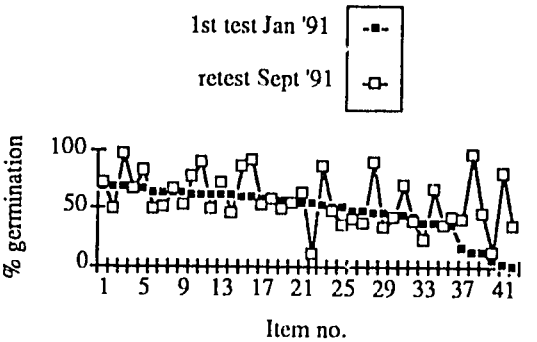

Fig. 7. Retest for percent germination in pepper.

To devise a more practical and efficient way of monitoring viability of stored seeds, grouping of pepper accessions based on percent germination was attempted. For the 1990 harvest, Ward's method was used to group accessions of pepper. Based on germination percentage, 10 clusters were recognized (Table 6). The groups were not associated with species or origin. These clusters will be used as the sampling unit in viability monitoring of pepper. Based on the nomographs at 8% seed moisture content and storage temperature of 5°C, it will take about 30 years to bring down viability of cluster 1 in pepper to 85%, 15 years for cluster 2, 10 years for cluster 3 and 3 years for cluster 4. Monitoring may be done after 2 years for cluster 4, 5 years for cluster 3, and every 10 years for clusters 1 and 2.

Table 6. Clusters recognized by Ward's method based on germination percentage in pepper.

Cluster	Percent germination		Accessions
	Range	Average	
1	98 0–100 0	98 8	54
2	94.5–97.5	96 0	61
3	90.5–94.0	92.4	38
4	87.5–90 0	88.8	22
5	78.5–86.0	82.2	24
6	74.0–77.5	75.8	10
7	65.0–72.0	68.7	6
8	56,5–57.0	56 8	2
9	39.5–40 0	39.8	2
10	0 0–1.5	00.8	2

Referee Test on Ultra-Dry Seed

Summary

For short-duration storage at room temperature, drying to very low moisture content can prolong the life of peanut and sesame seeds. For oil rape, drying from 7.6 to 2.5% seed moisture content had no effect on viability after 3 months storage at room temperature.

Introduction

GRSU has agreed to participate in the IBPGR referee test on ultra-dry seeds. The experiment is part of IBPGR's project to develop low-cost technology to conserve plant genetic resources. Experimental results have shown that, at least for certain crops, seed storage life could be significantly increased by

storing under ultra-dry conditions (seed moisture content below 5%). The referee test is conducted to verify the advantage of ultra-dry seed storage.

Materials and Methods

The test included three crops: oil rape (*Brassica napus*), peanut (*Arachis hypogaea*) and sesame (*Sesamum indicum*). Seeds sent by IBPGR to AVRDC have been dried to two moisture content levels (1.6 and 5.8% for sesame; 2.5 and 7.6% for oil rape and 2.4 and 7.0% for peanut). They were packed in hermetically sealed aluminum bags. Upon receipt, the materials were stored under three storage conditions: natural room temperature, medium-term storage temperature (5-10°C) and long-term storage temperature (subzero).

Germination tests were conducted on materials stored under room temperature at 0, 2 and 3 months after receipt.

Before each germination test, all the seed samples were premoistened with the following moisture-equilibrated method. Seeds of sesame and rape were placed in open petri dishes and sealed in a desiccator over a saturated solution of $CaCl_2$ for 24 hours under 20°C after which they were transferred to another desiccator with NH_4Cl saturated solution for 24 hours at 20°C. The same procedure was followed for peanut except that equilibrating with $CaCl_2$ was done for 48 hours.

Germination conditions were as follows: Sesame seeds [50 seeds, 4 replicates, 20°C (8 hours), 30°C (16 hours), top of blotter, 3 days]; rape seeds [50 seeds, 4 replicates, 25°C (24 hours), top of blotter, 3 days]; peanut seed [25 seeds, 4 replicates, 20°C (8 hours), 30°C (14 hours), rolled towel, 5 days].

Results and Discussion

The experiments yielded the following results: Oil rape showed no change in percent germination with 2.5 and 7.6% seed moisture content at 3 months after storage. Sesame, on the other hand, showed a decrease from 95.5 to 91.0% for seeds dried to 1.6%. For seeds dried to 5.8% moisture, the decrease was much greater, 96.5 to 35.5%. Peanut showed the same trend as that observed in sesame. For seeds dried to 2.4% there was no decrease in percent germination. However, for seeds dried to 7.0% moisture, percent germination decreased from 100 to 88%.

The experiment showed that drying seed to very low moisture content can prolong the storage life of sesame and peanut seeds kept at room temperature.

Conservation of Sweet Potato Germplasm

Summary

The AVRDC sweet potato germplasm collection consists of 1498 accessions. A total of 1188 accessions, which includes 56 breeding lines, are conserved in vitro; 543 accessions have been successfully meristemmed and maintained, with 366 accessions remaining to be meristemmed. GRSU has successfully subcultured 645 accessions. This year, 370 accessions were sent to the International Potato Center (CIP), Lima, Peru, bringing the total transferred to CIP to 573.

Introduction

AVRDC has been designated the repository of the Asia-Pacific sweet potato germplasm. Until the transfer of the sweet potato collection to CIP is completed, AVRDC will maintain the collection in both field and in vitro genebank.

Materials and Methods

In vitro conservation. Buds were disinfected twice with 1% commercial chlorox, 10 min the first time and 3 min the second time, then rinsed three times with sterile distilled water.

Disinfected buds were dissected out into small pieces (0.5-0.8 mm) for inoculation in the culture medium consisting of Murashige and Skoog (M & S) medium and 1 ppm Auxin (IAA). Sucrose was 3% w/v, agar 0.85% w/v, and pH 5.7.

Results and Discussion

In vitro conservation. The status of the sweet potato collection conserved in vitro is given above. Of the 1498 accessions, 1132 (76%) are conserved in vitro. An additional 56 breeding lines are also maintained for distribution purposes.

Conservation, Evaluation and Utilization of Vegetable Genetic Resources — A Collaborative Network Project for Southeast Asia

Summary

Three collecting expeditions were undertaken in cooperation with the National Plant Genetic Resources Laboratory of the Philippines in previously identified priority areas. A total of 994 samples of at least 27 genera from 12 provinces were collected.

Collected materials were subjected to routine seed health tests or grown out in a quarantine screen cage. Preliminary seed increase and characterization were done under quarantine. Extent of variation was observed.

Passport data were incorporated in the Center's crops passport database.

Four national program staff of the Philippines, Thailand and Indonesia visited GRSU to observe and/or train in genetic resources management.

Introduction

Initially, the activities of GRSU have been concentrated on the principal crops of AVRDC. However, we recognize that an international effort on vegetables should try to cover other vegetable crop species as well, taking into consideration the priorities of national programs especially in developing countries.

Thus, this project was proposed by AVRDC and approved for financial support by the Japanese government (JICA) for the period 1989–95. Its objectives are the extensive collection of vegetable germplasm in the Southeast Asian countries of Malaysia, Philippines, Thailand and Indonesia and possibly China and Indo-China; the multiplication of materials to get enough seeds for long-term storage and for distribution; the characterization and evaluation of the collection and the documentation of the collecting information and characterization data which will be put together in one central file. The project will also provide for the training in genetic resources of national program personnel from the countries involved.

At the end of the project, important vegetable germplasm from Malaysia, Philippines, Thailand, and Indonesia would have been conserved in long-term storage. Since seeds of the collected material together with passport, characterization and evaluation data would be available from a central file, extensive utilization of the materials in germplasm enhancement programs is expected. The diversity in the materials will provide a broader genetic base for vegetable breeding programs, and will provide safety back-ups to the dangers of a limited and highly uniform gene pool.

The nationals trained through the project would form a pool of skilled individuals in plant genetic resources work, which is expected to result in the upgrading of the participating countries' national programs in plant genetic resources.

Materials and Methods

Collecting. As proposed, collecting activities were focused in the Southeast Asian countries. Collecting expeditions were undertaken in collaboration with national programs. In 1990, collecting was done in Malaysia and for 1991 in the Philippines. Collecting is being undertaken collaboratively with the National Plant Genetic Resources Laboratory (NPGRL), Institute of Plant Breeding, University of the Philippines at Los Baños. To map out an efficient strategy for collecting, passport data of the existing

collection at NPGRL and AVRDC were obtained and a distribution map prepared. A frequency distribution of the present collection at AVRDC and NPGRL was also prepared and was used as one of the criteria for determining species prioritization for collecting. The species where number of accessions in the collection was less than 100 were included in the priority list and in areas where there has been little or no previous collecting, even species with large collections were also included.

Towns and villages in the priority areas were visited one by one and the samples collected.

The devised collecting strategy took into account the asynchronicity of flowering of the vegetable species, due to differing photoperiod reaction. For the Philippines, the optimum collecting times for vegetables are from January to April for short-day species, and from September to November for long-day plants.

Collecting forms of AVRDC were used to record passport data and other information.

Quarantine procedures. The materials collected from Malaysia were sown on 7 January 1991 in clay pots (25 × 20 cm) which contained a mixture of 70% soil, 15% compost and 15% sand. The plants were maintained in the quarantine screenhouse.

To hasten flowering, vernalization of celery was done 7 days after sowing by exposing the plants to temperature slightly above freezing (2 to 5°C) for 7 days. After treatment, the plants were maintained under room temperature for 1 day and then returned to the quarantine screenhouse.

Disease monitoring was done. The Center's pathologist and virologist were requested to observe the plants and to verify the presence of infection. Plants suspected to be infected were isolated from the rest of the group.

Collections from the Philippines were subjected to routine seed health testing by the Bureau of Plant Industry, Philippines. Samples cleared for export were sent to GRSU for storage.

Seed increase. Seeds produced in the quarantine screenhouse were gathered and processed for storage.

Characterization. Preliminary characterization was done following IBPGR descriptors on materials planted in the quarantine screenhouse.

Documentation. Passport data based on the collecting forms were incorporated in the computerized passport data base of the GRSU collection.

Training. Four training scholars came to GRSU to observe and learn various aspects of genetic resources management.

Results and Discussion

Collection. The priority species for collecting based on AVRDC and NPGRL priorities are *Lycopersicon esculentum*, *Solanum melongena*, *Abelmoschus esculentus*, *Cucurbita* spp., *Capsicum annuum*, *C. frutescens*, *Lagenaria siceraria*, *Luffa* spp., *Momordica charantia*, *Vigna unguiculata* ssp. *sesquipedalis*, and ssp. *unguiculata*.

Based on the distribution map of existing AVRDC and NPGRL collection, the priority areas for collecting are:

Luzon — Ifugao, Ilocos Sur, La Union, Pangasinan, Tarlac, Nueva Ecija, Nueva Vizcaya, Pampanga, Bulacan, Rizal, Quirino, Eastern Laguna, Quezon (Bondoc Peninsula), Catanduanes, and Camarines Norte.

Visayas — Antique, Capiz, Negros Oriental, Samar, Eastern Samar, Northern Samar, Southern Leyte, and Siquijor.

Mindanao — Agusan del Norte, Agusan del Sur, Surigao del Norte, Surigao del Sur, Bukidnon, Davao City, Davao del Norte, Davao Oriental, Davao del Sur, Lanao del Norte, Lanao del Sur, Maguindanao, Misamis Occidental, Misamis Oriental, North Cotabato, South Cotabato, Sultan Kudarat, Camiguin, Zamboanga del Norte, Zamboanga del Sur, Basilan, Sulu, and Tawi-tawi,

The first expedition undertaken by one AVRDC staff member and three NPGRL employees in March 1991 covered the priority areas of Ilocos Sur, La Union, Pangasinan and Tarlac in Luzon, collecting 472 accessions (Table 7).

The second collecting trip covered priority areas in Mindanao: Davao City, Davao del Norte and South Catabato. Collecting was not so productive because the drought since November had set back planting of vegetables. Nevertheless 166 accessions were collected (Table 7).

A third expedition covering the provinces of Bulacan, Rizal, Laguna, Nueva Ecija and Pampanga in Luzon yielded 356 accessions (Table 7).

Table 7. Number of samples of vegetable germplasm collected from the Philippines in 1991.

Genus	Expedition		
	I	II	III
Abelmoschus	26	19	29
Atylosia	4	-	-
Basella	5	6	3
Benincasa	16	-	4
Brassica	1	1	4
Cajanus	16	3	13
Canavalia	3	-	1
Capsicum	7	20	23
Citrullus	2	-	1
Clitoria	5	-	1
Corchorus	-	-	2
Cucurbita	14	5	12
Cucumis	2	3	2
Dolichos	47	4	51
Gossypium	1	-	-
Lagenaria	25	6	15
Luffa	45	12	29
Lycopersicon	4	3	7
Momordica	11	12	7
Mucuna	6	-	-
Pachyrrhizus	9	3	1
Phaseolus	87	9	51
Psophocarpus	41	7	17
Sechium	-	-	1
Solanum	29	14	28
Vigna	62	32	52
Zea	2	-	1
Unclassified	2	7	1

The three expeditions yielded 994 samples of at least 27 genera from 12 provinces. Since varietal mixtures are expected the total distinct accessions may come up to more than 1000. The new collection included more than 100 accessions each of *Dolichos* spp., *Phaseolus* spp. and *Vigna* spp.

The main source of samples was home gardens or backyards of the houses in the villages. Farm stores and fields were also important collection sources. In many villages, farmers kept their own seeds for further cropping, and the vegetables produced were for family consumption only. It means that these materials will never get to any market or other places. Sometimes more than 10 different vegetables could be found in a farm, so the collection team would sit down and talk with the farmers, and from the small talk more farm stores were located and yielded collections. In the local market, some pumpkins and peppers were obtained. In the Philippines, collection was not done in seed shops because almost all the seeds they sold were F_1 hybrid materials imported from foreign seed companies.

In March the Leguminosae, Solanaceae and Cucurbitaceae were at the right stage of maturity for collecting. Hence, mature pods of different legumes hanging on the fences, ripened gourds lying on the roofs and other mature pods and fruit (e.g. Solanaceae) could be found in the field. Such a view could be seen in many villages at this period of the year, so many samples of these three families were collected.

Seed extraction was carried out every evening after collection. The extracted seeds were given primary drying using the air-conditioning of the base hotel.

Collection could not be done in some areas where security was endangered. Bridges and roads destroyed by a recent earthquake also caused a change in collecting plans.

Fortunately, collecting in Tarlac and Pampanga was undertaken before the eruption of Mt. Pinatubo, possibly saving some landraces and traditional varieties that could have been lost due to mudflows from the volcano.

Quarantine procedures. Part of the Malaysian collection planted in the AVRDC quarantine screenhouse is shown in Table 8. Four plants of yard-long bean and three yambeans were suspected to have virus infection. Routine procedures used at the Center to test for the presence of virus were conducted by the Virology group. The results are shown in Table 9. The identity of the viruses will be confirmed by the Center's virologist.

Table 8. Malaysian vegetable germplasm planted in the AVRDC quarantine screenhouse in 1991.

Crop	Species	No of Accessions
Yard-long bean	*Vigna unguiculata* ssp *sesquipedalis*	34
Snap bean	*Phaseolus vulgaris*	19
Eggplant	*Solanum melongena*	30
Winged bean	*Psophocarpus tetragonolobus*	9
Yam bean	*Pachyrrhizus erosus*	6
Celery	*Apium graveolens*	2
Total		100

Table 9. Results of tests for viral infection in Malaysian vegetable germplasm under quarantine at AVRDC in 1991.

Crop	Accession No.	Leaf Lesion	EM
V. unguiculata	Tun 235-4	+	flex
	Tun 234-2	+	isometric
	Tun 259-2	+ many	flex
	Tun 259-3	+	flex
P. erosus	To 91-2	-	isom ?
	To 91-3	-	-
	To 91-4	+ very few	iso ?

Routine seed health testing on the Philippine collection showed that most of the microorganisms detected were identified by the Center's pathologist as storage molds which could drastically lower seed viability. This observation implies that newly collected materials may have to be treated with fungicide and/or immediately dried to low seed moisture content and stored under conditions of low relative humidity (<60% RH).

Some samples were rejected for transfer to AVRDC due to disease and one yard-long bean sample due to *Callosobruchus maculatus*.

For those cleared for export, a portion of the seeds were sent to AVRDC for storage. The portion left in the Philippines will be seed increased and characterized after which seeds for long-term conservation will be sent to AVRDC.

Seed increase. The amount of seeds recovered from plants grown in the quarantine screenhouse is shown in Table 10. Fruit set was low for eggplant and yam bean did not flower due to photoperiodism.

Characterization. Primary characterization was done on the Malaysian collection planted in the quarantine screenhouse. IBPGR descriptors were used for yard-long bean, snap bean, winged bean and eggplant. For celery, a set of descriptors was prepared.

Snapbean. Variation was observed as early as the seedling state. Most obvious were hypocotyl color which ranged from green to greenish purple to purple. A wide range in values was also observed for quantitative traits. However, all accessions planted had ovate leaflet shape, no pubescence, and indeterminate growth habit.

Table 10. Amount of seeds harvested from Malaysian material planted in the quarantine screenhouse.

Crop	No. of accessions	Harvest (g)	
		Range	Total
Yard-long bean	23	6.3-144.7	1442.2
Snap bean	9	5.0-51.6	255.7
Eggplant	6	0.7-6 8	21.1
Celery	2	7.5-8.2	15 7
Winged bean	1	2.6	2.6

Flowering took place 63-64 days after sowing. Flower color was observed to vary from white to light purple to blue. In some cases different plants belonging to the same accessions differed in flower color and stem color. The variants were treated separately and given subaccession numbers (e.g. Ph 262, Ph 262-a). Pods varied from straight to slightly or markedly curved. Immature pods were either green or brown. Seeds also varied in shape (round to kidney-shaped) and color (pale blue to greenish green).

Yard-long bean. The yardlong beans had twiny growth habit. The hypocotyls noted were green to greenish purple. Leaflet shape was ovate or lanceolate. Variation was also observed in stem color.

Winged bean. Variation was observed in leaflet shape.

Yam bean. Plant growth was moderate. The length of the internode averaged 6.9 cm and average leaflet and pedicel length was 6 and 1.6 cm, respectively. Leaf color and petiole color were both green.

Celery. The celery were quite uniform in appearance.

Eggplant. Cotyledon length/width ratio ranged from very low to intermediate to high. Plant growth habit was upright and intermediate. The eggplants showed variation in leaf characters. Leafblade lobing was intermediate and strong. Leaf tip angle was acute, intermediate or obtuse. A few leafhairs were observed in some accessions. As in the snap bean and yard-long beans variation was observed between and within accessions.

Documentation. Data from the collecting forms for both the Malaysian and Philippine collection have been incorporated in the GRSU crops passport database.

Training. Two staff of NPGRL, Nestor C. Altoveros and Lea H. Villavicencio, visited AVRDC to devise vegetable germplasm collecting strategies for the Philippines, determine priority areas and species for collecting, based on current collections of NPGRL and AVRDC, evaluate IBPGR descriptors for preparation of descriptors for species where these are not available and to become familiar with GRSU facilities and activities.

A Thai national, Wichai Chawnan, from the Department of Agricultural Extension, Seed Center No. 7, Chiang Mai was trained at GRSU in collecting strategies, characterization, documentation and other genetic resources activities.

An Indonesian, Maman Suherman of the Lembang Horticultural Research Institute has undergone training in genetic resources management.

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Production Systems Program

Agricultural Economics

Introduction

A new agricultural economics research unit was established at AVRDC in 1991 with the hiring of two international staff in mid year and the acquisition of a post-doctoral fellow late in the year. Planning future research activities took up most of the time of the staff.

Agricultural economics research areas that are important to vegetable production systems include: quantification of constraints to the adoption of new technology, incorporating sustainable vegetable production; evaluation of the impact of research; assisting in reviews of principal and regional crops for AVRDC research programs; assessment of the distribution of the benefits from vegetable research; evaluation of the role of vegetables in the nutrition of low income people; development of management models for new production technologies; forecasting the demand and supply of vegetable commodities; evaluation of proposed household garden systems; and assessing the environmental impacts of vegetable production systems and new technology.

The economists will initially focus on evaluating: the scope for research-generated improvements to vegetable production systems; the impact of vegetable research on the income and nutrition of low-income people; the environmental impact of production systems and new technology; and household garden systems. These activities will be complemented by work on demand/supply relationships and statistical data bases for vegetables, the development and application of geographic information systems, and bioeconomic computer modeling.

The research activities will have an international focus, involving collaboration with national agricultural research systems and with international and regional research centers. The early stages of the socioeconomics projects will involve collation and use of available data before investing heavily in the collection of primary data.

Assessment of Research Impact

In contrast to private research and development companies where profitability is a key measure of performance, public research institutions usually resort to secondary measures such as the number of publications, or the number of new varieties released. However, in recent years a number of methodologies have been proposed for the ex ante and ex post evaluation of the impacts of publicly funded research. The agricultural economics group will review existing methodologies for their appropriateness to AVRDC's research agenda. Selected methods will be applied to economic evaluation of the impacts of past AVRDC research, and to assisting the establishment of priorities for future research. A preliminary study on the impact of AVRDC-improved mungbean varieties has been carried out (and issued as AVRDC Working Paper No.2) and is summarized in a later section.

Assessment of Environmental Impact

There is mounting concern about the environmental impact in the long-run of agriculture in general and vegetable production in particular. For vegetables, the concern is focused on the heavy use of pesticides and erosion from highland vegetable production areas, among others. Many proposals for reducing these problems have ignored socioeconomic factors and have consequently not been adopted by farmers. The agricultural economics group will assess the private and public cost-effectiveness of alternative vegetable production systems in terms of their capacity to ameliorate environmental problems. The studies will be done in conjunction with farm surveys, GIS and crop modeling.

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Analyzing Supply and Demand Relationships for Vegetables

The objectives of this work will be to: summarize past trends and current developments in trade flows of horticultural products produced in developing countries; review the performance of exporters of horticultural products and distill necessary conditions for success in the world market for horticultural products; review the market structure and demand in high-income importing countries of horticultural products and derive implications for horticultural exporters; and investigate the relationship between profitability and sustainability in horticultural production and suggest implications for future export strategies and policies. A study has been completed which reviewed the performance of several Asian countries regarding the exports of horticultural products (issued as AVRDC Working Paper No.1). A shortened version is presented in a later section.

Household Garden Systems

These systems offer the potential to improve the income and nutrition of low-income farmers, but are intrinsically labor-intensive and complex to manage. Socioeconomic research will help to identify those systems which are likely to appeal to target groups.

World Vegetable Statistics

The objective is to compile a comprehensive set of world vegetable statistics on production, consumption and prices for use in other research projects and in research management. The need for and usefulness of comprehensive data bases has been recognized at most IARCs.

Geographic Information Systems and Bioeconomic Modeling

Appropriate use of GIS and bioeconomic modeling technology will ultimately contribute to improved focusing of research efforts. Specifically, it is proposed to use GIS for the following purposes: to provide benchmark information on the extent, distribution and interrelationships between vegetable production and the physical, edaphic and socioeconomic environments of countries in South and Southeast Asia; to improve upon existing constraints analysis methodologies, i.e. assist in assessing the extent of major limiting factors to crop production in general and vegetable production in particular; and to provide a data base for crop modeling purposes and for analyses of the sustainability of cropping systems.

Prospects for Horticultural Exports of Developing Countries In Asia: Quality, Competitiveness and the Environment

This study reviewed the performance of Bangladesh, China, Malaysia, Pakistan, the Philippines, Taiwan and Thailand regarding their exports of fruits and vegetables. Drawing upon previous studies carried out at the International Food Policy Research Institute (IFPRI) and in-country data and other information collected from various sources and during personal interviews, the following issues received particular attention:

- Why have some developing countries in Asia been able to establish themselves as major exporters of fruits and vegetables, while other countries with similar growing environments have not?
- Which factors are important in developing a comparative advantage in the production and exports of fruits and vegetables?
- What is the relationship between profitability and sustainability in the production of horticultural products? What is an appropriate role for the government in addressing negative externalities resulting from increased horticultural production?

The study finds that the performance in exports varies widely among Asian developing countries (Fig. 1). Countries can increase their earnings from horticultural exports by decreasing the unit production costs of commodities with high own-price and income elasticities. For successful export performance, maximum cooperation between the private export sector, the government, the research community and the farmers

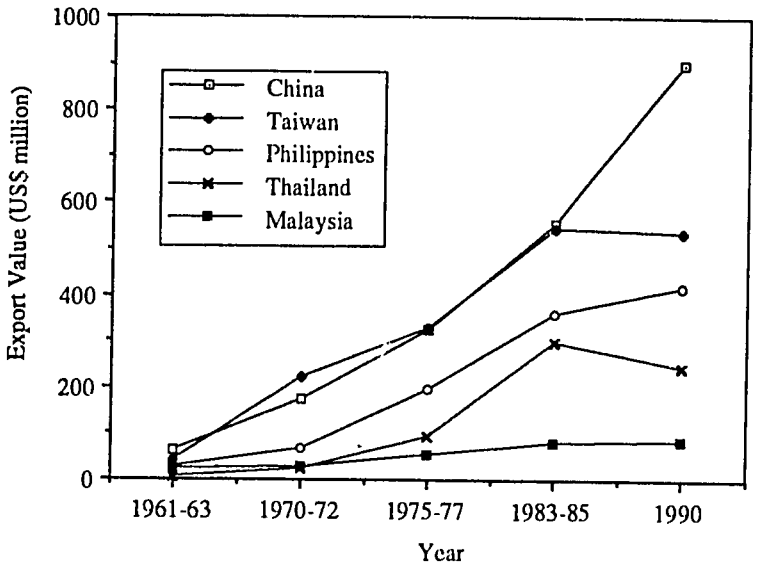

Fig. 1. Three-year average export value of fruits and vegetables in selected Asian countries.

is essential. The government can significantly influence export performance through conducive fiscal and monetary policies, provision of an efficient marketing infrastructure, and assistance in promotion, packaging and storage facilities. However, the trade-off between profitability and sustainability as well as the potential role of the government in reducing negative externalities that arise from increased horticultural production remain controversial issues.

Technological Changes for Processing Tomatoes in Taiwan: The Nature of the Supply Shift and Strategies for Cost Reduction

Introduction

Rapidly increasing prices for labor are quickly eroding Taiwan's competitive advantage in the production of agriculture commodities. This holds particularly true for commodities which are traditionally produced in relatively labor intensive ways. As far as vegetables are concerned, tomato represents a good example.

In this research, a partial budgeting approach is used to analyze the profitability of switching from manual harvesting of processing tomatoes to mechanized harvesting.

Materials and Methods

Technological innovations can be grouped into biological innovations and mechanical innovations.

In the literature most biological innovations were assumed to result in an equal percentage yield increase or correspondingly equal percentage cost reduction for all farmers so that the marginal or higher cost producers actually have a greater absolute cost reduction than inframarginal producers. This implies a divergent shift of the supply curve (Fig. 2a and Lindner and Jarrett 1978)[1]. However, the literature has recognized that there is no adequate evidence to support this common assumption. As far as the introduction

[1]Lindner, R.K and Jarrett, F.G. 1978 "Supply Shifts and the Size of Research Benefits". American Journal of Agricultural Economics. 60:48-58.

of the processing tomato variety UC-82 in Taiwan is concerned, no studies have been done to determine how the new cultivar affects the production costs for marginal and inframarginal farms.

A convergent shift of the supply curve implies that the absolute cost reduction is greater at the inframarginal levels of output than at the marginal levels of the output (Fig. 2b). Mechanical innovations tend to cause such a supply shift. Economies of scale, which link low costs and large farms is commonly present. Mechanical innovations are usually biased toward larger farms, causing more cost reduction on the bottom end rather than on the top end of the supply curves. Chern and Just (1978)[2] econometrically estimated the supply relations for the California processing tomatoes before and after the introduction of the mechanical tomato harvester. They found that mechanical harvesting shifted the supply curve for processing tomatoes towards more inelasticity, which is equivalent to a convergent shift. Chern and Just explained that due to the large investment costs associated with the mechanical tomato harvester, farmers become less reponsive to the prices of raw tomatoes, variable production factors, and competing crops. In other words, farmers are motivated to produce a large quantity of tomatoes to spread out the fixed costs of the machine and therefore tend to reduce their production when the price of tomatoes drops by an amount less than if they did not have a harvester.

However, as far as the introduction of the mechanical tomato harvester in Taiwan is concerned, a convergent shift of the supply curve for processing tomatoes seems unlikely. First, most California tomato farmers own mechanical harvesters while Taiwanese farmers would hire custom services, which do not inflict farmers with any costs. Second, it seems reasonable to assume that all farmers in Taiwan would be uniformly receptive to new cultural and harvesting practices so that the mechanical innovation reduces the production cost by the same absolute amount for both inframarginal and marginal levels of output. Accordingly, this study assumes that the combination of the introduction of a new tomato cultivar and the mechanical tomato harvester would cause a parallel shift of the supply curve for processing tomatoes in Taiwan.

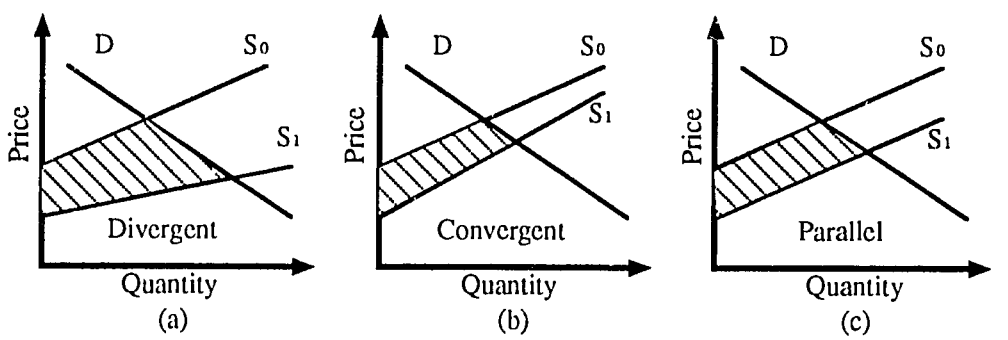

Fig. 2. Comparison of supply curve shifts based on biological and mechanical innovations in agriculture.

The sources of cost reduction are productivity improvement and cost-saving technology. Hwang (1989)[3] reported that UC-82's once-over harvest rate was 93%. Tsou (1991)[4] also reported that UC-82's yield was 73.9 t/ha if farmers hand harvest the first three clusters of tomatoes and then machine harvest the rest 2 or 3 weeks later. However, present data collected from eleven farmers, who joined the Tainan District Agricultural Improvement Station's (DAIS) project on mechanical harvesting in 1991 do not fully reflect the reported superiority of the new cultivar and the related cultural practices. The average yield of UC-82 harvested by hand plus machine was 67 t/ha, while that of conventional tomatoes, which were grown by

[2]Chern, W. S. and Just, R E 1978. Econometric Analysis of Supply Response and Demand for Processing Tomatoes in California Giannini Foundation Monograph No 37. September.

[3]Hwang, S L 1988. "A Study on Once Over Harvesting Technology of Processing Tomatoes. Screening for Once Over Harvesting Cultivars". Tainan District Agricultural Improvement Station Research Bulletin No 23 (Chinese)

[4]Tsou, S S.C. 1991. An Evaluation on the Research Project on Improving Taiwan's Agricultural Structure and Farm Income. The Council of Agriculture, Taiwan. (in Chinese)

the same 11 farmers and then handharvested was about 70 t/ha. According to the Taiwan Department of Agriculture and Forest, conventional cultivars produced 63 t/ha during the past 15 years, and the average yield of the past three years was 71 t/ha. Hopefully, farmers' yield of UC-82 can improve when farmers become familiar with the new cultural practices. In this study, by a PhD student from University of California, Davis, U.S.A., an equal productivity was assumed (70 t/ha) between UC-82 and other tomato cultivars.

Results and Discussion

The production costs of processing tomatoes between hand harvesting and mechanical harvesting are presented in Table 1. Only material, labor and power costs for various cultural and harvesting practices are calculated. Other fixed costs such as water users' fees and taxes on land are assumed to be the same regardless of how farmers grow or harvest their crops. The preharvest cost, which is obtained by subtracting the harvesting cost from the total cost is NT$6734/0.1 ha for mechanical harvesting and NT$6171/0.1 ha for hand harvesting.

Table 1. Production costs of processing tomatoes in Taiwan, 1991[a] (NT$/0.1 ha).

Field practices	Machine	Draft animals	Labor	Materials	Total
Land Preparation	616	0	0	0	616
	725	0	0	0	725
Bed Formation	219	181	0	0	400
	267	148	0	0	415
Planting	0	0	640	1016	1656
	0	0	447	482	929
Fertilization	0	0	195	324	519
	0	0	298	675	973
Intertilling, Banking,	251	44	566	0	861
and Weeding	235	0	540	65	840
Irrigation	0	0	96	20	116
	0	0	49	13	62
Pest Control	0	0	1124	811	1935
	0	0	1339	888	2227
Ripening	0	0	116	515	631
	0	0	0	0	0
Harvesting	767	0	1409	0[b]	2176
	0	0	3808	0	3808
Total	1853	225	4146	2686	8910
	1227	148	6481	2123	9979

Source. Data on preharvest costs are from surveys on 11 farms which joined the Tainan DAIS' mechanical harvesting project in the crop year 1990-91.
[a]The top (bottom) umbers of pairs portain to mechanical (hand) harvesting The mechanical harvesting strategy refers to the AVRDC-DAIS strategy and the hand harvesting to the conventional strategy in the text
[b]Data on fuel will be obtained from AVRDC.

The use of machine, however, is very effective in reducing harvesting cost, especially when the once-over mechanical harvest rate is high (Table 2). If farmers hand harvest the first 37% of the tomatoes and the machine harvests the rest of them, the harvesting cost drops from NT$544/t (hand harvesting) to NT$311/t. The harvesting cost is even lower when tomatoes are harvested by machine completely, and the cost per ton decreases as the once-over harvest yield increases. If the once-over harvest yield in farmers' fields could be as high as that on experiment stations, the harvesting cost by machine would be only one fifth as much as that by hand, or NT$110/t.

As far as the total cost is concerned, the conventional harvesting strategy (S1) is the most expensive among all strategies under investigation. About 38% of the production cost is attributable to harvesting. The AVRDC-DAIS strategy (S2) reduces the production cost by 11%. If Taiwan is able to increase farmers' once-over harvest yield to above 56 t/ha without increasing production costs, Taiwan would be better off harvesting tomatoes entirely by machine (S3-6). The potential cost reduction is 25% if farmers could completely reproduce the experiment stations' technology (S3). A once-over harvest yield of below 52.5

Table 2. The impact of yields and harvesting strategies on the production cost of processing tomatoes, Taiwan, 1991.

Harvesting strategies	Yield	Preharvest cost		Harvesting cost		Total cost		Change
	t/ha	NT$/0.1ha	NT$/t	NT$/0.1ha	NT$/t	NT$/0.1ha	NT$/t	%
S1: hand harvesting only conventional strategy	70	6171	882	3808	544	9979	1426	0[a]
S2: hand-machine harvesting AVRDC-DAIS strategy	70	6734	962	2176	311	8910	1273	-11
S3: machine harvesting only, the ideal strategy/yield	70	6734	962	767	110	7510	1072	-25
S4: machine harvesting only, 90% of the ideal yield	63	6734	1069	767	122	7501	1191	-16
S5: machine harvesting only, 85% of the ideal yield	60	6734	1122	767	128	7501	1250	-12
S6: machine harvesting only, 80% of the ideal yield	56	6734	1202	767	137	7501	1339	-6
S7: machine harvesting only, 75% of the ideal yield	52.5	6734	1283	767	146	7501	1429	0
S8: machine harvesting only, 70% of the ideal yield	49	6734	1374	767	157	7501	1531	+7
S9: machine harvesting only, 63% of the ideal yield	44	6734	1530	767	174	7501	1704	+20

Source: Data on preharvest costs are from surveys on 11 farms which joined the Tainan DAIS' mechanical tomato harvesting project in the crop year 1990-91.
[a]Benchmark.

t/ha under total mechanical harvesting strategies will render Taiwan worse off (S8-9). In other words, the once-over harvest yield needs to be equal to or higher than 52.5 t/ha to make farmers at least as well off as the status quo. The worst scenario (S9) is if the 11 farmers under the Tainan DAIS' mechanical harvesting project had not hand harvested the first tomatoes, which accounted for 37% of the total tomatoes harvested. This scenario assumes that on the average, 63% of the tomatoes are harvested. This scenario assumes that on the average, 63% of the tomatoes are harvestable by machine because the first 37% of the tomatoes are overripe and rotting in the field.

It is important that farmers are familiarized with new cultural practices to take advantage of the cost-reducing innovation. A combination of hand and mechanical tomato harvesting in Taiwan enables farmers to reduce the production cost of processing tomatoes by 11%. In case of complete mechanized harvesting, the cost can be reduced further by 12, 16 and up to 25% if farmers' once-over harvest yield can reach 60, 63, and 70 t/ha, respectively. The more tomatoes that are harvested by machine in a given land area, the lower the cost per ton for harvesting. What remains to be completed in this study is to translate cost reductions of selected strategies into farmers' supply response.

Preliminary Impact Assessment for AVRDC-Improved Mungbean Varieties in Five Countries

Based on preliminary analyses, the benefits to adoption of AVRDC mungbean lines appear to have been substantial for China (US$3–7m in 1989), Thailand (US$15–18m in 1988) and Indonesia (not quantified), but not for Pakistan; the situation for the Philippines is unclear. However, there are a number of questions that remain unanswered, largely due to a lack of data. It is not clear what contribution is made by inputs other than seed, the price effects of increases in output have not been estimated, the timing of benefits in relation to the timing and level of research costs have not been examined, and with the exception of Thailand, it has not been possible to reliably estimate the areas sown to AVRDC varieties. The results are preliminary and further data gathering is planned for 1992.

Analytical Laboratory

Determination of Quality-Related Chemical Composition in Pepper

Summary

The required quality properties of pepper fruits as raw materials of major processing are reviewed. Attempts were made to simultaneously determine as many components and properties as possible by near infrared reflectance spectroscopy (NIRS), simultaneously with minimum sample preparation. Moisture, capsaicin, color, crude protein, crude fat, fiber, total sugars, and alcohol insoluble solid can be determined with acceptable accuracy. This technique can also be used to determine contents of individual sugars with less accuracy. Poor determinations of ash and vitamin C were observed. Further improvement on determination of these two constituents is required to make it a more effective analytical tool for quality evaluation of pepper varieties for processing.

Introduction

Pepper is an important vegetable worldwide, and is consumed fresh or processed into various products. Popular processed products are dried pepper, paprika powder, oleoresin, frozen products and pepper sauce. Raw materials with specific characteristics are required for different processed products. Besides appearance, there are many constituents related to the quality of these products. Pungency and color are two most important characteristics for most of these products. Other constituents such as fiber, ether extract and vitamin C, are important for certain products but not for others. Chemical analyses are generally applied to evaluate the quality of raw materials for processing. Specific varieties are selected to meet quality requirements of various industries.

Analytical methods have been developed and recommended to calculate the concentrations of various quality-related constituents. Sophisticated equipment and/or labor-consuming procedures are often associated with these analytical methods. Attempts were made to calculate most of these characteristics using one single technique with minimum sample preparation. The near infrared reflectance spectroscopy (NIRS) was adopted as a rapid analytical tool in achieving this objective. Experimental results demonstrated that over 10 constituents can be determined simultaneously by NIRS in less than 1 min. Research will be carried out to study the possibility of determining the remaining properties using the same technique.

Materials and Methods

Pepper samples. Pepper fruits were washed in tap water and the samples dried at 45°C for 4 days in a hot-air oven. The dehydrated samples (10% moisture) were then ground in a centrifuge mill with a 0.5 mm screen. The powdered samples were used for chemical and NIRS analyses.

Chemical analysis. The manual methods for chemical analysis of various constituents are listed in Table 1. For total crude fat extract determination, n-hexane was used. Experimental results have shown that the solid soluble in n-hexane was slightly less than that in ether. Fiber contents were determined using three different methods: crude fiber, acid detergent fiber and neutral detergent fiber which provided information to calculate the contents of various fiber constituents for quality evaluation. Each sample and the mean values were analyzed to calibrate NIRS.

NIRS analysis. NIRS analysis was performed on a scanning type instrument (NIR System 6500). The step-up regression procedure was applied for establishing regression models of constituents tested.

Table 1. Chemical analyses required for quality evaluation of raw materials for processing of pepper fruits.

Components	Processed Products of *Capsicum*						
	Ground paprika	Ground chili	Oleoresin paprika	Oleoresin chili	Canned *Capsicum*	Frozen *Capsicum*	Pepper sauces
Color	•	•	•	•		•	
Flavor	•	•	•	•		•	
Pungency	•	•	•	•	•	•	•
Oleoresin yield		•	•				
Moisture	•	•					
Ash, total	•	•					
Ash, acid insoluble	•	•					
Ether extract	•	•					
Crude fiber		•					
Total nitrogen		•					
Starch		•					
Appearance and odor			•	•	•		
Vitamin C					•		
Sugar							•
Texture							•
Residue solvent			•	•			

Source. CRC Critical Reviews in Food Science and Nutrition Vol 23, Issue 3.

Results and Discussions

In spite of the fact that ground paprika and capsicum oleoresin are commodities of international trade, there are no universally accepted specifications on their chemical composition or properties. Each market may have its own preferences. Information from literature on analytical requirements for major constituents of pepper fruits is essential to the processing industry to produce quality products. The constituents of concern for major processed products summarized from the literature are listed in Table 2. There are 15 characteristics to be evaluated to identify the right varieties for different processed products. There are analytical methods available for each of these constituents but most of them require specific equipment and/or are very labor-intensive. It can also be very expensive to provide chemical composition data for a breeding program.

Table 2. Conventional methods of chemical analysis for pepper.

Constituent	Analytical method
Moisture	Oven-dry (105°C)
Crude protein	Micro-kjeldahl
Crude fat	Soxhlet (n-hexane)
Crude fiber	Acid and alkali hydrolysis
ADF	Acid detergent hydrolysis
ADF	Neutral detergent hydrolysis
lignin	72% sulfuric acid hydrolysis
Starch	Perchloric acid hydrolysis
Sugars	Anthrone colorimetric method
glucose	HPLC
fructose	HPLC
sucrose	HPLC
Ash	Furnace at 550°C
Alcohol insoluble solid	80% alcohol extracts
Vitamin C	Colorimetric method with 2, 6-dichloroindophenol
Color	Spectrophotometric method with $K_2Cr_2O_7$ and $Co_SO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ as a standard
Capsaicin	HPLC

NIRS is a rapid analytical technique which is able to simultaneously determine several components with minimum sample preparation and at low cost. However, this method requires the calibration of instruments using data sets obtained by manual methods. Regression statistics are then applied to evaluate the accuracy and precision of the prediction models. A successful model often depends on the concentration and properties of absorption spectra of the respective components. Experiments were carried out to study the feasibility of simultaneous determination of as many components and properties as possible in pepper fruits by this technique. The prediction statistics for chemical compositions tested are summarized in Table 3. Acceptable regression coefficients (R) and low standard errors of prediction (SEP) were observed for some of the constituents, including pungency and color value, the two most important characteristics of pepper fruits. The regression models for vitamin C and ash were found to be less accurate. Further improvement of the analyses of these two constituents will be needed before this technique can be used for evaluation of breeding lines.

Table 3. Prediction statistics of pepper constituents.

Constituent	Calibration curve				Performance test	
	No of wavelengths used	Range	R (No)[a]	SEC	R (No)	SEP
Moisture (%)	4	4 80 – 10 27	0 98 (138)	0.407	0.97(30)	0 66
Capsaicin (mg/g)	6	0 02 – 9 32	0 94(32)	0 28	0 91(32)	0 85
Color (color value)	5	8 45 –149 67	0 97(37)	1.71	0 92(29)	1 71
Crude protein (%)	5	12 57 – 23 77	0 97(30)	0 40	0 96(29)	0 45
Crude fat (%)	3	7 22 – 17 03	0 98(36)	0 37	0 95(29)	0 60
Crude fiber (%)	5	13 83 – 32 89	0 97(37)	0 86	0 95(29)	0 96
ADF (%)	5	16 82 – 34 37	0 94(46)	1 23	0 92(29)	1 24
NDF (%)	3	20 67 – 43 67	0 97(48)	1 36	0 95(29)	1 53
lignin (%)	4	5 42 – 16 23	0 94(39)	0 78	0.93(29)	0 75
Starch (%)	5	1.44 – 2 38	0.86(33)	0 20	0.85(29)	0 19
Total sugars (%)	5	1.30 – 22.86	0.91(39)	1.99	0.91(29)	1.91
glucose (mg/g)	5	1 34 – 42.38	0 87(42)	0 80	0 85(29)	0.87
fructose (mg/g)	4	3.99 –117 82	0.88(35)	1.08	0.84(29)	0 19
sucrose (mg/g)	5	12.38 – 58 12	0 89(30)	0 75	0 88(29)	0.7'
Alcohol insoluble solid (%)	5	40 01 – 63 46	0 95(50)	1.63	0 93(29)	1 63
Ash (%)	5	4.16 – 7 11	0 65(30)	0 44	0.63(29)	0 75
Vitamin C (mg/100g)	5	47 16 –510 37	0.68(59)	2 04	0.65(29)	7 02

[a]Number of samples tested. "#Q'P

Calibration procedures of partial least square (PLS) and step-up were used for pepper fruits for all components tested. The step-up procedure generally provided better results. Differences between SEP and standard errors of calibrations (SEC) are much smaller by step-up than PLS procedure. This suggested that overfitting may occur if one uses PLS to develop prediction models.

The poor regression coefficients for ash content implied that minerals present in pepper fruits may not necessarily associate with other organic components that have a strong absorption in the near infrared region. This result also prevented the calculation for the approximate compositions of pepper fruits. However, information on starch and sugar content may provide some estimation on N-free extract of pepper samples.

Sugars are one of the major constituents contributing to the taste of pepper fruits, and the main components for pepper sauce fermentation. The concentration of lactic acid and the pH value of pepper sauce are often associated with the concentration of sugars in pepper fruits. The collective role of sugars, however, is not always made clear. Information on the concentration of individual sugars is more useful than total sugars. NIRS analysis was able to determine total as well as individual sugars simultaneously, without additional effort.

The nature of fiber is also required information for graded chili powder. Fiber is also a major contributor to the consistency of chili sauce after fermentation. However, these two properties are determined according to fibers. Cellulose and lignin are important for ground chili and ground paprika, and pectin for chili sauce. Regression models have been established in our studies for crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF) which will provide more specific information in evaluating pepper varieties as raw materials for different products. Seeds were not removed in samples for calibration. The prediction models developed were not applicable to the materials for paprika, the seeds of which were removed. Different regression models will be needed for these types of products.

Vitamin C is not only an important nutrient in pepper fruits, but it acts as an antioxidant in many products as well. It will be desirable to determine this important constituent simultaneously with other components. The poor prediction statistics might be due to the interference of pigments to the color reading of the manual method used. An HPLC method will be used to calibrate the NIRS in 1992. Significant improvements on accuracy of prediction models might be achieved by changing to a better manual method.

Flavor was the only remaining property that is important to most of the pepper products, but cannot be determined by NIRS. Studies on improving the calibration technique in determining this property by NIRS are under way. With flavor determination, one may be able to determine all major constituents using a single instrument and the same samples in the future.

NIRS has been demonstrated as a powerful tool in determining many quality-related components of pepper fruits. More than 100 samples can be evaluated per day with minimum sample preparation and cost. Experimental results indicate that this technique is useful to identify pepper varieties for processing. Further work will be carried out to fine-tune this technique for quality evaluation in pepper breeding programs.

Quality Evaluation of Vegetable Soybean

Summary

Near infrared reflectance spectroscopy (NIRS) was applied to determine concentrations of individual sugars and amino acids in vegetable soybean. Satisfactory results have been obtained for sucrose, fructose, glucose, and glutamic acids. Less accurate results were obtained for total oligosaccharide, and a few individual amino acids. Regression studies suggested that one may use NIRS to simulate the panel tests on overall quality rating of vegetable soybean (R=0.95). Pod color is an essential characteristic for quality vegetable soybean and it cannot be determined by NIRS. Color ratings made with the color chart method and the color differential were compared. The results of one method can be equated with the results of the other method through a conversion formula. It was also concluded that analyses of chlorophyll content in pod shells do not provide a reliable determination of pod color.

Introduction

The eating quality of vegetable soybean is based on taste, sweetness, flavor and texture. Previous work in AVRDC has demonstrated that NIRS is a useful technique in simultaneously determining several quality-related properties in vegetable soybean within a short period of time. Satisfactory regression models have been established to estimate the concentrations of moisture, protein, fat, fiber, ash, total sugars, starch and total free amino acids. The same technique also proved to be useful in determining the texture of vegetable soybean seed without changing the sample preparation procedure for analysis of other constituents.

Studies were carried out in 1991 to further improve the quality evaluation method for vegetable soybean. NIRS was also applied to determine individual amino acids and sugars. A color differential meter was used to verify the color rating system of the color chart. Taste panels for vegetable soybean were formed to rate its eating quality. A regression model has been developed to simulate the quality rating made by the panels. Results of these studies are highlighted here.

Materials and Methods

Samples and sample preparation. Vegetable soybean samples were obtained from the AVRDC fields and from multilocational trials in southern Taiwan. Green pods were harvested but 80% were left and allowed to reach physiological maturity. The pods harvested were blanched and frozen under -40°C after precooling. The usual sample preparation procedure for chemical and NIRS analyses was applied.

Chemical analysis. Soluble extracts of 80% ethanol solution were used to determine the concentrations and characteristics of individual sugars and free amino acids after drying under vacuum condition. Separation and quality determination of amino acids as well as sugars were performed by HPLC. Instrument conditions used are presented in Table 4.

Color measurement. Pod color can be rated either by color chart or by color differential meter calibrated against a white standard scale. Values of -a/b, -1000 × [a/ b × L] and $\tan^{-1}$ (-b/a) were suggested by different investigators to express pod color. Chlorophylls in pod shells were extracted with 80% acetone, and quantified spectrophotometrically under 660 and 642.5 nm.

Table 4. Instrument conditions for analysis of individual sugars and amino acids by HPLC.

Condition	Individual sugar	Amino acid
Column	Sugar-PAK™ I 6 5 mm × 30 cm, Waters	PICO-TAG™ 3 9 mm × 15 cm, Waters
Mobile phase	Water	0.14M sodium acetate, 0 0005% TEA, pH 6.40
Gradient	-	6–60% acetonitrile
Temperature	90°C	38°C
Flow rate	0.5 ml/min	1 0 ml/min
Detection	RI, 8×	254 nm

Panel tests. Panel tests were carried out by the Institute of Food Science and Technology, National Chung-Hsin University. Selected panels were trained for 6 months in tasting known samples of vegetable soybean twice a week. Tests were conducted to confirm the ability of trained panels in rating sweetness, taste, flavor and texture of vegetable soybean by quantitative descriptive analysis. Samples were presented to panels for evaluation of individual characteristics and for an overall rating. The overall rating of 33 samples was used to establish simulation models of NIRS.

Results and Discussion

The statistics for individual sugars in vegetable soybean samples are summarized in Table 5. Sucrose, glucose and fructose were determined. Relatively low R values obtained for raffinose and stachyose could be due to their low concentrations. However, total oligosaccharides may still be obtained by using NIRS regression models.

Table 5. The prediction statistics of individual sugars in vegetable soybean by NIRS.

Sugar	Content range (mg/g)	No. of samples	R	SEP
Total sugar	52 70 –117.00	38	0.97	0.33
Sucrose	39 70 –102.70	25	0.96	1 17
Fructose	3 29 – 14.95	25	0 95	0.67
Glucose	7.35 – 13 71	25	0.92	0.17
Raffinose	0.01 – 5.72	14	0.73	0.73
Stachyose	0 01 – 4 26	14	0.73	0.62
Oligosaccharide	0 01 – 8 97	14	0.84	0.60

Glutamic acid is a major contributor to the taste of vegetable soybean and it is the predominant free amino acid of the commodity. Regression studies have shown that there was a linear relationship between concentrations of glutamic acid and total free amino acids. However, the correlation coefficient obtained was not high enough to estimate glutamic acid by determination of total free amino acids ($R^2 = 0.76$). NIRS was applied to predict glutamic acid after calibration. Statistics on glutamic acid and other selected free

amino acids are summarized in Table 6. A satisfactory estimate of the concentration of glutamic acid was obtained. Lower regression coefficients observed for other free amino acids could be due to their lower concentrations in vegetable soybean seeds.

Table 6. The prediction statistics of selected amino acids obtained by a filter-type and a scanning-type NIRS.

Free amino acid	Content range (mg/g)	No of samples	Filter-type[a]		Scanning-type[b]	
			R	SEP	R	SEP
Glutamic acid	1 90–22 6	26	0.89	2 71	0 91	2.01
Alanine	0 24–19 0	26	0.85	3 04	0.92	2.24
Aspatic acid	0.26–3.6	26	0 81	0 60	0.85	0.60
Tyrosine	0 11–2 1	26	0 80	0.35	0 82	0 34
Methionine	0 05–1.80	26	0 80	0.65	0 85	0 54
Histidine	1 91–17.9	26	0.89	1.97	0.95	1.47

[a]Technicon model 400.
[b]NIRSystem model 6500

Color charts have been commonly used to grade green pods of vegetable soybean. To evaluate pod color more objectively, the color differential meter was used by several research institutes. Several ways of expressing color, such as -a/b, -1000 × [a/b × L] and tan -1 (-b/a), were recommended by different authors. The color chart method and the method of color measurements by differential meter were compared. Regression analyses were applied to verify the relationship of these two methods. A linear relationship can be observed between color chart ratings and color values expressed by all three methods. Correlation coefficients obtained between color chart rating and color reading expressed by -a/b, -100 × [a/b × L] and tan -1 (-b/a) were 0.95, 0.98 and 0.94, respectively (Table 7). Expression of color value by tan -1 (-b/a) is recommended for use in the local community based on its higher correlation coefficient with the color chart method, and the positive relationship between these two methods. A regression model of color chart rating = -13.3 + 15.0 × [tan -1 (-b/a)] can be used to convert color values between these two methods.

Chlorophyll was thought to be the major factor contributing to pod color. Analysis of color values and chlorophyll contents in shell suggested that the relationship was not linear (Fig. 1). The relationship can be expressed by the model $y = -93.067 + 80.320x - 9.916x^2 + 0.422x^3$ ($R^2 = 0.87$). This result suggested that in addition to chlorophylls there were other factors associated with pod color. The notable ones were hair color and moisture content.

Table 7. Correlation coefficients obtained between color chart rating and color reading by color meter.

Color chart	Range		
	-a/b	-1000 × a/b*L	tan -1 (-b/a)
1	0.58	148	1 04
1.5	0.52–0 66	128–164	0 99–1.09
2	0.46–0.63	105–149	1 01–1.14
2.5	0.44–0.62	95–144	1.01–1.16
3	0.44–0.58	93–126	1 05–1 15
3.5	0.44–0.57	92–127	1 05–1 16
4	0.41–0.53	83–115	1.09–1.18
4.5	0.35–0.50	72–111	1.11–1.23
5	0.32–0.47	75–103	1.13–1.26
5.5	0.19–0.47	41–103	1 13–1.39
6	0.19–0.41	39–83	1 18–1.39
R^2 (mean)	1 0	1.0	1.0

Thirty-three vegetable soybean samples of 12 varieties were rated by the panels based on their appearance, color, texture, sweetness, taste and flavor by descriptive analysis. An overall rating was also given to each sample. As all panels were trained and selected, the deviation among panels was relatively low (SD ranges from 0.29 to 0.69). Variety GC83006 was rated higher than the other varieties by local panels. Attempts were made to simulate panel rating by NIRS. A good regression model can be obtained based on the spectra at visible and near infrared regions (Fig.2). This result suggested that one may use NIRS to evaluate the overall quality of vegetable soybean when trained panels are not available. These findings are to be further confirmed. Experiments are planned to compare the preference of Taiwanese and Japanese consumers. The same approach can be applied to develop local preferences for vegetable soybean in other countries in the future.

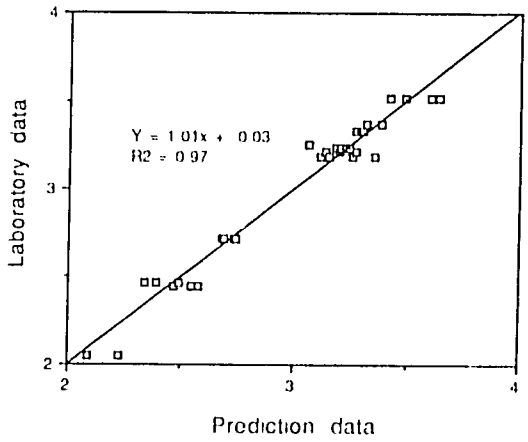

Fig. 1. Relationship between the color values and chlorophyll content of vegetable soybean pod shells.

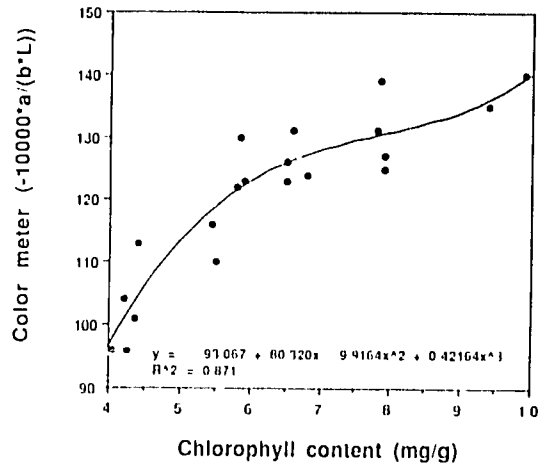

Fig. 2. Calibration curve of overall preference of vegetable soybean.

It can be concluded that NIRS is not only a good method in identifying major components in vegetable soybeans such as protein, fat and starch, etc., but it is also a practical technique to estimate quality-related mineral composition such as sucrose and glutamic acid. Changing sample preparation procedures is not necessary to get more descriptions on quality of vegetable soybean. The establishment of a successful regression model of predicting panel-rated eating quality by NIRS is significant. This implied that one may be able to evaluate products for markets of different preferences without relying on specially trained panels. The good correlation coefficient between color ratings by the color chart method and the color differential meters suggested that either one could be used based on available facilities.

The results obtained from one method can also be converted to those of other methods through a conversion formula.

Crop Management

Mechanical Harvesting of Processing Tomato: Effects of Two Planting Dates and Four Densities

Summary

Labor costs for harvesting processing tomato comprise a great proportion of total costs. On a per person basis, mechanical harvesting was 8–12 times quicker than hand harvesting, with greater efficiency when planting date or variety lead to greater yield. A single hand harvesting 15 days prior to mechanical harvesting considerably reduced the proportion of unmarketable yield if compared to a single mechanical harvest.

Introduction

One of the major costs involved in the cultivation of processing tomato is the cost of manual harvesting. This is particularly evident not only in Taiwan (e.g. on average 34–40% of total costs is attributed to harvesting) but also in other Southeast Asian countries where labor is becoming scarce as a consequence of industrial development. Earlier trials (AVRDC Progress Report, 1989) have demonstrated the benefits of ethrel application (39.5%, diluted 400 times) 2 weeks before harvest to improve uniformity of maturity and mechanical harvest efficiency. The present experiments evaluated the effects of various planting densities on harvesting efficiency, and quantified the effect of mechanical harvesting on the efficiency of labor use.

Materials and Methods

The experiment was run twice. First sowing and transplanting were carried out on 5 September and 26 September 1990, and in the second run sowing and transplanting were done on 5 October and 30 October 1990, respectively. Land preparation and transplanting to the field in the first planting were conducted under heavy, wet, soil conditions, whereas soil conditions during the second planting were optimal. Tomato cultivars Peto 86 and PT 4121 were transplanted as main plots, with subplots in a split-plot design comprising spacing treatments: one plant/15 cm, one plant/20 cm, 2 plants/20 cm, and one plant/30 cm. Distance between rows was 1.5 m, and each plot consisted of one row of 36 m length. Harvested area was 54 m^2 per plot.

Treatments were replicated in three blocks, and data collected from the two runs were analyzed in a combined ANOVA, with the experimental run as the main (fixed) effect, cultivars as the split plot, and spacings as the split-split plots. During the first planting, ethrel was applied 14 days before harvest at 39.5%, diluted 400 times. Harvesting was done with an Italian Coopmes SC 89/011 /90 tomato harvester. Since yield loss was great with the harvester, in the second planting fruit was harvested once by hand the day before an ethrel application—15 days before the mechanical harvest.

Border rows in both plantings were hand-harvested, and timing for field harvest operations on 54 m^2 plots was accurately recorded in all treatments.

Results and Discussion

Large differences were evident between plantings in mechanically harvested marketable yield (Table 1). Yields from the second planting were vastly superior, most likely due to more favorable planting and cooler growing conditions. Cultivar PT 4121 had a consistently greater marketable yield than cultivar Peto 86, and planting at one plant per 30 cm was superior to the other (higher density) spacings (Table 1).

Table 1. Effects of date of planting, cultivar and plant spacing on mechanically harvested marketable fruit yield (t/ha) at AVRDC.

	Transplanting date				
	First (26 September 1990)		Second (20 October 1990)		
Spacing	Peto 86	PT 4121	Peto 86	PT 4121	Mean
1 plant/15 cm	22.7	26.6	54.3	69 6	43.3
1 plant/20 cm	23 1	21.4	59.2	68.3	43.0
2 plants/20 cm	24.2	30.6	54.8	66.7	44.1
1 plant/30 cm	23.7	29.6	68.3	67.2	47.2

SED (4 df) cultivar means = 1.15
SED (24 df) spacing means = 1.57
SED (24 df) spacing means within cultivar within a date = 3 15

No differences between cultivars in the unmarketable (i.e. spoiled or rotten) and green fruit yields were evident, but both were influenced by spacing; the highest density (i.e. 2 plants/20 cm) had the greatest green fruit yield and the least unmarketable yield (Table 2). The unmarketable yields also differed between planting dates (4.9 vs. 2.3 t/ha for the first and second planting); the single-hand harvest 15 days before the mechanical harvest in the second planting considerably reduced the unmarketable yield loss (equivalent to 16.6% and 3.4% of the total mature fruit yield in each planting, respectively). A further indication of the harvest loss in the first planting was evident from the comparison between the yield of hand-picked border rows and the mechanically harvested yields. The latter was 40% less than that of hand-picked yields, although these were possibly inflated due to the border effect.

Table 2. Unmarketable (i.e. spoiled or rotten) and green fruit yields (t/ha) as influenced by plant spacing (means of two plantings and two cultivars).

Spacing	Yield	
	Unmarketable	Green
1 plant/15 cm	3.7	2.6
1 plant/20 cm	3.7	2.6
2 plants/20 cm	3.3	3.1
1 plant/30 cm	3.7	2.5
SED (24 df)	0.2	0.2

Harvest efficiency of the mechanical harvester (as weight of total fruit per hour per person—Table 3) was greater in the second planting (Table 1). Similarly, harvest efficiency was greater under the highest yielding-lowest density spacing treatment (Table 3).

Table 3. Effects of a) date of planting and b) plant spacing on mechanical harvesting efficiency (kg or total fruit/hour/person).

a)	First planting	Second planting	SED (4 df)		
	998	1408	80[a]		
b)	1 plant/15 cm	1 plant/20 cm	2 plants/20 cm	1 plant/30 cm	SED (24 df)
	1132	1086	1161	1431	89

[a]No valid statistical text—for comparison only.

On a per person basis, machine harvesting was 9.5 to 12.25 times more efficient than hand harvesting. In the first planting, hand harvesting was at the rate of 85 and 99 kg/hour for PT 4121 and Peto 86 respectively, and in the second planting at 145 and 131 kg/hour respectively (vs. 1042 and 953, and 1460 and 1355 kg/ha, respectively when machine harvested).

The harvesting machine required seven operators: the driver and six sorters. The average rate at which the machine worked was 33 hours/ha in both plantings. This was much less than the rate of 8 hours/ha expected by commercial operators of harvesting machines, and reflects the inexperience of AVRDC's operators on the harvester, and the time lost in harvesting short rows of tomatoes.

Simple partial budget analyses are underway.

Maximum Yield Trial and Gap Analysis for Fresh Market Tomato

Summary

The influence of various soil conditioners and fertilizer amendments on tomato yield was evaluated during autumn. Fruit yields over the fourth to ninth harvests were significantly improved with application to the soil of 30 t/ha steel slag when compared to the control treatment. Total fruit yield with steel slag was 15 t/ha more than control yields, and the combined application of a foliar fertilizer plus a commercial organic fertilizer resulted in a 10 t/ha increase above control yields. Both treatments which enhanced yields would result in greater returns to tomato producers.

Introduction

Fresh market tomato yields of 80–100 t/ha are frequently obtained by proficient farmers, and at AVRDC. Various soil conditioners and fertilizer amendments were evaluated during autumn for their potential benefit on fruit yield.

Materials and Methods

Seeds of the tomato variety FMTT 33 were sown on 12 September 1990 and transplanted to the field on 5 October into double-row beds spaced at 1.5 m with plants at a between- and within-row spacing of 0.6 m and 0.4 m, respectively. Plots comprised four rows, each 4.8 m in length. Basal fertilizer was broadcasted to all plots at the rate of 80:80:50:10 kg $N:P_2O_5:K_2O$ Borax/ha and incorporated prior to transplanting. Two side-dressings of 60:0:60 were also applied. Specifications of treatments, replicated three times within a randomized complete block design, are presented in Table 4. It should be noted that plants in the SS treatment were transplanted 6 days later than the rest, to provide time for the SS to react with the soil. Within each plot a 14.4 m^2 bordered area was harvested, over the period 75–140 days after transplanting (DAT). After the final fruit harvest, six plants per plot were uprooted and dried and weighed.

Results and Discussion

Plant height was unaffected by treatments (after allowing for the delayed transplanting of SS), as were the first three harvests over the period 75–90 DAT. From the fourth harvest onwards (96 DAT) the SS treatment resulted in consistently more marketable yield until the final harvest (Table 5). Fruit pH was greatest and brix lowest for the SS treatment 90 DAT and for brix alone 111 DAT (Table 5). Average fruit size (g/fruit) was superior in the same treatment over the periods 4th–6th and 7th–9th harvests (Table 5). Accumulated total and marketable yields in the SS and TF + BA treatments were greater than those of the CK treatment (Table 6). After the final fruit harvest, the standing plant weights did not differ between treatments.

Greatest yields in the SS treatment were due to a range of possible reasons. Besides increased availability of N and K, the other elements Ca and Mg provided by SS would have increased the soil cation exchange capacity CEC considerably. SS has also been reported to promote soil microbiological activity, and to improve soil structure.

Table 4. Soil amendment and fertilizer treatment specifications.

Treatment	Text abbreviation	Chemical composition, application rate and frequency
Check	CK	
TF #1 organic fertilizer	TF1	0.14 kg/m² at land preparation· —organic matter 60%, humus acid 6%, total nitrogen 1 5%, P_2O_5 4 0%, K_2O 3.0% SiO 8.0%, CaO 7.0%, MgO 1.0% other minor element Fe, Mn, Zn, Cu
BASF foliar fertilizer	BASF	diluted × 400 and applied 5 times, each at 500 l/ha; — macroelement N 20%, P_2O_5 19%, K_2O 19%. minor element MgO 0.5%, Cu 0 04%, Fe 0 1%, Mn 0 [illegible]%, Mo 0.005% others 1.32%
TF #1 + BASF	TF+BA	As TF #1 and BASF
SH	SH	0.1 kg/m² at land preparation· —4 4% bagasse (sugarcane) 8 4% rice husk powder, 4 25% oyster shell powder, 8 25% urea, 1.04% potassium nitrate, 13 16% calcium superphosphate and 60.5% mineral ash (31% silicon dioxide, 44% calcium oxide, 1.7% magnesium oxide, 18% aluminum oxide and 1% ferrous oxide)
NC-R Soil conditioner	NC-R	0.15 kg/m² at land preparation —anaerobic microbes of lactobacillus and yeast
Steel slag	SS	30 t/ha at land preparation —

	SiO_2	CaO	MgO	FeO	MnO	Al_2O_3	TiO_2	K_2O	Zn	Cu
Total %	34.6	39 2	7.3	0 45	0 33	17.1	0.53	0.66	0 008	0.007
Soluble % (in 0.5 N HCl)	21.6	23.9	4 9	0 31	0 28	9.7	0.15	0.48	0.0002	-

Table 5. Cumulative yields and quality characteristics as affected by soil amendments and fertilizers.

Treatment	Marketable yield over harvest periods (t/ha) 1st–3rd	4th–6th	7th–9th	Fruit pH 90 dat	Fruit brix 90 dat	111 da	Average fruit size (g) [illegible]–111 dat	122–140 dat
CK	36.3	28.8	17.4	4 19	4.93	6[illegible]	[illegible]35	140
TF1	36.1	31.5	17 0	4.17	5.13	5[illegible]	27	121
BASF	36.7	29.2	18.2	4.16	5.27	5.5[illegible]	37	136
TF+BA	38.6	30.4	21.6	4.18	5.00	5	[illegible]1	31
SH	33.9	30 4	19.1	4.18	5.23	5.[illegible]	[illegible]8	126
NC-R	37.9	27.2	18 1	4.15	5.13	5.3[illegible]	[illegible]1	143
SS	28.1	40.8	28.2	4.26	4.70	4.9[illegible]	[illegible]58	148
SED (12 df)	0.5	0.9	1.0	0.0	0.1	0.14	4.1	7.5

Table 6. Total and marketable yields, and plant dry weight at final harvest.

	Treatment CK	TF1	BASF	TF+BA	SH	NC-R	SS
Total yield (t/ha)	91.9	98.2	93.4	101.4	95.4	90.9	107.4
Marketable yield (t/ha)	82.5	84.7	84.1	90.7	83.4	81 2	97.1
Plant weight (g)	116	105	121	116	137	125	134

Present costs of SS at NT$1000/t would make the application practices economical given the increase in fruit yield over the CK treatment. Increased fruit pH and reduced brix with the SS treatment would make the fruit more desirable to the consumer, and so add to the overall value of that treatment.

If part of the benefit of the SS treatment is related to improved soil structure, then this treatment merits attention during the hot summer.

The additional unit cost of TF + BA, and labor for the five applications of the BA component, would also make this treatment economical, given the 8 t/ha increase in marketable fruit yield.

Seed Priming of Processing Tomato, Hot Pepper, and Chinese Cabbage

Summary

Seed priming with ethylene glycol or potassium salts hastened emergence of hot pepper and tomato in the spring. Germination of Chinese cabbage was inhibited by priming with potassium salts. Tomato yield at first harvest was enhanced by priming, but for none of the species was there a significant effect of priming on total yield. Seed priming could reduce the time to produce seedlings of a suitable size for transplanting, thereby favoring specialized producers of transplants.

Introduction

Uniform-sized, vigorous seedlings are essential for successful transplanting, particularly under adverse conditions or when mechanically transplanted. Over the past year the effects of various treatments, e.g. seedling module size and media content, starter solutions, and priming, have been studied.

Seed priming or osmo-conditioning, has been reported to effect synchronous and earlier germination than for nonprimed seeds, as a result of a "pregermination" effect on the seeds. Seeds may be primed by soaking in a solution of high osmotic potential for a designated period. Seeds of three species were primed and growth response of seedlings and yield response in the field in spring and summer were evaluated.

Materials and Methods

Seeds of processing tomato (cv. Peto 86), hot pepper (cv. Passion) and Chinese cabbage (cv. ASVEG # 1) were primed in 1990. Priming at AVRDC was done for 10 days in the dark at 15°C. Seeds were then rinsed in deionized water, air-dried, and stored in a desiccator at 15°C together with the untreated seeds. Two priming treatments were done at AVRDC, in PEG-6000 solution (275 g/l water) or KNO_3 (15.1665 g/l water) + K_2HPO_4 (20.9016 g/l water). Another set of the same seed was simultaneously sent to Horticulture Research International (HRI-Wellesbourne, U.K.) for priming there, together with a control set which was not primed. Seeds were sown on the dates indicated in Table 7. The field design was a randomized block design with three replications, and details of transplanting dates and other field operations are presented in Table 7.

Emerged plants were counted until constant values were achieved. At transplanting 100 plants per treatment × species combination were measured for height (soil level to the growing point), separated into roots, stems and leaves, and dried to a constant weight. Periodic readings of crop light interception (with a LI-COR LI-1000 line quantum sensor) and crop cover using a grid quadrat method were taken, together with destructive samples for growth analyses. Total and marketable yield data were also collected.

Data are presented for the spring sowing only.

Results and Discussion

Emergence. With the exception of the potassium salt treatment on Chinese cabbage seeds (which did not germinate) priming hastened emergence with the greatest effect evident in hot pepper (Fig. 1). Maximum % emergence was also considerably greater by 10–15% in the primed treatments of hot pepper and Chinese cabbage (Fig. 1).

Seedlings at transplanting. The effect of earlier emergence in primed treatments was also manifest in the size of plants at transplanting. Tomato and pepper seedlings were taller and heavier in the primed versus the control treatments; the potassium salt treatment promoted greater aboveground dry weight in both species, and root weight in pepper, whereas greatest tomato root weight was evident in the PEG

Table 7. Field details for seed priming experiments.

	Processing tomato	Chili pepper	Chinese cabbage
Experiment 1			
Sowing date	1 February	1 February	15 April
Transplanting date	1 March	7 March	6 May
Harvest date	2, 14, 23 May; 11 June	30 May; 11, 24 June; 1, 9, 17 July	10, 18 June
Experiment 2			
Sowing date	9 July	19 June	24 June
Transplanting date	8 August	16 July	15 July
Harvest date	-[a]	-	16 August; 3 September
Both			
Within-row spacing (m)	0.3	0.3	0.4
Between-row spacing (m)	1.5	0.75	0.75
Harvest area (m^2)	16.2	7.2	7.8
Basal fertilizer (N, P_2O_5, K_2O)	40-80-50	120-120-120	60-90-40
Side dressing (N, P_2O_5, K_2O)	40-0-50	40-10-20	20-0-0
	40-0-50	40-10-20	20-0-30
		40-10-20	20-0-30
		40-10-20	

[a]Data not available

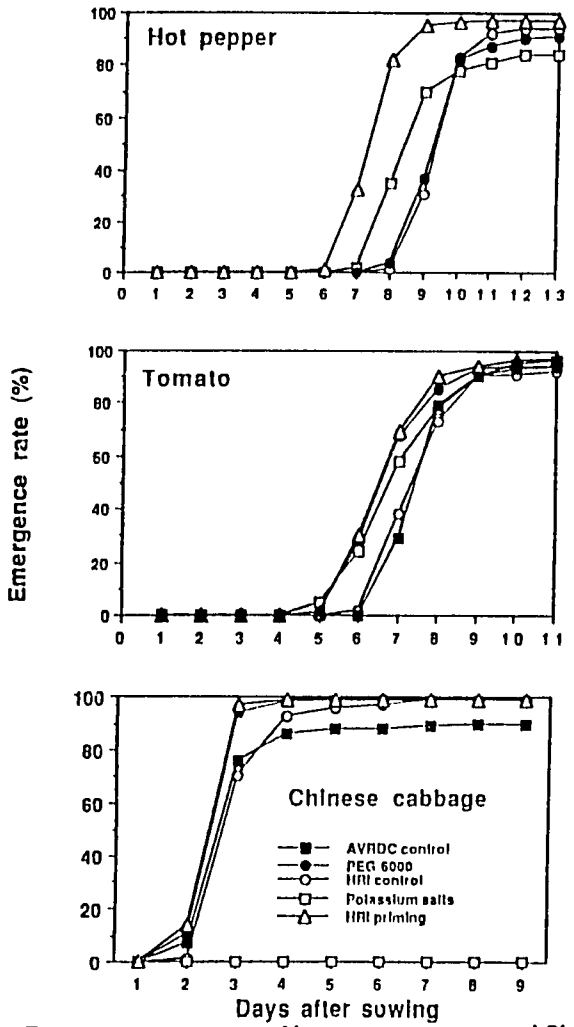

Fig. 1. Emergence responses of hot pepper, tomato and Chinese cabbage to different seed priming treatments

treatment (Table 8). For Chinese cabbage, however, the HRI primed treatment was superior for all measured characters with the exception of root dry weight (Table 8).

Table 8. Seedling size at transplanting as affected by seed priming.

Species	Treatment	Attribute (+ SE)			
		Height (cm)	Leaf no.	Top dry wt (mg)	Root dry wt (mg)
Processing tomato	AVRDC control	7.1 (0.2)	3 9 (0.1)	166 (6.2)	28 (0.9)
	Potassium salts[a]	[illegible] (0.3)	4 6 (0.1)	229 (7.4)	36 (2 1)
	PEG-6000	10.6 (0.2)	4.3 (0.1)	214 (6.3)	40 (1.5)
	HRI[2] control	6 2 (0.2)	3.6 (0.1)	139 (5 7)	25 (1.1)
	HRI primed	9 6 (0.3)	4.2 (0.1)	202 (7 5)	35 (1.5)
Hot pepper	Potassium salts	6 8 (0.1)	6.4 (0.1)	142 (5.3)	39 (2.3)
	PEG-6000	6.5 (0.1)	5.8 (0.1)	132 (5 2)	34 (1.7)
	HRI control	6.3 (0.1)	5.6 (0.1)	109 (3.6)	28 (1 2)
	HRI primed	6.5 (0.1)	6.0 (0.1)	129 (3.7)	49 (1.6)

Species	Treatment	Leaf area (cm^2)	Leaf no.	Leaf dry wt (mg)	Stem dry wt (mg)	Root dry wt (mg)
Chinese cabbage	AVRDC control	51.3 (3.6)	4.4 (0.08)	96.0 (6.4)	25.1 (1.35)	14.7 (0.6)
	PEG-6000	56.1 (3.2)	4.6 (0.08)	109.1 (5.6)	27.8 (1.32)	13.0 (0.5)
	HRI control	38.3 (2.2)	4.4 (0.64)	95.3 (5.3)	21.5 (1.09)	9.3 (0.5)
	HRI primed	89.7 (2.9)	5.4 (0.64)	186.4 (6.3)	48.6 (1.44)	13.6 (0.8)

[a]$KNO_3 + K_2HPO_4$
[b]Horticulture Research International (U.K.)

There was no evidence to suggest that the priming treatments improved uniformity of plant size at transplanting, since standard errors did not differ greatly between treatments within a species for any measured attribute.

Light interception, crop cover and date of first flowering There were no significant differences for tomato or pepper between treatments for light interception or crop cover. At 48 days after transplanting (DAT) light interception ranged from 61 to 65%, and for tomato at 38 DAT interception varied from 47 to 51%.

Crop cover in Chinese cabbage was similarly not affected by priming treatments. Appearance of first flowering was earlier at an average of 2 days in primed tomato treatments (SED = 0.6; data not presented).

Harvest data. There was no significant effect of priming on total yield for any of the species. However, at the first harvest of tomato both the AVRDC priming treatments and the HRI priming gave greater yields than their respective controls (potassium salts—0.6 kg/plant, PEG—0.6 kg vs. control 0.5 kg; and HRI—0.5 kg vs. control 0.4 kg).

General Discussion

During spring, although hastening emergence and enhancing seedling growth, seed priming had no significant effect on total yields of tomato, pepper or Chinese cabbage. Data from summer sowing await analysis.

Seed priming may have some application to the commercial producer of seedlings, representing a 2-day economy in each month of seedling production (i.e. 6.7% time-saving). High quality seeds were used in this study (Fig. 1). For other species additional benefit of seed priming has been reported for poor quality seed.

Summer Vegetable Soybean for Fresh Market In Taiwan

Summary

Based upon data from three sowings (July, August and September) of three vegetable soybean lines, it was concluded that summer production for this crop is highly feasible. Pod yields ranged from 7 to 11 t/ha, with lowest total and pod yield obtained in the first sowing—most likely resulting from high night temperatures and flooding. Yield differences between lines were minimal, as were differences between fertilizer treatments.

Introduction

Vegetable soybean is not traditionally grown during the summer in Taiwan. However, due to diversification away from rice culture, there is a demand for suitable summer vegetables, amongst which may be included vegetable soybean. The present study was therefore run to identify the potential of this crop for fresh market production, comparing three lines sown on three separate occasions at three rates of fertilizer application.

Materials and Methods

Three vegetable soybean lines (AGS 292, G 9053 and G 10134) and three fertilizer rates (60:60:60, 30:30:60, and 30:120:100 kg $N:P_2O_5:K_2O$/ha) were arranged factorially in 3 m × 5 m plots, in three blocks within a randomized complete block design. Fifty percent of N, 70% of P_2O_5 and 50% of K_2O were applied as basal fertilizer and the rest was applied as a top-dressing at the R_1 stage. Three seeds were sown per hill, thinned to two, at 40 plants/m^2 in pair-row beds set 1 m apart. The experiment was planted on three dates: 17 July, 16 August, and 21 September 1990. The durations from sowing to the R_1, R_4, and final harvest stages were recorded, and at stage R_4 six bordered plants per plot were sampled for growth attributes, e.g. fresh and dry weights of component parts, and leaf area. Light interception by the crop was measured at R_4 and 1 week before harvest, and lodging was recorded at the latter date. At harvest, plants from 3 m^2 bordered sample areas were removed from each plot, and after height and node number were recorded, pods were separated into groups with zero, one, two or three seeds from subsamples of 10 plants/plot, and weighed, as were stems and leaves. Graded pod yields comprised of two or more seeded pods, with minimum width and length of 1.3 and 4.5 cm, respectively.

All data were subjected to ANOVA which combined results from the three sowing dates.

Results and Discussion

The R_4 stage was achieved sooner at later sowings (42, 39, 35 days after sowing for the first, second, and third sowing dates).

Root dry weight at R_4 was influenced by sowing date, with the heavier root systems evident in the first and third sowings and the lightest in the second sowing (0.87, 0.75 and 0.44 g/plant). The variety G 9053 had the heaviest root system in the first sowing but the lightest in the other two sowings. Aboveground dry weight at R_4 was greatest in the first sowing and least in the second (Table 9). Variety G 9053 had (or nearly had) the heaviest aboveground weight in all three sowings.

Since plant height at R_4 and final harvest was similarly affected by sowing date and variety, only data for final harvest are presented (Table 9). Plant height of AGS 292 was significantly less than that of the other two lines with the exception of the third sowing date, when AGS 292 plant height was similar to that of G 9053. Plant height of all lines was notably less for the second sowing date, as was the height of the first pod (at node 11.6 vs. 15.4 and 14.4 for the first and third sowings).

The number of pods per plant was less in AGS 292 than for the other two varieties, especially so at the first sowing, for which it was itself markedly greater than those of the second and third sowings.

Table 9. Some growth and final harvest characteristics for three vegetable soybean lines planted on three occasions during summer in Taiwan.

Treatments		Growth stage								
		R_4		Final harvest						
Sowing date	Genotype	Root dry weight (g/plant)	Above ground (g/plant)	Plant height (cm)	Nodes/ plant	Branches/ plant	Leaf area/ plant (cm^2)	Total plant wt (t/ha)	Pod yield (t/ha)	Grading ratio (%)
First	AGS 292	0.9	4	39	9	0.8	187	13 2	8	45
	G 9053	0.9	6	48	9	1.6	257	13.7	7	42
	G 10134	0.9	5	43	9	1.3	303	13.4	7	46
Second	AGS 292	0.4	3	31	8	2.2	521	17.3	11	62
	G 9053	0.4	4	34	8	2.1	662	19.0	11	67
	G 10134	0.5	3	35	8	1.6	587	18.1	10	59
Third	AGS 292	0.7	4	39	7	1.2	663	18.3	10	74
	G 9053	0.7	5	39	7	1.4	632	18.1	10	68
	G 10134	0.8	5	43	7	0.7	686	19.2	10	67
SED genotypes (48 df)		0.0	0	1	ns	0.2	37.1	0.6	0	2
SED genotypes in sowing date (48 df)		0.1	0	1	ns	0.19	45.4	0.7	0	2
SED between dates, for same or different genotypes (±6 df)		0.1	1	2	ns	0.26	67.1	1.2	1	3

The second sowing had the greatest numbers of branches whereas the total node number per plant was less at the later sowings (Table 9).

Leaf area per plant was markedly less at the earliest sowing (248 vs. 589 and 660 cm^2/plant for the first, second and third sowings) as it was for variety AGS 292, however differences between varieties were less marked at the last sowing (Table 9).

Light interception at R_4 was considerably greater in the third and less in the second sowing (85, 72 and 91% for the first, second, and third sowings). Differences between lines and fertilizer rates were marginal but significant for interception at R_4 (Table 10) with superior values for G 9053 and the 60:60:60 kg $N:P_2O_5:K_2O$/ha fertilizer treatment. One week before harvest the influence of sowing date on light

Table 10. Light interception (%) at R_4 and 1 week before harvest as influenced by genotype, fertilizer treatment, and sowing date.

Treatment	R_4	Treatment		Week before harvest
AGS 292	81	Sowing 1	AGS 292	83.0
G 9053	85	1	G 9053	90.3
G 10134	83	1	G 10134	89.6
SED (48 df)	2			
60:60:60	85	Sowing 2	AGS 292	77.1
30:30:60	81	2	G 9053	87.0
30:120:100	82	2	G 10134	81.5
SED (48 df)	2			
Sowing 1	85	Sowing 3	AGS 292	89.0
Sowing 2	72	3	G 9053	91.4
Sowing 3	91	3	G 10134	93.1
SED (6 df)	1[a]			
		SED between lines (48 df)		3.6
		between sowings (6 df)		2.2
		lines within a sowing (48 df)		6.3

[a]No valid statistical test—for comparison only.

interception was similar to that at the R_4 stage; however, between lines light interception by AGS 292 was significantly less than that of the other two lines, and differences between fertilizer treatments were not apparent.

Total aboveground plant weight was significantly less at the first than at the other two sowings (13.4 vs. 18.1 and 18.6 t/ ha for the first, second, and third sowings). The greatest difference (significant at the 11% level) between lines was noted in the second sowing (Table 9). Pod yield was similarly affected by sowing date (7.7, 10.6 and 9.9 t/ha in the first, second, and third dates) but differences between lines were greatest in the first sowing (P=0.06). For graded pod yield AGS 292 was superior in the first and third sowings whereas for the second sowing G 9053 achieved highest graded yield.

Grading ratios increased with later sowings (44.3, 62.7 and 69.6%) and followed the trends in graded pod yield across lines and sowing dates in that AGS 292 had superior ratios in the first and third sowings with G 9053 superior in the second.

In a comparison between weather conditions across the three sowing dates, total evaporation and mean maximum temperature were similar (Table 11) whereas mean minimum was considerably cooler at later sowing (24.2, 22.9 and 19.7°C). Three typhoons occurred during the first and second sowing, for which total precipitation was 867 and 620 mm respectively, whereas rainfall was only 12 mm during the third sowing.

Table 11. Weather conditions and crop duration[a] during three sowings of vegetable soybean.

Sowing date	R_4 stage	Harvest	Mean max temp (°C)	Mean min temp (°C)	Total evaporation (mm)	Total precipitation (mm)
18 July	42	72	31	24	306	857
17 August	39	69	31	23	295	621
22 September	25	69	29	20	314	13

[a]Mean of three lines, days after sowing

The three typhoons occurred during the first 3 weeks of the second sowing, and water logging may have been responsible for the lower light interception measured at the R_4 stage compared to the other two sowings (Table 10) and the reduced aboveground and belowground dry weights (Table 9). Plants remained short yet branching was more profuse in the second sowing as measured at final harvest. High night temperature and to a lesser extent, flooding during typhoons, reduced total plant dry weight, pod yield, and the grading ratio during the first sowing, but nevertheless, yield levels were highly acceptable for a summer-grown crop. Although the third sowing did not experience typoons, the cooler temperatures and earlier flowering limited total and pod yields to those of the second sowing.

Higher nitrogen rates favored early light interception, but, perhaps due to high inherent soil fertility, no yield or yield component characteristic was significantly affected by fertilizer regime.

Cropping Systems

Household Gardening in Asia: Some Policy Implications for AVRDC

Summary

Household gardening can potentially alleviate undernourishment for millions of people. However, credibility of the benefits of garden projects, and sustained adaptive research leading to fine-tuned solutions are indispensible to success. Specific research areas related to development of methodologies for collection of household information relevant to adoption of gardens, to the design of simple seed technology and the identification of appropriate crop species and varieties are emphasized. To catalyze these activities, the setting up of a garden resource center at AVRDC is advocated.

Recommendations

Small-scale garden production can be a low-cost, low-risk and ecologically sound source of food and income for the most deprived groups. However, its relevance to a particular community depends on agroecological conditions, local needs and resources and the socioeconomic situation. Households will make the decision to engage in gardening or to accept improved technologies for their existing gardens on the basis of their compatibility with their own needs, not on the basis of professionally determined objectives or national policy goals.

Household gardens, like any other crop production system, need sustained research and extension support to develop solutions to problems and offer options that enhance their productivity. This garden system does not need an institutional approach to improve production. Nor is this necessary. Potential technical solutions to garden problems will be available from crop improvement or management practices that have been developed for marginal production conditions. Developing and delivering viable garden technology will also require the creation of a linkage between on-station research and the final users of the technology—the farming households.

Household gardens, or resource-poor agriculture in general, may not obtain the gross production impact that is realized by directing technology towards large- and medium-scale commercial production. But, as the Green Revolution experience indicates, gross output is somewhat meaningless if 800 million people (two-thirds of whom live in Asia) remain chronically hungry despite per capita caloric supply amounting to 107% of the total requirement in 1985. The extent of undernourishment in nutrients (vitamins, minerals and protein) is undoubtedly greater. However, increasing food supply alone is not a solution if the poorest of the poor do not have access to it.

This is especially true for horticulture. At least in the case of cereal crops, many developing countries, fearing mass starvation in the 1950s and 1960s developed technologies that provided quick increases in aggregate food production. Public procurement and subsidized sales were used to ensure that resource-poor rural households were able to benefit as consumers (inadequately though). But no such distributive policies to benefit the neediest groups exist for horticultural products. Hence, increasing commercial vegetable production, even if it does reduce prices and extend availability both geographically and seasonally, is unlikely to increase vegetable consumption among cash-poor marginal households which make up three-quarters of the developing world's poorest households. Capital-intensive, surplus-oriented technology is beyond their reach to earn income as producers. Meanwhile, habitat destruction and commercialization of agriculture have displaced many wild foods and indigenous crops that used to ensure a balanced diet for deprived families.

There is an imperative need, therefore, for horticultural research to move from an exclusive focus on maximizing gross production impact per unit of research investment to a broader economic and

consumption impact that puts a greater stress on small-scale marginal production systems such as household gardens.

The following specific areas have been identified for policy, research and development support:

Policy advocacy. Although, many governments have incorporated garden promotion into their national plans, support for household gardening remains marginal. Governments are not convinced that promoting household production is an effective way of addressing the food and income needs of the poorest sector. Microlevel studies that document the nutritional and economic impact of small-scale traditional gardens and introduced project gardens complemented by macro surveys on the extent of household production and its total monetary value are needed to influence national agricultural policy. Collecting data on small-scale continuously harvested plots is not easy. However, quite a lot of information is available from studies on farming systems, women in development and nutrition and consumption surveys.

Resource center. A resource center to (1) provide technical assistance and training services to projects, especially those that are organized by nongovernmental organizations, and (2) serve as a clearinghouse for the collection and exchange of information on project implementation strategies should be established.

At present, the International Institute of Rural Reconstruction in the Philippines (IIRR) is the only organization involved in training project personnel in biointensive gardening techniques. IIRR has also distributed its biointensive gardening kit worldwide. There is no other national or international organization that caters to garden project designers and managers. There is no body of accumulated knowledge to fall back on. The report of the AVRDC/UPWARD Household Garden Projects Workshop (Midmore et al. 1991) will make a contribution in this direction since it outlines successful implementation strategies and common pitfalls based on the experiences of practitioners. Also, the establishment of a regular newsletter or support for an existing one—such as "Gardens in Development"—would serve as a focus for an eventual network of garden-related institutions, scientists and project designers.

Adaptive research. An array of potential varieties and cultural practices that are appropriate to low external input, multicropped subsistence production are already available on-station. Hence, in the immediate future, the focus will be on testing and adapting technologies to specific environments with the participation of the user households, fine-tuning the proposed solutions to their needs and circumstances, evaluating the introduced technology and transferring it to the extension services for dissemination. An international center is not as well positioned as national programs to do this sort of adaptive research on a sustained basis. However, since nothing like it is being done at the national level (with the exception of Bangladesh), a well-documented and publicized internationally-sponsored effort can provide both a model test case as well as guidelines to agricultural research institutions in developing countries.

Rapid appraisal, design and evaluation techniques. One of the main criticisms of adaptive research employing participatory approaches is their high cost due to regional specificity. Developing mapping techniques that correlate agroecological zones with the biological structure of the garden system could greatly simplify project appraisal and design. Guidelines for standardizing the collection of information about household organization (who gardens? what changes will the family have to make to adopt the new technology and will they be feasible?), the role of garden production within the household economy, the availability of resources and factors of production, local institutional structures and production constraints, would enhance the capability of adaptive research to reach marginal households more effectively. Finally, current methodologies for evaluation of garden projects are extremely unsatisfactory. The more rigorous strategies are either impractical (maintaining elaborate consumption or production records at the individual family level) or extremely costly (monitoring serum levels of vitamin A). The simpler ones are ambiguous (project cost per garden established) or misleading (relative nutrient cost). Low-cost yet effective evaluation methodologies that clarify the objectives of gardening interventions while measuring their impact would relieve the paucity of solid evaluative studies that is stopping funding agencies from investing in garden projects.

Seed production, storage and packaging. Supply of good quality seed has been the single major infrastructural constraint to successful promotion of household gardening. Stressing the use of locally available species and varieties is one solution to the problem. Research on sustainable local seed production

systems is another. Other potential research areas concern low-cost storage and packaging of seeds. AVRDC also needs to link up with nongovernmental organizations (NGOs) and the private seed industry to quickly pass on improved varieties and selections—the official channels are much too slow and unreliable in reaching small-scale household producers.

Crop improvement. Most crop improvement research at AVRDC and the national research centers has focused on the needs of commercial growers. Visual appearance, transportability, high yields, short growing periods, narrowly confined harvests, ease of mechanization and postharvest processing are some of the characteristics that vegetable breeders conventionally aim for. However, the requirements of marginal farmers are often at odds with these breeding goals. For instance, small but continuous harvests may be preferred by subsistence producers to large, one-shot harvests. Poorer households are rather more tolerant of defects in shape or blemished appearances than middle-class urban consumers. Crops grown under household garden conditions (shading, poor soils, low application of capital inputs) are also subject to different stresses compared to those grown in monocropped commercial systems.

Research priorities in entomology, plant pathology and virology, and pest and disease problems experienced in polycropped gardens are seldom the same as those faced by commercial farmers. There is also much room for developing alternative pest management for gardens, perhaps beginning with the collection of available information on species combinations that effectively deter certain pests, and developing low-cost biocides brewed from locally available plants and herbs.

Vegetable Soybean in Cropping Systems: Effect of Residues on Soil-N Dynamics and Growth of Two Vegetable Species

Summary

Intensive vegetable production systems often lead to decline in soil fertility and productivity over time. The scope for inclusion of vegetable soybean within intensive vegetable production systems, to stem the decline, was studied. Release of nitrate-N reached a peak 10 days after incorporation of soybean residues, and subsequently declined when the field was flooded. Yields of the two test crops, Chinese cabbage and kangkong, planted one month after incorporation of vegetable soybean residues, were not enhanced by vegetable soybean residues. Yield of Chinese cabbage was generally reduced if aboveground soybean residues were incorporated, although aboveground plant weight 3 weeks before harvest was promoted in plots without fertilizer. Rotation with vegetable soybean dramatically reduced yield of kangkong (by 4–6 t/ha). This experiment will continue to be monitored over a number of years.

Introduction

Continuous cropping of vegetables without rotation with fallow or green manure crops often leads to soil with low organic matter content and fertility. Extreme deterioration of the physical and chemical structure of the soil leads to low yield. Reduced yields often prompt farmers to add more high-cost chemical fertilizers to their crop to maintain their yields.

Instead of increasing the chemical fertilizer inputs, different alternatives should be introduced to compensate for the loss of fertility. Rotating crops with legumes as green manure may help to maintain and promote the organic matter content and fertility of the soil. The ability of legumes to produce their own symbiotically fixed nitrogen also makes them good sources of nitrogen.

An experiment was therefore carried out to determine the residual effect of vegetable soybean as a green manure on the subsequent crops, Chinese cabbage and kangkong. In this trial, the legume crop itself is a marketable product, which should enhance its economic suitability to the rotation system.

To obtain the greatest benefits to subsequent crops in rotation following legumes, it is important to know the supply of nitrogen (N) available to crops. The N of plant residues is not readily available, and has to go through processes of decomposition and mobilization.

Data were therefore collected to evaluate the decomposition rate of vegetable soybean residues in the soil. This is important when understanding the pattern of nitrogen released by the plant residues to obtain efficient use of N and to minimize losses through leaching. A buried bag technique was tested.

Materials and Methods

Vegetable soybean

Vegetable soybean planting was arranged in a randomized complete block design with two control plots in which vegetable soybean was not planted. All treatments were replicated three times. The experiment included the following treatments; fertilizer (with or without), variety G 10134 or AGS 292, residue practice (soybean tops left or removed from the field), and two checks (no vegetable soybean, with or without fertilizer).

Vegetable soybean was planted on 22 March. Field plot size was 4 m × 4 m and the spacing for soybean was 50 cm between and 10 cm within rows; with two plants per hill. The fertilized plots received 20-60-60 kg NPK/ha as a basal fertilizer and 20 kg N/ha was applied twice as a side-dressing.

AGS 292 was harvested on 27 May and G 10134 on 3 June. Total plant yield and number and total pod weight were determined from a bordered area of 1 m^2. Pod number and weight, nodule number and weight, and plant and root weights were determined on six randomly chosen soybean plants.

Depending on residue practice (removal or in situ incorporation of aboveground plant material), soybean was chopped and rototilled into the soil.

Subsequent crops

Each plot was split into two halves, and on each half a subsequent crop was planted on 2 July. Chinese cabbage was planted into 1.5-m wide beds with spacing of 40 cm within and 75 cm between rows. NPK applied as a basal fertilizer was given at a rate of 0-90-60 kg/ha and twice after 10 and 20 days 0-30-60 kg/ha was applied as a side-dress fertilizer. Kangkong was drilled in 1.5-m wide beds with a 25 cm between-row spacing. It received 0-100-34 of NPK/ha as a basal fertilizer and as a side-dressing K was applied at 33 kg/ha, 10 and 20 days after sowing.

Crop cover of Chinese cabbage was measured four times (on four plants within each plot), starting 2 weeks after transplanting. At 3 weeks after transplanting, stem and root weights were measured on four cabbage plants from each plot. At harvest (12 August), 6 weeks after planting, total weight of cabbage, number of unwrapped leaves, head weight and head number were measured by harvesting a bordered area of 4.8 m^2. Root and aboveground weights of Chinese cabbage were measured on two plants per plot.

Leaf area of kangkong (10 plants) was measured twice, 1 week before and at harvest time (31 July). Stem and root weights were measured on 10 plants at both sampling and at harvest time. Total yield of kangkong was measured from a bordered area of 2 m^2. Average plant height (base of stem to growing point) at harvest was measured on 10 plants from each plot.

Analysis of soil N content was done before and after the planting of Chinese cabbage and kangkong.

Decomposition rate of vegetable soybean

The study of the decomposition rate of vegetable soybean was limited to the treatments where no fertilizer was added and where the tops of soybean were incorporated into the soil. Three replications of both varieties and the control (no soybean, no fertilizer) were included.

Topsoil was collected from the plots at the time of soybean harvest. Soil was air-dried and passed through a 2-mm sieve.

Plant (aboveground) and root samples of vegetable soybean (minus the harvested pods) were collected from the same plots as the soil. Fresh samples were chopped, and 10 g of root or shoot were kept for each bag. Samples of shoots and roots were either stored inside plastic bags at ±4°C or oven-dried at ±70°C for 48 hours. The dried samples were ground to powder.

Each sample, 10 g of fresh or 3.5 g of dried material, was mixed with 250 g of air-dried soil and some water (±20 ml), then placed in net bags made of synthetic fiber. Control bags contained 250 g air-dried soil. The bags were labelled and closed with iron string. They were buried horizontally to a depth of 15 cm, into original plots, where beds were prepared for Chinese cabbage planting. The beds were lightly watered before incorporation of the bags.

The bags were withdrawn periodically at 2, 5, 10, 21, 30 and 60 days after incorporation. The plant and root material, except powder, which remained in the bags was removed from the soil before

determination of soil moisture and soil chemical properties. Inorganic nitrogen, NH_4^+ and NO_3^-, was extracted by 1 N KCl and determined by the distillation method. The results were corrected for soil moisture, which was measured by the oven-dry method at 105°C. The soil samples for the analysis of pH, total carbon content, total nitrogen and C/N ratio were air-dried and sieved through a 2-mm sieve. The pH was measured on soil-water suspensions (2:5). The total nitrogen content of the soil was analyzed by regular Kjeldahl method using H_2SO_4 and selenium for the digestion step. The total carbon was analyzed by Walkley-Black-method, and calculated by regression analysis against hipuric acid (60.33 % C) standard.

The organic matter, total nitrogen and C/N ratio of vegetable soybean plant and root material at harvest were measured. All the above mentioned soil properties were measured on the soil before soybean incorporation.

Results and Discussion

Vegetable soybean production

Greatest total aboveground biomass production of vegetable soybean was achieved with fertilizer applications (21.8 t/ha vs. 20.6 t/ha without fertilizer), but the difference was not significant. Variety G 10134 gave significantly higher yield than variety AGS 292, with or without fertilizer. The higher biomass production of variety G 10134 is partly due to the fact that it was harvested 8 days later than AGS 292. Before the harvest of AGS 292, the field lacked water, but G 10134 was irrigated twice after the harvest of AGS 292.

Variety G10134 achieved a greater pod yield than did AGS 292, but the difference was not significant (Table 1). Variety G 10134 produced significantly more roots than did AGS 292; both root fresh and dry weight were more than 50% higher in the former.

Table 1. Effect of fertilizer (F) on yields and yield components of two vegetable soybean varieties.

Treatment	Aboveground biomass (t/ha)	Pod yield[a] (t/ha)	Root wt.[a] (t/ha)	Nodule wt.[a] (t/ha)	Total biomass[a] (t/ha)
AGS 292 with F	20.1	12.2	0.6	0.4	21.1
G 10134 with F	23.5	12.5	1.1	0.7	25.3
AGS 292 without F	19.8	12.0	0.6	0.6	20.9
G 10134 without F	21.5	12.4	1.0	0.8	23.3
SED between varieties (6df)	0.7	ns	ns	ns	0.9
SED between fertilizer (6df)	ns	ns	0.0	0.1	ns

[a]Based upon six plants per plot.

Fertilizer applications resulted in remarkably lower numbers of nodules per plant. Nodule weight was also slightly reduced. The presence of excess soil mineral N inhibits root nodule formation during seedling formation, and an addition of mineral N may cause nodule senescence, which decreases N_2 fixation.

Although nodule numbers were similar between varieties, the nodule fresh weight of G 10134 was greater by 35%. This difference was greater in plots with added fertilizer.

Since the total biomass production is important when plant material is used as green manure, and the variety G 10134 produced much more biomass than AGS 292 both with and without fertilizer application, it might be expected to enhance more the organic matter content and fertility of the soil. Also, more nitrogen might be released for the growth of subsequent crops. However, because extra irrigation enhanced the growth of G 10134 after harvest of AGS 292, and because of 3–4 days longer growing period of G 10134 which is a potential disadvantage in intensive cropping, it is difficult to say whether the variety G 10134 would be much better as green manure than AGS 292 (Table 2).

Decomposition of vegetable soybean and influence on soil properties

pH values. For the first 2 days the pH values of the soil suspensions decreased slightly in all but plant (i.e. aboveground) treatments of variety AGS 292 (Figs. 1 and 2). Over the subsequent 4 weeks, the values increased gradually, except during the rainy period, 14–20 days after incubation, when the values were

Table 2. Some properties (% dry weight basis) of the vegetable soybean varieties added to the soil.

	Plant part	Total N (%)	Total C (%)	C/N ratio
G 10134	Plant	2.4	46.8	19.8
	Root	2.2	45.2	20.5
AGS 292	Plant	1.9	47.0	25.2
	Root	1.9	47.5	25.2

largely unchanged. The rainfall during the experiment is presented in Figure 3. The pH values of powder treatments (of both varieties) increased at a much higher rate than the pH of chopped treatments. After reaching the peak in 21–30 days of incubation, the pH of all treatments tended to decrease toward the end of the experiments (60 days).

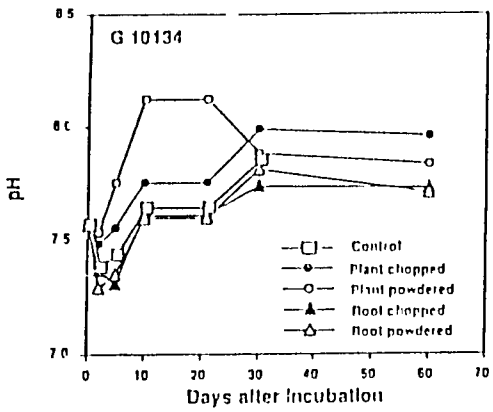

Fig. 1. Fluctuation in soil pH during the decomposition of vegetable soybean (G 10134) residues.

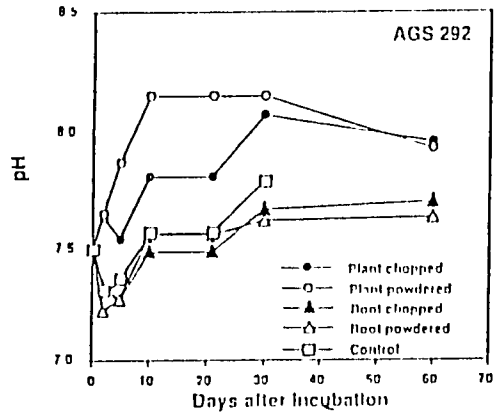

Fig. 2. Fluctuation in soil pH during the decomposition of vegetable soybean (AGS 292) residues.

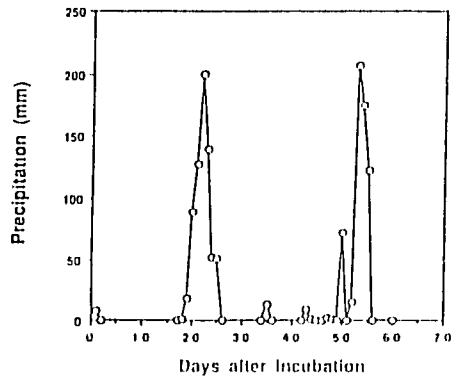

Fig. 3. Daily rainfall during the experiment.

Total carbon content. Immediately after incubation, the carbon content in plots with either variety of vegetable soybean showed rapid increase in all treatments reaching a maximum in the first 2 days (Figs. 4 and 5). During the subsequent 3 days the total carbon content decreased almost to the original level, except in powder treatments, which decreased at a slower rate over the whole of the incubation period. The considerably higher organic matter content of powder treatments is due to the complete mixing of the powder which provided organic material directly to soil, while for chopped treatments, the undecomposed material was removed from the soil after withdrawal of the bags.

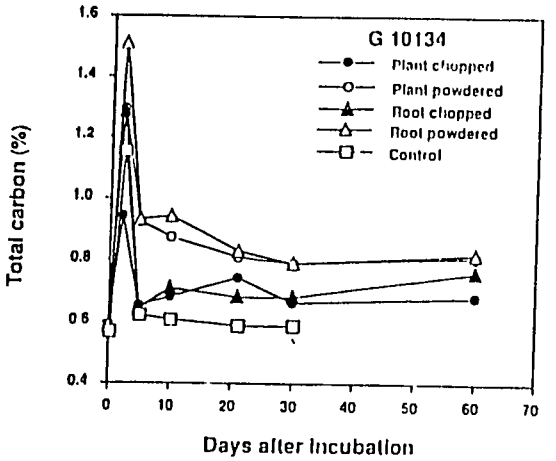

Fig. 4. Changes in the organic matter content of soil during the decomposition of vegetable soybean (G 10134) residues.

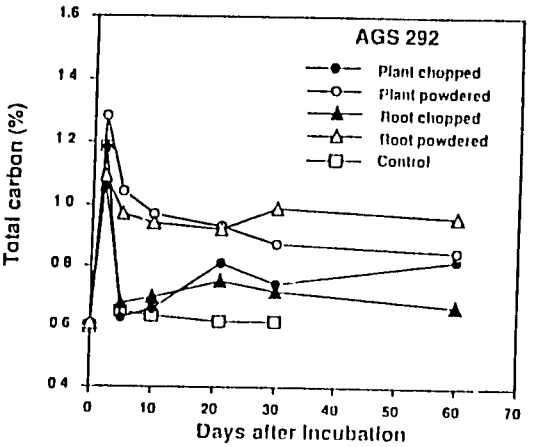

Fig. 5. Changes in the organic matter content of soil during the decomposition of vegetable soybean (AGS 292) residues.

Total nitrogen content. The incorporation of organic material into the soil was accompanied by a rapid increase in the N content of the soil. The peak was reached on the 2nd or 5th day after application in all but treatments with chopped plants (Figs. 6 and 7). Greatest values were apparent for AGS 292. Powder treatments increased the N content of the soil considerably more than chopped treatments. This again was due to higher amounts of organic material intimately mixed with the soil. The slower rate of nitrogen accumulation in chopped treatments was also likely to be due to low soil moisture content, which prevented the beginning of decomposition. The total N content of control soil was unchanged, and was considerably lower than the N content of the treatments with added organic material.

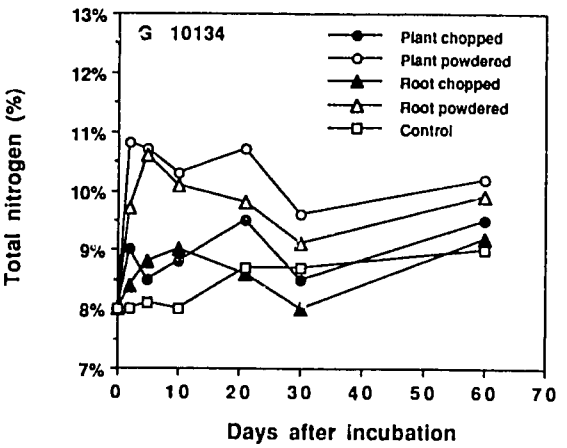

Fig. 6 Changes in the total nitrogen content of the soil during the decomposition of vegetable soybean (G 10134) residues.

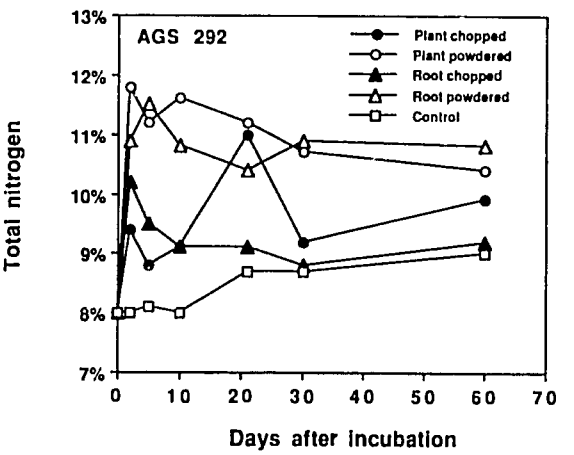

Fig. 7. Changes in the total nitrogen content of the soil during the decomposition of vegetable soybean (AGS 292) residues.

After 10 days of incubation the N content of soil in all treatments decreased until the 30th day, except in treatments that incorporated chopped plant residues and the control, when values increased toward the end of the incubation. The high peak in N content of the chopped plant treatments following 3 weeks of

incubation was attributed to the heavy rain accelerating the decomposition of the leaves. (Visual observation indicated the rapid decomposition of the leaf component between 10 to 20 days of incubation—corresponding to the wetting of the soil.)

C/N ratio. The C/N ratio increased immediately after the application of organic material, reaching a peak after 2 days of incubation in all treatments (Figs. 8 and 9). The ratios followed patterns similar to the total carbon fluctuations, since fluctuations and absolute values for total soil N were much less apparent.

The organic matter and percent N content of the soil increased considerably after soybean incorporation. However, the ratio of organic material to soil in bags was higher than in reality (×10), and thus the real degree of change in soil organic matter content in the fields cannot be estimated.

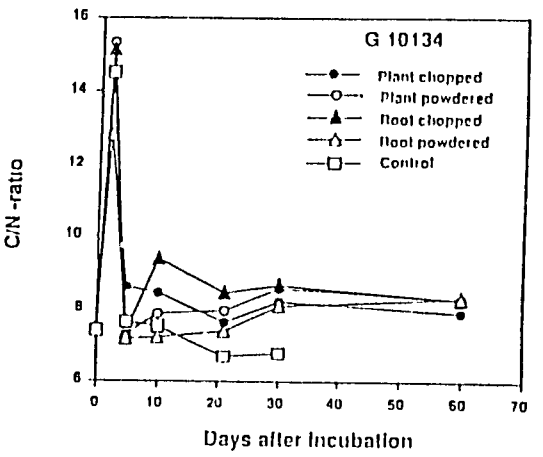

Fig. 8. Changes in the C/N (carbon to nitrogen) ratio during the decomposition of vegetable soybean (G 10134) residues.

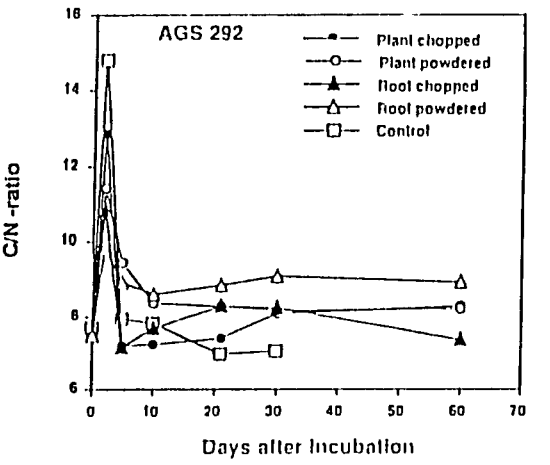

Fig. 9. Changes in the C/N (carbon to nitrogen) ratio during the decomposition of vegetable soybean (AGS 292) residues.

Nitrate-nitrogen. The amount of NO_3-N mineralization by chopped treatments reached a peak after 5–10 days of incubation (Figs. 10 and 11). The NO_3-N release by variety G 10134 was slightly slower than by variety AGS 292. A more rapid release of NO_3-N by chopped treatments is likely to be due to the decomposition of the easily decomposable substances. The high amount of NO_3-N released by control treatment (no soybean) was partly due to the decomposition of soil organic matter and higher initial NO_3-N content of the soil upon incorporation. This soil did not lose inorganic N to crop use since it was fallow during the vegetable soybean experiment. Also, the control treatment did not contain any soybean residues, which often tie up soluble nitrogen from the soil at the beginning of their decomposition.

Powder treatments, except the root powder of AGS 292, released less NO_3-N than chopped treatments. The lower release and slight immobilization of NO_3-N by powder treatments is attributed to the higher content of easily decomposable carbon, which is known to promote nitrogen immobilization in soil.

After 10 days of incubation the NO_3-N release decreased drastically in all treatments. The decrease is attributable to the heavy rain (18–20 days after incorporation, Fig. 3) and flooding, which often results in leaching of easily soluble nitrates. The bag material used allowed the penetration of water. Also, the buildup of soil microorganisms stimulated by application of decomposable material, might have reduced the available NO_3-N in soil by using NO_3-N for building cell protein.

After a 21-day incubation NO_3-N increased rapidly, decreasing again after 30 days of incubation toward the end of the experiment in all but root powder treatments. The increase could be caused by the recovery of the soil bacteria, since moist soil appears to be more favorable for bacterial activity than does dry soil.

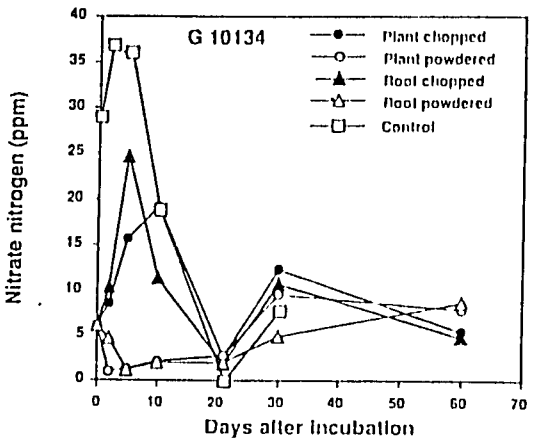

Fig. 10. Fluctuation of nitrate nitrogen during the decomposition of vegetable soybean (G 10134) residues.

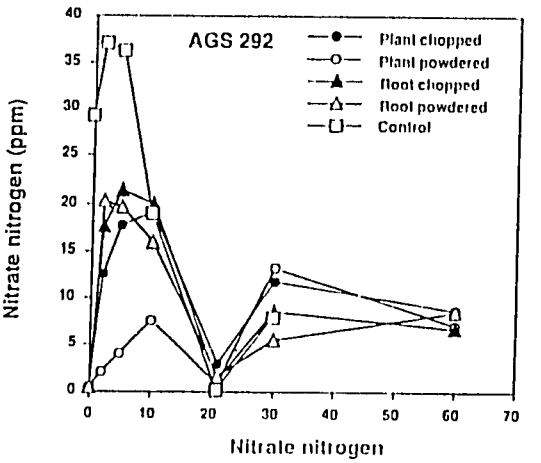

Fig. 11. Fluctuation of nitrate nitrogen during the decomposition of vegetable soybean (AGS 292) residues.

Ammonium-N. The NH_4-N release showed considerable fluctuations between different treatments for the first 10 days (Fig. 12 and 13). The NH_4-N release by root treatments of variety AGS 292 reached a maximum in 2 days, then decreased rapidly to low levels. This may be due to NH_4-N volatilization which increases with increasing pH, or to drying of the soil and conversion of NH_4-N to NO_3-N. Plant treatments showed a slight decrease over the same period; for the first 2 days the NH_3-N content of chopped treatments for variety G 10134 decreased, then increased for the subsequent 3–7 days. The NH_4-N levels of powder treatments stayed rather low.

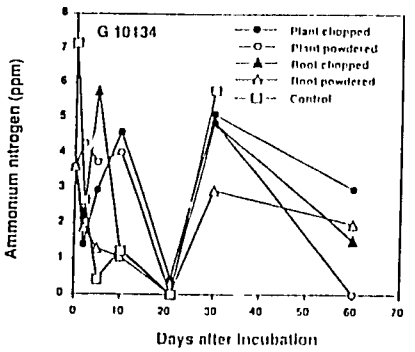

Fig. 12. Fluctuation of ammonium nitrogen during the decomposition of vegetable soybean (G 10134) residues.

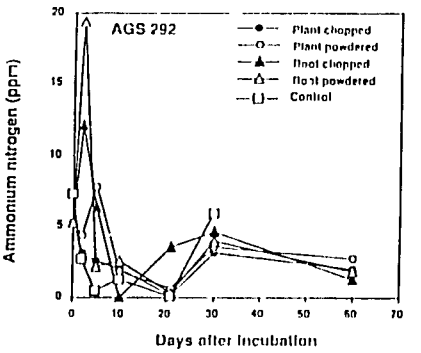

Fig. 13. Fluctuation of ammonium nitrogen during the decomposition of vegetable soybean (AGS 292) residues.

After 10 days of incubation no NH_4-N was released by any treatment. After 21 days of incubation, there was a recovery in NH_4-N release, possibly due to the recovery of soil bacteria stimulated by remoistened soil. After the recovery of NH_4-N release, the levels continued to decrease toward the end of the incubation.

Yield of Chinese cabbage

Crop cover developed fastest where fertilizer had been applied earlier (Fig. 14). Despite large differences at the beginning of the growth between green manure and fertilizer treatments, they were no longer significant at the end of the growth period. Despite the faster rate of crop cover development by

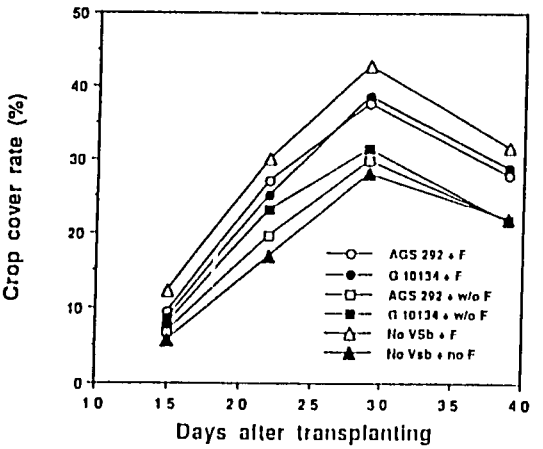

Fig 14. Changes in crop cover of Chinese cabbage.

fertilizer treatments, the stem weights at sampling time, about 3 weeks before harvest, indicated that the growth habit of Chinese cabbage was rather similar among treatments. There was, however, a tendency for stem weight at sampling to be less following the incorporation of variety G 10134 than AGS 292. On plots without fertilizer, growth at sampling was slightly promoted in plots previously planted to vegetable soybean. Between different treatments, fertilizer application alone had the highest head yield, average head weight and heading efficiency (ratio of head weight to unwrapped leaf weight), while treatments without any kind of fertilizer had the lowest. However, soybean green manure treatments were not significantly smaller. Fertilizer alone had the highest head number per unit area, but there were no significant differences between any treatments. When green manure was combined with fertilizer application the practice of incorporating the tops of soybean in general gave poorer results than when tops were removed. However, when green manure was used alone, incorporating the tops of G 10134 promoted the results, but this was not so for AGS 292.

Differences between soybean varieties and between residue practices were small. However, removing the tops of soybean from the field seemed to give slightly better results than leaving them (Table 3).

Table 3. Effect of different fertilizer and residue practices on the yield and other characteristics of Chinese cabbage.

Treatment	Total yield (t/ha)	Head wt (g)	Heading effiency[a]	Stem wt at sample
AGS 292 (r) with F	19.7	194	0.3	199
AGS 292 (1) with F	18.3	268	0.3	248
G 10134 (r) with F	20.0	185	0.3	170
G 10134 (1) with F	18.8	197	0.3	143
AGS 292 (r) without F	16.1	144	0.3	226
AGS 292 (1) without F	12.6	129	0.2	140
G 10134 (r) without F	12.5	132	0.3	169
G 10134 (1) without F	13.4	134	0.3	180
No vsb with F	21.7	230	0.3	170
No vsb without F	14.5	179	0.3	115
SED between fertilizer (14df)	0.9			

(r) = soybean tops removed from the field.
(1) = soybean tops incorporated.
[a]Marketable/total yield.

The lower yield in treatments with green manure alone indicates that the N release is too slow to meet the needs of fast-growing Chinese cabbage.

Yield of kangkong

Yield, plant height and leaf area recorded in treatments without soybean green manure were generally greater than in those with soybean green manure. However, the differences between treatments for the latter two attributes were not significant (Table 4).

Table 4. Effect of different fertilizer and residue practices on the yield and other characteristics of kangkong.

Treatment	Yield (t/ha)	Plant height (cm)	Leaf area (cm^2)	Stem wt at harvest (g)	Stem wt at sampling (g)
AGS 292 (r) with F	7.7	14.1	51.1	10.9	5.7
AGS 292 (1) with F	7 9	12.8	45.9	11 5	4.8
G 10134 (r) with F	8 7	13.5	53.8	15.3	4.8
G 10134 (1) with F	7.3	13.0	37.9	9.8	6.1
AGS 292 (r) without F	6.1	13.3	42.3	9.3	5.0
AGS 292 (1) without F	6.7	12.7	36.1	10.0	5.3
G 10134 (r) without F	6.1	12.4	42.4	8.8	6.0
G 10134 (1) without F	7.5	13.8	42.5	12.0	5.0
No vsb with F	12.3	14.3	52.8	15.1	7.2
No vsb without F	10.9	15.2	53.5	15.8	6.8
SED between plots with soybean, no vsb + F, and no vsb no F (25df)	0.3	ns	ns	2.9	ns

(r) = soybean tops removed from the field.
(1) = soybean tops incorporated.

The positive effect of fertilizer on the yield of kangkong was consistent, but not significant. At sampling time, 1 week before harvest, the leaf area and stem and root weights of kangkong were rather similar between all the treatments, indicating that nitrogen release by green manure was sufficient at the earlier stage of growth, but that growth was more retarded by final harvest time because of the lack of nitrogen. The yield of kangkong might also have been reduced by immobilization of available soil nitrogen by soybean residues.

Differences between residual effects of soybean varieties on kangkong yield were not significant; however, yields in plots planted to variety G 10134 were slightly greater than those planted to AGS 292. There were no real differences between residue practices on kangkong yields.

General Conclusions

To obtain maximum yield of Chinese cabbage in rotation with green manure, the organic material should be well decomposed and combined with fertilizer application both of which ensure a sufficient nitrogen supply for the growth of cabbage. It might be unreasonable to expect a significant benefit to be attributable to the residual effects of one crop of vegetable soybean. Therefore, it is recommended that the experiment follow the increase of organic matter over a number of seasons for each treatment.

There was no beneficial residual effect of soybean green manure on the growth of kangkong. The rather unexpected high yield of kangkong obtained without any form of fertilizer suggests that other factors, such as flooding and original nitrogen supply in the soil, influenced the growth of kangkong. More information is needed to determine the residual effects of soybean green manure on kangkong.

Chinese cabbage and kangkong both grew too fast to obtain real benefits from incorporated soybean green manure. The differences between the responses of the successive crops to the previous fertilizer and to the green manure treatments were not totally comparable, since nearly 5 weeks elapsed between the harvesting of soybean and their planting. This may have reduced the available N supply to the Chinese cabbage and kangkong. As the decomposition study showed, the highest net immobilization of inorganic

nitrogen was during the first 5–10 days of incubation. Also, flooding resulted in leaching of soluble N. Some of the residual effects of soybean green manure will be evident in the future, since green manure has the advantage of enriching soil organic matter and maintaining soil productivity, which in pure vegetable cropping are often reduced to very low levels.

One benefit of using water accessible synthetic fiber as the bag material was that the moisture content inside the bags followed the fluctuations in the field soil moisture. Thus, the amounts of NH_3-N and NO_3-N released in bags rather reliably predicted the actual pattern (if not the actual quantity) of N released in the field.

Intercropping Peppers and Maize

Summary

Three experiments were run in Taiwan in which maize was intercropped with peppers in various varietal and spatial combinations. Intercropping with maize reduced CMV incidence in peppers, with tall grain maize being more effective than shorter sweet corn.

Yields of intercropped pepper never reached 50% of sole pepper cropping, but the yield reduction in pepper due to sweet corn was less marked than that by taller grain maize. The yield reduction in pepper by tall grain maize was less when planted on alternate double row ridges than if planted on the same ridge as pepper.

Since the mixtures of maize and pepper were rarely more productive than planting each crop in separate plots, further experiments are required to determine the minimum maize population which could effect reduction in CMV without reduction in pepper yields.

Introduction

Pepper yields in the tropics are often low as a result of poor agronomy and rampant virus infection. Appropriate management practices to overcome these constraints should improve crop productivity and economic returns for the producer.

Intercropping peppers with maize has the potential both to increase land productivity, through a more efficient use of on-farm and off-farm resources, and to reduce virus incidence, through the barrier effect of maize to the aphid virus vectors.

Various varietal and spatial combinations of intercrops of maize and pepper were studied in four experiments, three of which are reported here.

Materials and Methods

Peppers were transplanted on 31 August (experiment I), 25 September (experiment II) 1990 and 13 March (experiment III), 1991. All plots received 25 t/ha compost, and 200:120:120 kg/ha of $N:P_2O_5:K_2O$ as ammonium sulfate, superphosfate and potassium chloride, respectively. In experiment I and II both sweet pepper (var. Blue star) and hot pepper (var. Szechuan PBC 076-9-10-3 (OP)) were intercropped with the maize variety Tainan 351. In experiment III the hot pepper variety Hot Beauty (Known You Seed Co.) was intercropped with the sweet corn variety TN 236 and the grain corn variety TN 11 (Table 5). Following harvest of maize in experiment III some plots (i.e. where maize plants were completely removed) were planted with the AGS 292 variety of vegetable soybean.

Row direction was S/N in experiment I, S/N in experiment II and E/W in experiment III. In experiment III all treatments were transplanted on the same date, whereas in experiment I and II these varied according to treatment. In all experiments plot size was 30 m² (five beds, each 6-m long).

Data collected included the fresh yield of pepper, dry maize grain yield, fresh cobs for sweet corn, light interception (with a LI-COR LI-1000 radiometer) and infection of cucumber mosaic virus (CMV) on 20 plants per central portion of each plot. In experiment III numbers of aphids were also counted on 20 maize and pepper plants per plot. Data were subjected to analyses of variance.

Table 5. Experimental details.

Expt I and II Treatment	Description	Expt I Transpl. pepper	Expt I Sow maize	Expt II Transpl. pepper	Expt II Sow maize	Spacing (between × within row m) Pepper	Spacing (between × within row m) Maize	Total population/m²
HP	Sole hot pepper	31 Aug.	-	25 Sept.	-	1.0 × 0.3	-	3.3
SP	Sole sweet pepper	31 Aug.	-	25 Sept.	-	1.0 × 0.3	-	3.3
MZ	Sole maize	-	31 Aug.	-	25 Sept.	-	1.0 × 0.2	5.0
HZO	Hot pepper /maize same ridge	31 Aug.	31 Aug.	25 Sept.	25 Sept.	1.0 × 0.3	1.0 × 0.2	8.3
SZO	Sweet pepper /maize same ridge	31 Aug.	31 Aug.	25 Sept.	25 Sept.	1.0 × 0.3	1.0 × 0.2	8.3
HZ2	Hot pepper /maize same ridge	31 Aug.	7 Sept.	25 Sept.	20 Sept.	1.0 × 0.3	1.0 × 0.2	8.3
SZ2	Sweet pepper /maize same ridge	31 Aug.	7 Sept.	25 Sept.	20 Sept.	1.0 × 0.3	1.0 × 0.2	8.3
Experiment III Treatment								
PO	Sole hot pepper, one row per bed					1.0 × 0.3	-	3.3
PT	Sole hot pepper, two rows per bed					0.5 × 0.3	-	6.7
GO	Sole grain corn, one row per bed					-	1.0 × 0.2	5.0
SO	Sole sweet corn, one row per bed					-	1.0 × 0.2	0.3
PG1R	Pepper/grain corn same bed, remove maize at harvest					1.0 × 0.3	1.0 × 0.2	5.0
PG1C	Pepper/grain corn same bed, cut maize to pepper height at harvest					1.0 × 0.3	1.0 × 0.2	8.3
PG2R	Pepper/grain corn alternate bed, remove maize at harvest					(0.5 × 0.3)/2	(0.5 × 0.2)/2	8.3
PG2C	Pepper/grain corn alternate bed, cut maize to pepper height at harvest					(0.5 × 0.3)/2	(0.5 × 0.2)/2	8.3
PS1R	Pepper/sweet corn same bed, remove maize at harvest					1.0 × 0.3	1.0 × 0.2	8.3
PS1C	Pepper/sweet corn same bed, cut maize to pepper height to harvest					1.0 × 0.3	1.0 × 0.2	8.3
PS2R	Pepper/sweet corn alternate bed, remove maize at harvest					(0.5 × 0.3)/2	(0.5 × 0.2)/2	8.3
PS2C	Pepper/sweet corn alternate bed, cut maize to pepper height at harvest					(0.5 × 0.3)/2	(0.5 × 0.2)/2	8.3

Results

Experiment I

Neither sole hot pepper nor sole sweet pepper crops exceeded 60% light interception (LI) whereas maximum LI in sole maize or intercropped plots for both pepper types varied between 80 and 90% (Fig. 15). Initially LI was greater in maize plots intercropped with peppers and less in the maize intercrop treatment planted 1 week later than the rest, but by 100 days after transplanting (DAT) no differences between sole maize only or intercrops were evident.

Following maize harvest 125 DAT, LI was similar in sole and intercropped pepper plots, with a tendency for it to be greater in the sole plots, and in the hot pepper plots.

Sampling at 59 DAT showed the incidence of CMV in peppers was reduced by intercropping, more so in the treatment with simultaneous transplanting of pepper and sowing of maize. At the later sampling, although intercropping still reduced CMV incidence, the benefit was greater in the plots with later-sown maize (Table 6).

Cumulative yields of pepper over harvest dates are presented in Fig. 16. Major contributions to total yield were evident over the period 90–140 DAT and 240–280 DAT, the period 140-240 DAT representing

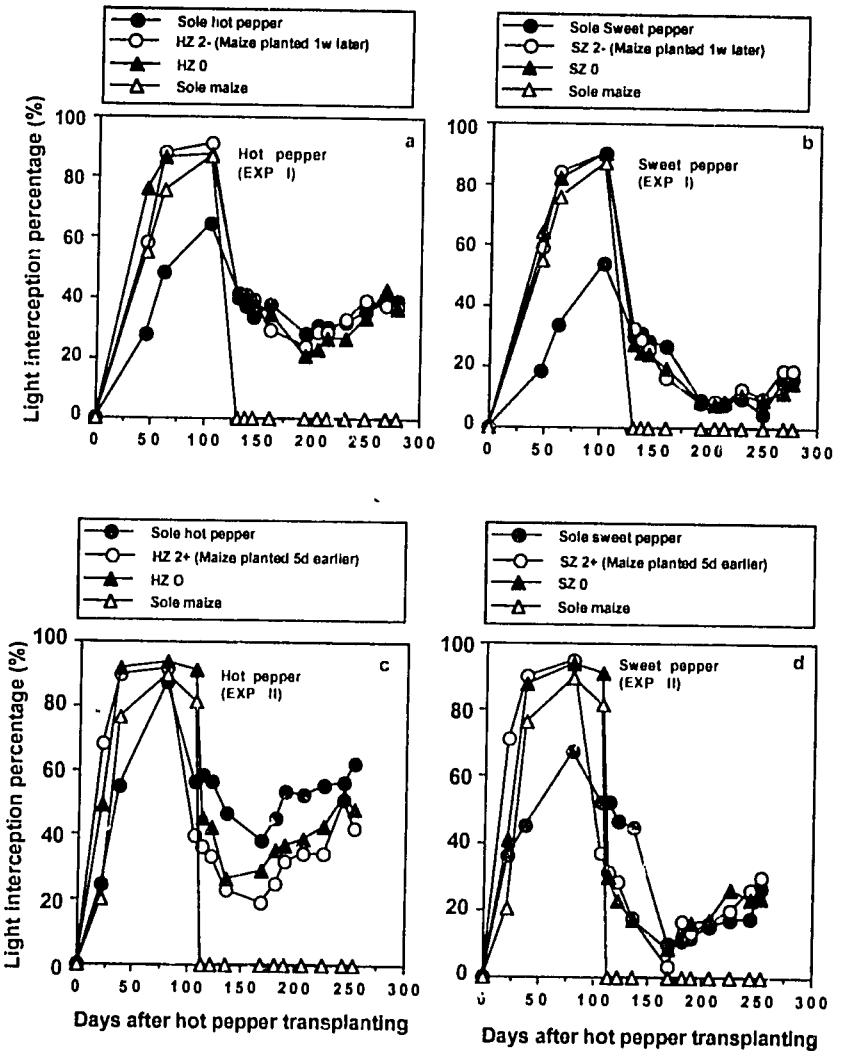

Fig. 15. Light interception of sole and intercrops in experiments I and II.

Table 6. Incidence (%) of CMV in sole and intercropped pepper plots in experiments I and II.

Crop	Treatment		Expt I 59 dat	Expt I 116 dat	Expt II 91 dat
Hot pepper	Sole	HP	50	97	83
	Same day sowing	HZ0	0	63	30
	Different day sowing	HZ2	27	40	7
Sweet pepper	Sole	SP	57	100	45
	Same day sowing	SZ0	13	70	47
	Different day sowing	SZ2	23	53	23
SED between treatment means			19	16	14
SED between treatment within a crop			-	-	19

the coolest (winter) period when fruit set was minimal. Intercropping severely reduced pepper yields, but less so for sweet pepper when sowing of maize was delayed.

Differences between maize yields in sole or intercropped plots were not significant, although there was a tendency for intercropped yields with sweet pepper to exceed, and for hot pepper to reduce yields, compared with sole maize yields.

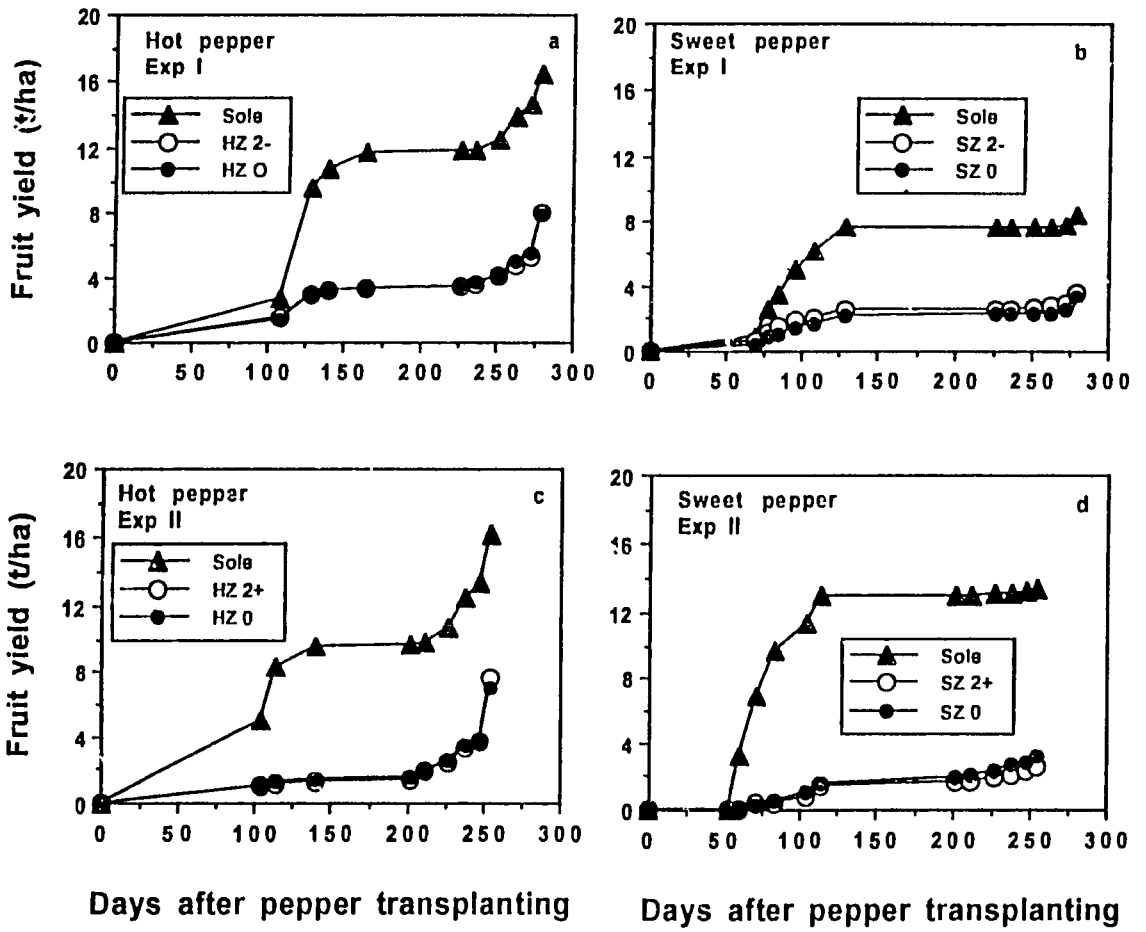

Fig. 16. Cumulative fruit yields of pepper in experiments I and II.

To determine whether productivity on the intercropped plots exceeded that of planting the crops on separate p[illegible]es of land, the Area Time Equivalency Ratio (ATER), which takes into account the opportunity [illegible] nd in the sole plots of the shorter season crop once that crop has been harvested, was used. Assuming [illegible] the intercrop was left until 280 DAT (Fig. 16), planting in sole crops would have been more advantageous (from the production viewpoint) than intercropping for both sweet and hot pepper (Table 7). If the intercrop had been terminated prior to the cool period (120–140 DAT, Fig. 16), intercropping of hot pepper would have been more productive than sole cropping, whereas for sweet pepper there was no advantage either way.

Experiment II

Sole crop LI for hot pepper exceeded 80% whereas for sweet pepper it did not achieve 70% (Fig. 15). Maximum LI was achieved 69 DAT in all plots, and declined thereafter, especially in sole hot pepper and plots in which maize was harvested. Minimum interception (±160 DAT) varied from 20–40% in hot pepper to 0–10% in sweet pepper, and increased to 40–60% and 20–30% respectively by 255 DAT. After maize

Table 7. Area time equivalency ratios (ATER) for intercrop treatments (ATER=((Y (IA)/TI)/)Y(SA)/TSA)) + ((Y(IB)/TI)/Y(SB)/TSB)) when Y=Yield, T=time, IA= intercrop B, SA=sole A, where SB=Sole B, I=time from initial planting to final harvest of intercropped plots).

Treatment				Intercrop period (days) 280	HZ=165 SZ=130
Experiment I	Hot pepper	Same day sowing	HZ0	0.9	1 3
	Hot pepper	Different day sowing	HZ2	0.9	1.3
	Sweet pepper	Same day sowing	SZ0	0.9	1 0
	Sweet pepper	fferent day sowing	SZ2	0 9	1.0
Experiment II	Hot pepper	Sa :e day sowing	HZ0	0.9	0.8
	Hot pepper	Different day sowing	HZ2	0.9	0.8
	Sweet pepper	Same day sowing	SZ0	0.7	0.9
	Sweet pepper	Different day sowing	SZ2	0 7	1.0

harvest, LI of intercropped hot pepper did not reach that of sole hot pepper, although for sweet pepper once minimum LI was reached, further LI was similar across treatments.

Incidence of CMV was evaluated only once (91 DAT) during this experiment, by which time sole plots of hot pepper had 83% infection, compared to marked reductions in the intercropped plots (Table 5). For sweet pepper the only reduction in CMV incidence was evident in plots transplanted into an earlier (5 day) sown maize crop.

Cumulative pepper yields showed similar trends to those in experiment I, but yields before the cool winter were notably less for hot pepper and greater for sweet pepper (Fig. 16). Relative yield reduction of both hot and sweet pepper in intercrop treatments was greater in experiment II than experiment I. Following the cool spell renewal of fruit production was superior in hot than sweet pepper.

Maize yields did not differ significantly between treatments, although there was a tendency for the maize sown before the pepper to have superior yields to that sown at the time pepper was transplanted.

In no treatment did the ATER markedly exceed unity, indicating that sole plot planting would be superior to intercropping.

Experiment III

Light interception by sweet and grain corn was incomplete, reaching 65% by 60 DAT (Fig 17a). Both single and double row (PO and PT) pepper reached 90% LI, with the latter reaching the maximum 9 days earlier (Fig 17a). Pepper and sweet corn planted on the same bed had superior LI to intercropped paired rows of each crop on separate beds, but there was no noticeable effect of removing or cutting sweet corn at pepper canopy height on LI (Fig. 17b). A similar improvement of LI in associated planting of pepper and grain corn on the same bed over intercropped paired rows of each crop on separate beds was evident, an effect which was maintained after maize harvest (Fig. 17c). Following harvest of sole maize, LI of the subsequent vegetable soybean crop reached > 60% by 120 DAT. Intercropping of soybean in pepper plots where maize was removed resulted in increases in LI only when planted as paired rows between paired pepper rows. There was no marked influence of maize type (sweet or grain) on the subsequent pepper LI once maize was cut or removed.

Thirty-seven days after transplanting, virus incidence was almost nonexistent, but by 67 DAT up to 0–27% incidence was evident, with maximum values in the low density sole pepper crop and least incidence in the pepper planted on the same bed as grain corn (Fig. 18). Alternate paired rows of pepper and high density sole maize had similar, intermediate infection levels. By 88 DAT, incidence of CMV had risen to 55–58% in sole pepper plots. Taller grain maize continued to suppress CMV incidence (10–14% incidence) compared to the shorter sweet corn (29–32%). Aphids were more prevalent on maize than pepper plants 37 DAT, and more so in maize intercropped with pepper on the same than on alternate double row beds (Table 8).

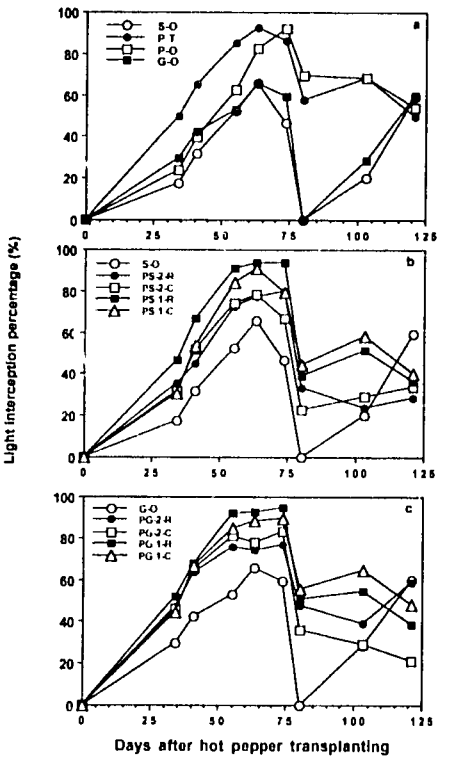

Fig 17. Light interception of sole and intercrops in experiment III.

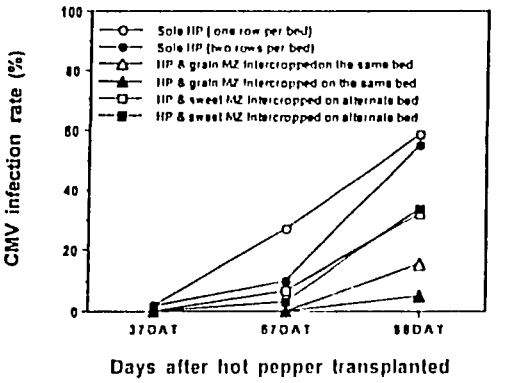

Fig. 18. Progress of cucumber mosaic virus infection in hot pepper plants in experiment III.

Table 8. Influence of intercrop treatments in experiment III on aphid populations on pepper and maize plants 37 dat (number per plant).

Treatment	On maize	On pepper
PO Sole pepper, 1 row/bed	-	1.3
PT Sole pepper, 2 row/bed	-	1.0
GO Sole grain maize	6.3	-
SO Sole sweet corn	9.3	-
PG1 Pepper/grain maize same bed	8.2	0.7
PG2 Pepper/grain maize alternate bed	3.7	0.7
PS1 Pepper/sweet corn same bed	9.0	0.0
PS2 Pepper/sweet corn alternate bed	7.5	0.3

High density pepper plantings (treatment PT) gave 45% greater cumulative yield than the lower density treatment (PO, Fig. 19), which itself was 100% more productive than the intercropped pepper yields. Pepper yields when intercropped with sweet corn were essentially similar across treatments (Fig. 19a); however, double paired row planting of grain maize with pepper led to greater pepper yield than if planted together on the same bed (Fig. 19b). Although the reducing effect of maize intercrops on pepper yield was evident even after maize was removed, maize type had no effect on pepper when both crops were planted on separate alternating double row beds. In contrast, when planted on the same bed as pepper, grain corn markedly reduced subsequent pepper yield after maize harvest when compared to the effect of sweet corn (Fig. 19c).

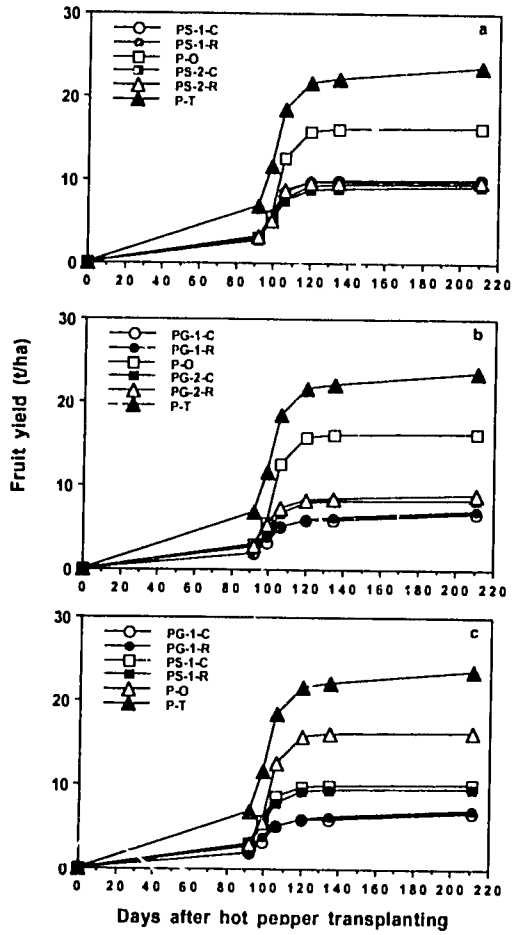

Fig. 19. Cumulative fruit yields of hot pepper in experiment III.

Marketable yields of sweet corn were greatest when planted on the same bed as pepper (Table 9). Lodging of some alternate double row plots of sweet corn was responsible for low yields. Grain yield of field maize in double row alternate intercrop plots was marginally less than that in intercrops with pepper on the same bed (Table 9), which in turn was 20% less than sole maize grain yield.

When calculated on the basis of a 211-day intercrop period no ATER (for maize and pepper) exceeded unity (Table 10). Pepper yields did not increase after 135 DAT, due to the detrimental effect of waterlogging following a typhoon. Calculated on a 135-day intercrop period ATER's exceeded unity (Table 10) when compared to the low pepper population treatment (PO) but not when compared to the higher population (PT). Pepper yield suffered more from competition with maize in intercropped treatments than did maize yield from competition with pepper.

Table 9. Maize yields (t/ha) as influenced by intercropping with hot pepper in experiment III.

Treatment	Sweet corn	Grain maize
Sole maize	4.6	4.6
Pepper/maize same bed, remove maize	4 8	3.8
Pepper/maize same bed cut maize	4 5	3.9
Pepper/maize alternate bed, remove maize	4.1	3.6
Pepper/maize alternate bed, cut maize	2.9	3.6

Table 10. ATERs in experiment III calculated with low or high density sole pepper yields, and for 211 or 135 days intercrop durations (i.e. including the hot wet summer period or not).

		211-day intercrop		135-day intercrop	
		Remove maize	Cut maize	Remove maize	Cut maize
Low density pepper					
Sweet corn	Same bed	1.0	1 0	1.2	1.2
	Alternate bed	1.0	0 8	1.1	0.9
Grain maize	Same bed	0 8	0.8	1.0	0.9
	Alternate bed	0.9	0 9	1.1	1.0
High density pepper					
Sweet corn	Same bed	0.8	0.8	1 0	1.0
	Alternate bed	0 8	0.6	1.0	0.8
Grain maize	Same bed	0 7	0.6	0.9	0.8
	Alternate bed	0.7	0.7	0.9	0.9

Vegetable soybean yields were greatest in sole treatments (5.6 and 6.5 t/ha following grain or sweet corn respectively). In intercropped treatments yields were greater in plots previously intercropped with grain maize (2.8 t/ha) than previously intercropped with sweet corn (2.0 t/ha), i.e. greater yield where pepper growth was more suppressed by the previous intercrop.

Results and Discussion

Intercropping maize with pepper reduced CMV incidence in the latter in all three experiments. Taller (grain) maize was more effective in reducing CMV than was shorter (sweet) corn, as was planting maize and pepper on the same bed compared to planting alternate beds with paired rows of separate crops.

Light interception by pepper, after maize was cut or removed from intercrop treatments, was less than that of sole treatments in each experiment, and pepper yields never matched those of sole plots. Pepper yields were reduced more so when grain maize was planted on the same as opposed to alternate beds (i.e. pepper intercepted less light when grown on the same bed as maize).

Likewise, when maize was grown on the same bed as pepper, yield reduction of pepper was substantially less with the shorter (sweet) corn than with the taller (grain) maize.

Experiment I favored hot pepper yields (12 t/ ha) compared to those of experiment II (10 t/ha) before the onset of cool conditions. The reverse was true for sweet pepper, which achieved only 7.5 t/ha in experiment I vs. 13 t/ha in experiment II. Earlier fruiting in the cooler conditions of experiment II (i.e. > 3 t/ha at 50 DAT vs. > 3.0 t/ha at 75 DAT in experiment I) favored sweet pepper yield in that experiment. The first yield peak in experiment III reached 16 t/ha in the low-density planting and 22 t/ha at the high density, both considerably greater than the autumn (experiments I and II) yields.

Using the ATER as a measure of productivity, apparent improvements due to intercropping were evident only for hot pepper in experiment I, if the experiment had been terminated before the cool winter (i.e. at 130 DAT for sweet pepper and 165 DAT for hot pepper). However, data in experiment III show that sole pepper yields were improved at denser plantings, therefore the ATER advantage of intercropped hot pepper in experiment I may have been due to greater overall plant population in that treatment.

Sweet corn, intercropped with hot pepper on the same bed in experiment III, while not reducing CMV as much as did grain corn , competed less for light. ATERs based upon the low-density hot pepper planting showed advantages for the intercrop treatment, but based upon high-density hot pepper, ATERs were close to unity.

Further experiments are required to determine the minimum maize population required to effect reduction in CMV incidence, with concomitant minimal competition with pepper.

Intercropping of Sugarcane and Vegetable Soybean

Summary

The potential to intercrop vegetable soybean with sugarcane was studied in Taiwan. Two or three rows of soybean at the same gross population were planted between rows of cane, the latter planted 1.3 m apart. Pod yield reached 6 t/ha in one vegetable soybean variety; however, neither variety nor row number influenced the number of cane plants. Weed growth in cane plots with soybean was greatly reduced compared to sole cane.

Introduction

To gain short-term returns from land which has been planted to the long-term crop sugarcane, farmers look to intercrops that can be grown within the inter-row space before complete sugarcane canopy closure. Development of suitable agronomic practices for potential intercrops will have widespread application in many tropical countries. Already a collaborative project is under way in Bangladesh, and further scope exists in other cane-producing countries. The experiments run in Taiwan in which vegetable soybean was intercropped with sugarcane were planted in spring and autumn, but only data from spring are available.

Materials and Methods

Sugarcane variety ROC 10 was planted in rows spaced 1.3 m apart by the Shanhua Sugar Factory on their own land on 19 January 1991. On 25 February two vegetable soybean lines (AGS 292 and G 9053) were sown in either two or three rows per raised bed between the cane rows. Three seeds were sown per hill, either in two-row plots with 10 cm within and 60 cm between rows on the bed, or in three-row plots with 15 cm within and 30 cm between rows. After emergence seeds were thinned to two per hill. The vegetable soybean populations were identical in all treatments. Sugarcane received a banded basal fertilizer application of 44:36:72 kg/ha of N, P_2O_5 and K_2O plus a side-dressing of 156 kg/ha N 165 days after planting. Vegetable soybean received an additional 20:60:60 kg/ha of N, P_2O_5 and K_2O as a broadcast basal fertilizer dose, and 20 kg/ha N as side-dressing at the R_1 and R_5 developmental stages. Vegetable soybean was harvested 73 days after sowing (DAS). Within each soybean line × spacing treatment one of three post-soybean-harvest practices were implemented: 1) all aboveground soybean residues were removed, 2) all aboveground soybean residues were incorporated, and 3) the same process as #1, but followed by sowing of mungbean on 20 May 1990 at 3 plants every 10 cm within rows in 2 rows 30 cm apart and between adjacent cane rows. These latter plots received 15:60:100 kg/ha of N, P_2O_5 and K_2O. Mungbean was plowed down 44 DAS.

In addition to the plots with soybean intercropped with cane, sole plots of soybean (planted at 30.8 plants/m^2), and of cane were included in the completely randomized design, with two replications. Sole cane plots either received their normal complement of fertilizer, or the normal complement plus that applied to plots with soybean and mungbean. All plots were 5.2 m wide and 6 m lo

Besides initial soil samples, data on light interception, growth analysis at R_2 and R_4 stages, weed population at vegetable soybean harvest, and yield and yield components at vegetable soybean harvest were also collected. The latter was collected from a strip 4 m long on a bordered area on the central bed of each plot. The sugarcane is at present still in the field, as is the repetition of the experiment planted in September 1991.

Results and Discussion

At the R_2 stage, approximately one-half of the soybean plants had nodules, a value which did not increase over the duration of the soybean crop. At harvest, however, nodule fresh and dry weight were greater in the three-row plots compared to those of the two-row plots (0.25 vs 0.19 g dry weight/6 plants, SE = 0.015). Root dry weight was similarly greater at the R_5 stage (5.6 vs. 5.3 g/8 plants, SE = 0.161), but at harvest no differences between row spacings were evident for yield or its components. More nodules were formed at any growth stage on roots of AGS 292 than on roots of G 9053 (e.g. at R_2, on 5.2 vs 2.6 plants per 8 sampled, SE = 0.192). Fresh weight of pods was greater at R_5 stage for AGS 292 (39.1 vs 16.5 g/8 plants, SE = 1.76) as was marketable pod yield at final harvest (6.0 vs. 4.4 t/ha, SE = 0. 038) although total aboveground fresh weight did not differ between varieties.

Neither soybean variety nor row spacing treatments influenced the cane plant number, but light interception was consistently greater in the three-row plots (Fig. 20).

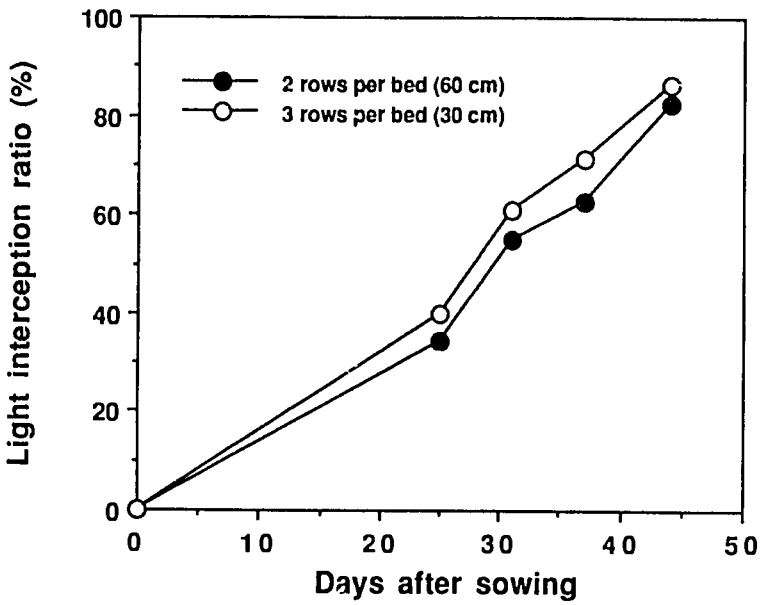

Fig. 20. Light interception in ratio different row spacings.

Comparisons between yields of sole and intercropped plots of vegetable soybean are still to be made. Weed control in plots with vegetable soybean, although not differing between varieties or row spacings, was far superior to that of sole cane. No weed growth was evident at harvest of vegetable soybean in the intercropped cane plots, but weeds covered 46% of the ground at that time in the sole cane. Plots were hand-weeded and 26 days later weed cover ranged from 5 to 6% in the plots which previously had vegetable soybean, to 11% in rototilled sole plots, to 41% in sole nonrototilled plots. Before the mungbean crop formed harvestable pods, it was plowed down 44 days after sowing at the time of earthing-up the sugarcane in all plots. Fresh weight of mungbean at the time of plowing down was 14.2 t/ha (14.7 t/ha with roots).

It appears feasible to intercrop vegetable soybean with sugarcane without loss of cane plant population. The influence of vegetable soybean and mungbean residues on cane yield will be estimated at cane harvest.

Further work in Bangladesh is directed to study the scope of suitable crops for intercropping at the beginning and end of the sugarcane season.

Soil Science

The Effect of Starter Solution on Summer Production of Chinese Cabbage and Tomato

Summary

Two field experiments were carried out in summer 1991 to evaluate the effect of types, concentration and application method of starter solution needed for Chinese cabbage and tomato production. Applying starter solution to plants after transplanting can significantly improve the initial growth and yield of both Chinese cabbage and tomato. It can also reduce the amount of basal fertilizer required. Hence, it is a very promising technique for summer vegetable cultivation. Both liquid fertilizers No. 1 and 4 applied at a rate of 120 mg P_2O_5 /plant appear to be the most appropriate for Chinese cabbage, whereas for liquid fertilizer No. 4, applied at the rate of 120 mg P_2O_5 /plant appeared superior to other compound fertilizers as a safe starter for tomato. Application of the starter solution through irrigation water would be a possible way to save labor costs and decrease the fertilizer damage to plants.

Introduction

A proper supply of readily available nutrients and water to plants helps seedling establishment, decreases transplanting shock, and enhances rooting under high-temperature conditions. Healthy initial growth of plants after transplanting contributes to good vegetable yield. Traditional fertilizer application through either broadcast or banding may not immediately meet the nutrient requirements of plants before they start rooting. Hence, a small amount of liquid fertilizer may prevent plants from wilting, accelerate recovery from transplanting shock and boost early nutrient uptake. This project aimed to evaluate the effects of types, concentrations and application methods of starter solution needed for Chinese cabbage and tomato production.

Materials and Methods

Two field experiments were carried out in summer 1991 on a randomized complete block design with two replications. Details of treatments are presented in Table 1 for Chinese cabbage and Table 3 for tomato. Different amounts of locally available liquid fertilizer with varying compositions of N-P_2O_5-K_2O were diluted to 10 ml and applied to each plant after transplanting, immediately followed by about 20 ml of water. Chinese cabbage cultivar Hybrid 82-156 was transplanted on 9 August and harvested on 19 September 1991. Tomato cultivar FMTT 22 was transplanted on 9 August. Data from harvests on 30 October, 4, 8, 14 and 21 November are presented here. One-third of the plants were surveyed at 10 and 21 days after transplanting (DAT) for Chinese cabbage and tomato to study their initial growth responses.

Results and Discussion

Chinese cabbage trial. Leaf numbers and top growth as well as root development were significantly greater following starter solution application (treatments 1–6, 11–15, Table 2). Visible responses occurred as early as 4 DAT. Applying 120 mg P_2O_5 of liquid fertilizer No. 1 per plant produced highest total fresh and dry weights at 10 DAT; the second highest was achieved by applying 300 mg P_2O_5 of liquid fertilizer No. 4 per plant. Similar results were obtained on head yield and total yield (treatments 1, 13–14). Liquid fertilizer No. I contained 240 mg of N while fertilizer No. 2 contained 150 mg N/plant. Both solutions had higher N contents than the other treatments. Therefore, not only P_2O_5 accelerated rooting, but N also affected rooting more pronouncedly than did P and K. In treatments 1–14, no basal fertilizer was applied, and in

Table 1. Experimental design of Chinese cabbage experiment in summer 1991.

Treatment	Starter fertilizer[a]		Seedling method	Transplanting condition
	Type	Amount (mg/plant) $N-P_2O_5-K_2O$		
T_1	LCF # 1[b]	240-120-120	M_1[c]	Wet, wo/basal (F_2)[d]
T_2	LCF # 1	120-60-60	M_1	Wet, wo/basal (F_2)
T_3	LCF # 4	60-120-60	M_1	Wet, wo/basal (F_2)
T_4	LCF # 4	30-60-30	M_1	Wet, wo/basal (F_2)
T_5	LCF # 5	60-120-120	M_1	Wet, wo/basal (F_2)
T_6	LCF # 5	30-60-60	M_1	Wet, wo/basal (F_2)
T_7	K_2HPO_4	0-120-159	M_1	Wet, wo/basal (F_2)
T_8	$(NH_4)_2HPO_4$	47-120-0	M_1	Wet, wo/basal (F_2)
T_9	P fert., P_2O_5 18%	0-240-0	M_1	Wet, wo/basal (F_2)
T_{10}	P granular, P_2O_5 18%	0-240-0	M_1	Wet, wo/basal (F_2)
T_{11}	LCF # 4	300-600-300	M_1 + cob + inj	Wet, wo/basal (F_2)
T_{12}	LCF # 4	300-600-300	M_1 + cob + coat[e]	Wet, wo/basal (F_2)
T_{13}	LCF # 4	150-300-150	M_1	Wet, F_2, wo/shading
T_{14}	LCF # 4	150-300-150	M_1	Wet, F_2, w/shading
T_{15}	LCF # 4	60-120-60	M_1	Wet, w/basal (F_1)
T_{16}	Check	0-0-0	M_1	Wet, w/basal (F_1)

[a]Liquid fertilizer is applied to each plant after transplanting; solid fertilizer is put on the bottom of each seedling.
[b]LCF# 1, liquid compound fertilizer No. 1, $N-P_2O_5-K_2O$ = 12 - 6 - 6%
LCF# 4, liquid compound fertilizer No 4, $N-P_2O_5-K_2O$ = 6 - 12 - 6%
LCF# 5, liquid compound fertilizer No 5, $N-P_2O_5-K_2O$ = 4 5 - 9 - 9%
[c]Seedling medium. M_1 = Soil· SCC· Sand. Rice husk = 3.1 1:1
[d]Fertilization·

Time	$N-P_2O_5-K_2O$	Remark
F_1 Basal	60-90 60	C F. #39, 500 kg/ha
Top 1 (10 DAT)	30-7.5-15	C F #1, 500 kg/ha
Top 2 (20 DAT)	30-7.5-15	C F. #1, 500 kg/ha
Total	120-105-90	
F_2,Top 1 (10 DAT)	30-45-30	C F. #39, 250 kg/ha
	30-7 5-15	C F. #1, 150 kg/ha
Top 2 (20 DAT)	30-45-30	C.F #39, 250 kg/ha
	30-7.5-15	C F. #1, 150 kg/ha
Total	120-105-90	

[e]Combination of adhesive and fertilizer coated on corn cob.

Table 2. Effect of starter solution and cultural practices on Chinese cabbage initial growth and yield, summer 1991.

Treat-ment no.	Leaf No. (no./plant)	Fresh weight at 10 DAT (g/plant)			Dry weight at 10 DAT (g/plant)			Yield (t/ha)	
		Leaf	Root	Total	Leaf	Root	Total	Head	Total
1.	12.3 a	49.5 a	2.7 ab	52 2 a	4 2 a	0.29 a	4.5 a	13.1 a	24.0 a
2.	11.3 bc	33.8 b	2 4 a-c	36.2 b	3.0 b	0 21 a-d	3 2 b	10.6 a-c	21.2 ab
3.	10.8 cd	26 4 c	2 7 ab	29.1 c	2.6 bc	0.24 a-c	2.9 bc	8.4 b-e	16.9 a-d
4.	10.7 cd	20.2 d	2 6 a-c	22.7 cd	2.2 cd	0.22 a-c	2.4 cd	8.8 b-d	20.2 a-c
5.	10.8 cd	26.9 c	2.0 a-c	28 9 c	2.5 b-d	0.19 b-e	2.7 b-d	7.5 [illegible]-f	16.3 a-d
6.	10 3 d	19.1 d	2.1 a-c	21.2 d	1.9 d	0.18 c-e	2.1 d	4.5 e-h	12.7 c-f
7.	8.8 e	9.1 e	1.2 c	10 3 e	1.0 e	0.10 e	1.1 e	3.4 f-h	8.2 ef
8.	10.8 cd	20.4 d	2.2 a-c	22.6 cd	2.2 cd	0.19 a-e	2.4 ce	7.1 c-g	15.5 b-e
9.	8.9 e	9.8 e	1.6 bc	11.3 e	1.1 e	0.13 de	1.2 e	2 8 h	7.5 f
10.	9.1 e	8.8 e	1.2 c	10.0 e	1.0 e	0.12 de	1.2 e	3.1 gh	8.0 ef
11.	11.2 bc	26.6 c	2.2 a-c	28.9 c	2.8 bc	0 24 a-c	3.1 bc	6.5 d-h	17.9 a-d
12.	11.2 bc	22.1 cd	1.6 a-c	23.7 cd	2.3 cd	0.17 c-e	2.4 cd	5.9 d-h	15.5 b-e
13.	11.7 ab	46.2 a	2.6 a-c	48 8 a	4.0 a	0.28 ab	4.3 a	11.8 ab	21.8 ab
14.	11.7 ab	47.1 a	3.0 a	50.2 a	3.8 a	0.26 a-c	4.1 a	11.5 ab	21.4 ab
15.	11.4 bc	27.2 c	2.3 a-c	29 5 c	2.6 bc	0 20 a-d	2.8 b-d	12.0 ab	22.3 ab
16.	8.9 e	9.1 e	1.7 a-c	10.8 e	1.1 e	0.13 de	1.2 e	5 0 d-h	11.3 d-f

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 3. Evaluation of the effect of starter solution for summer tomato, 1991.

Treatment	Starter fertilizer[a]		Seedling method	Transplanting condition
	Type	Amount (mg/plant) $N-P_2O_5-K_2O$		
T_1	LCF # 1[b]	240 - 120 - 120	M_1[c]	Wet, wo/basal (F_2)[w]
T_2	LCF # 4	150 - 300 - 150	M_1	Wet, wo/basal (F_2)
T_3	LCF # 4	60 - 120 - 60	M_1	Wet, wo/basal (F_2)
T_4	LCF # 4	30 - 60 - 30	M_1	Wet, wo/basal (F_2)
T_5	LCF # 5	60 - 120 - 120	M_1	Wet, wo/basal (F_2)
T_6	K_2HPO_4	0 - 120 - 159	M_1	Wet, wo/basal (F_2)
T_7	$(NH_4)_2HPO_4$	47 - 120 - 0	M_1	Wet, wo/basal (F_2)
T_8	P fert., P_2O_5 18%	0 - 240 - 0	M_1	Wet, wo/basal (F_2)
T_9	P granular, P_2O_5 18%	0 - 240 - 0	M_1	Wet, wo/basal (F_2)
T_{10}	LCF # 4	300 - 600 - 300	M_1 + cob + coat[e]	Wet, wo/basal (F_2)
T_{11}	LCF # 4	60 - 120 - 60	M_1	Wet, w/basal (F_1)
T_{16}	None (Check)	0 - 0 - 0	M_1	Wet, w/basal (F_1)

[a]Liquid fertilizer is applied to each plant after transplanting, solid fertilizer is put on the bottom of each seedling.
[b]LCF# 1, liquid compound fertilizer No 1, $N-P_2O_5-K_2O$ = 12-6 6%
LCF# 4, liquid compound fertilizer No 4, $N-P_2O_5-K_2O$ = 6-12-6%
LCF# 5, liquid compound fertilizer No. 5, $N-P_2O_5-K_2O$ = 4.5-9 9%
P fertilizer: usual super phosphate, P_2O_5 = 18%, in powder
P granular: usual super phosphate, P_2O_5 = 18%, in granular
[c]Seedling medium: M_1 = Soil· SCC. Sand Rice husk = 3.1:1:1
[d]Fertilization:

Time	$N-P_2O_5-K_2O$	Remark
F_1. Basal	90 - 135 - 90	C.F. #39, 750 kg/ha
Top 1 (3 WAT)	60 - 15 - 30	C F. #1, 300 kg/ha
Top 2 (6 WAT)	60 - 60 - 60	C F. #43, 400 kg/ha
Total	210 - 210 - 180	
F_2. Top 1 (3 WAT)	75 - 112 5 - 75	C.F. #39, 625 kg/ha
Top 2 (5 WAT)	25 - 37 5 - 25	C F. #39, 208 kg/ha
	50 - 20	Straight F.
Top 3 (7 WAT)	60 - 60 - 60	C.F. #43, 400 kg/ha
Total	210 - 210 - 180	

[e]Combination of adhesive and fertilizer coated on corn cob.

treatments 7, 9 and 10, no N was applied in the starter fertilizer. As a result growth and yields were significantly poorer than the other treatments. Even when top-dressing was applied at 10 DAT, the growth could not equal the other treatments. Starter fertilizer therefore plays an important role in the initial growth of Chinese cabbage.

Corn cobs coated with fertilizer and put in seedling pots to serve as a nutrient battery did not prove to be a good method of application (treatments 11 and 12). Comparing the results of treatments 15 and 16, both of which received basal fertilizer, treatment 15 yielded much higher than treatment 16 due to application of a small amount of starter fertilizer to it. Applying 120 mg P_2O_5 liquid fertilizer No. 4 with starter fertilizer is an appropriate practice for improving Chinese cabbage yield.

Tomato trial. In treatment 1 where 120 mg P_2O_5 liquid fertilizer No. 1 was applied, about 25% of the plants died 1 day after fertilizer application (Table 4). Since the tomato root system is more sensitive to environmental changes, the treatment that is best for Chinese cabbage becomes harmful to tomato. Total top growth and root development at 21 DAT was best in treatment 11 which received 120 mg P_2O_5 liquid fertilizer No. 4 applied with basal fertilizer. The result of this treatment did not differ significantly from that of treatment 2 which received 300 mg P_2O_5.

With basal fertilizer, starter fertilizer application promoted nearly 100% initial growth of tomato as compared with the check plot. Increasing application amounts to 300 mg P_2O_5 liquid fertilizer No. 4, without basal fertilizer, yielded the second highest amount of dry matter. These results confirmed the superior effect of liquid fertilizer No. 4 as a starter solution. No differences were found on light interception of plants measured at 60 DAT.

Due to high temperature, fruit setting in the first 2 months was not very good. The effect of the starter solution became less as reflected in total fruit number and fruit yield (Table 5). Despite the late fruit setting

Table 4. Effect of starter solution on the initial growth (21 DAT) of tomato, summer 1991.

Treatment	Dead plants at 1 DAT (%)	Plant height (cm)	Root fresh wt	Leaf fresh wt	Total fresh wt	Root dry wt	Leaf dry wt	Total dry wt
			g/plant					
1.	25.0 a	39.7 b-d	5.4 bc	67.4 b-d	122.0 b-f	0.7 b-d	5.1 b-d	9.9 b-e
2.	7.5 b	41.8 b	6 0 ab	85.2 ab	161.0 ab	0.9 ab	6.5 b	12.8 b
3.	3.3 b	41.1 b	4.8 b-e	76.8 bc	142.5 b-e	0.8 b-d	5.8 bc	11.3 bc
4.	0.8 b	39.6 b-d	5.2 b-d	63.5 b-d	118.2 c-f	0.7 b-d	4.9 cd	9.3 c-f
5.	4.2 b	41.1 b	5.7 b	79 4 ab	148.8 bc	0.8 a-c	5.7 bc	11.3 bc
6.	0.8 b	34.2 ef	3.5 ef	48.8 de	89.2 fg	0.5 e	3.7 de	6.8 fg
7.	0.8 b	37.4 c-e	4.2 c-f	56.3 c-e	102.3 d-g	0.6 c-e	4.3 c-e	8.3 c-g
8.	1.7 b	36.2 de	3.3 f	52.0 de	94.3 e-g	0.5 e	3.9 de	7.1 e-g
9.	1.7 b	32.5 f	3.3 f	41.0 e	75.4 g	0.5 e	3.2 e	5.9 g
10.	4.2 b	40.4 bc	5.4 bc	69.0 b-d	131.0 b-e	0.8 b-d	5.1 b-d	10.2 b-d
11.	0.8 b	45.4 a	7.1 a	100.0 a	198.0 a	1.0 a	8.0 a	15.9 a
12.	0.8 b	35.8 ef	3.9 d-f	55.4 c-e	100.4 e-g	0.6 de	4.1 de	7.8 d-g

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 5. Effect of starter solution on the yield of tomato, summer 1991.

Treatment	Light interception at 60 DAT	Total marketable fruit no. (no/m²)	Ave. marketable fruit weight (g/fruit)	Total marketable yield (t/ha)	Total yield (t/ha)
1.	0.8 ab	44.4 a-c	99.1 ns	44.4 a-c	46.3 a-c
2.	0.8 ab	48.0 a	100.3	48.6 a	50.7 a
3.	0.8 ab	45.6 ab	95.3	44.3 a-c	46.9 a-c
4.	0.8 a	46.2 a	104.9	48.5 a	50.6 a
5.	0.7 bc	44.2 a-c	99.1	44.4 a-c	46.0 a-c
6.	0.8 a	37.4 c	101.4	38.2 c	40.5 bc
7.	0.8 a	47.7 a	95.9	46.5 a	48.5 a-c
8.	0.8 ab	41.5 a-c	95.8	41.3 a-c	43.1 a-c
9.	0.7 c	45.2 a-c	102.0	46.4 ab	48.4 a-c
10.	0.8 ab	46.5 a	101.1	47.4 a	50.1 a
11.	0.9 a	45.3 a-c	102.3	46.7 a	49.0 ab
12.	0.8 a-c	37.8 bc	100.9	38.4 bc	40.1 c

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

in all plots, the check plot produced significantly lower overall fruit yield than the other treatments. This confirmed the finding that use of starter solutions is an important technique for vegetable production in the tropics.

Applying starter solution to plants after transplanting can improve the initial growth and yield of both Chinese cabbage and tomato. It can also reduce the need for basal fertilizer, hence, it is a very promising technique for summer vegetable cultivation. Both liquid fertilizer No. 1 and 4 applied at a rate of 120 mg P_2O_5/plant appear to be the most effective for Chinese cabbage, whereas liquid fertilizer No. 4 at the same rate of 120 mg of P_2O_5/plant proved superior to other compound fertilizers as a safe starter fertilizer for tomato. Application of the starter solution through irrigation water is a possible way to save labor costs and reduce fertilizer damage to plants.

Integrated Cultural Practices for Hot Pepper

Summary

Experiments were conducted to develop integrated cultural practices and adequate seedling media for hot pepper cultivation by using easily attainable materials. Plastic mulching, with a total of 220-160-200

kg N-P_2O_5-K_2O/ha applied in band as basal and split two or four times as side-dressing were all acceptable techniques for hot pepper cultivation. Cultivar Chain Fair yielded slightly more than Long Chili, but the latter matured earlier than the former. Neither of them are heat-tolerant cultivars. Yields were relatively low in summer. Recommended seedling media were in the ratio of, Soil: SCC: RH = 3:2:1 or Soil: SCC: Sand = 3:2:1 or Soil: SCC: Verm = 3:2:1. Soil should comprise 50% of the media, but should not exceed 70%. Germination rate was mainly governed by EC of the media. Seedling media significantly affected the seedling quality, hence the yield was considerably influenced by the media. Usage of commercial organic fertilizer for raising seedlings deserves further study.

Introduction

Hot pepper is a relatively new commodity crop selected by AVRDC. Its root system is similar to that of tomato, but more fibrous and more sensitive to environmental changes. Adequate seedling medium and advanced cultural practices were reported previously for Chinese cabbage and tomato. Thus, optimum management practices should be devised for this crop. The objective of this trial was to clarify the fertilization techniques and seedling medium suitable for hot pepper cultivation.

Materials and Methods

Spring trial. An RCB design with two replications was adopted in this experiment with treatments composed of different mulching methods, rate and time of fertilization, and application techniques (Table 6). Local hot pepper cultivars Chain Fair and Long Chili were transplanted on 5 March 1991, and harvested six times on 22 May, 5 and 9 June, 3 and 16 July and on 5 August.

Summer trials. The growth response of hot pepper was examined by using 18 seedling media of different compositions. Seedling media tested are summarized in Table 11. Media were prepared by mixing locally available components. Commercial organic fertilizer was introduced to some media since organic compost was not available. Seeds of hot pepper cultivar Long Chili were sown on 15 July 1991 and transplanted to the field on 14 August. The performance of seedlings was compared before transplanting. Plant growth at 21 DAT was surveyed, and data on yields from four (1, 11, 15 and 21 November) of the six harvests are presented here.

Results and Discussion

Spring trial. Marketable fruit yield of Chain Fair at each harvest tended to increase rapidly from 1st to 3rd harvest, and decrease gradually up to the final harvest, irrespective of treatments as shown in Table 7. The same tendency was also observed in Long Chili. However, its yields of 1st and 3rd harvest were greater than for Chain Fair cultivar. In terms of total marketable yield, Chain Fair was superior to Long Chili with the same treatment.

Among treatments for Chain Fair, no significant differences existed except in treatments 1 and 8 which seemed to yield more than treatment 4. This indicated that fertilizer amount was not the limiting factor of production. Total yield with plastic mulch was superior to that with rice straw mulch as recommended previously for sweet pepper cultivation. Double band application was not beneficial to fruit yield. Similar results held true for Long Chili. Broadcasting all fertilizer as basal (treatment 2) was not recommended because some plants wilted after transplanting due to fertilizer damage. Fruit production reached a peak earlier in Long Chili than in Chain Fair, hence Long Chili seemed to belong to an early-maturing type. However, fertilization shifting from early growing period ($F_{1,2}$) to later growing period ($F_{5,6}$, i.e. fertilizer regime F_6) was not effective for increasing yield.

Due to high temperature, many fruits dropped before reaching full maturity (Table 8). Total dropped fruit number and weight were greater in Long Chili than in Chain Fair. As mentioned, Long Chili matured earlier than Chain Fair; it showed the greatest number of dropped fruit at first survey (66 DAT) and then decreased in the remaining two surveys, whereas Chain Fair dropped its fruit most severely at 87 DAT. Although no significant differences were observed between treatments, cultural practices such as rice straw mulch seemed to reduce fruit dropping (treatments 4 and 11). The relationship between fruit drop and temperature deserves further study.

Table 6. Treatments of different cultural practices for hot pepper, spring 1991.

Treatment	Cultivar	Mulching	Soil moisture	Fert. method	Applied method[c]
T_1	Chain Fair	Plastic	Dry BFT[a]	F_1[b]	Single
T_2	Chain Fair	Plastic	Dry BFT	F_2	Broadcast
T_3	Chain Fair	Plastic	Dry BFT	F_3	Single
T_4	Chain Fair	R Straw	Dry BFT	F_3	Single
T_5	Chain Fair	Plastic	Dry BFT	F_3	Double
T_6	Chain Fair	Plastic	Dry BFT	F_4	Single
T_7	Chain Fair	Plastic	Dry BFT	F_5	Single
T_8	Chain Fair	Plastic	Dry BFT	F_6	Single
T_9	Long Chili	Plastic	Dry BFT	F_1	Single
T_{10}	Long Chili	Plastic	Dry BFT	F_3	Single
T_{11}	Long Chili	R Straw	Dry BFT	F_3	Single
T_{12}	Long Chili	Plastic	Dry BFT	F_3	Double
T_{13}	Long Chili	Plastic	Dry BFT	F_4	Single
T_{14}	Long Chili	Plastic	Dry BFT	F_5	Single
T_{15}	Long Chili	Plastic	Dry BFT	F_6	Single

[a]BFT: before transplanting
[b]Fertilization method:

Treatment	Time	$N - P_2O_5 - K_2O$	Remark
1. F_1	Basal	60 - 90 - 60	C.F. #39
	- 80	Straight F KCl	
	Top 1 (28 DAT)	30 - 30 - 30	C.F #43
	- 10 -	Straight F.	
	Top 2 (56 DAT)	30 - 30 - 30	C F. #43
	Total	120 - 160 - 200	
2. F_2	Basal	160 - 160 - 160	C.F. #43
	- 40	Straight F. KCl	
	Total	160 - 160 - 200	
3. F_3a	Basal	120 - 120 - 120	C F. #43
	Top 1 (28 DAT)	40 - 40 - 40	C F. #43
	Top 2 (56 DAT)	60 - 0 - 40	C F. Pao-hsiao #2
	Total	220 - 160 - 200	
4. F_4	Basal	60 - 60 - 60	C F. #43
	(check)	60 - 60 - 60	Straight F.
	Top 1 (21 DAT)	40 - 10 - 20	C F. #1
	Top 2 (42 DAT)	40 - 10 - 20	C.F. #1
	Top 3 (63 DAT)	40 - 10 - 20	C.F. #1
	Top 4 (84 DAT)	40 - 10 - 20	C F. #1
	Total	220 - 160 - 200	
5. F_5	Basal	140 - 120 - 120	Straight F.
	Top 1 (21 DAT)	40 - 10 - 20	C.F. #1
	Top 2 (42 DAT)	40 - 10 - 20	C F. #1
	Top 3 (63 DAT)	40 - 10 - 20	C.F. #1
	Top 4 (84 DAT)	40 - 10 - 20	C F. #1
	Total	300 - 160 - 200	
6. F_6	Basal	60 - 60 - 60	C F. #43
	Top 1 (14 DAT)	- 70 - 80	Straight F.
	Top 2 (28 DAT)	40 - 10 - 20	C F. #1
	Top 3 (42 DAT)	40 - 10 - 20	C.F. #1
	Top 4 (A1stH)	40 - 10 - 20	C F. #1
	Top 5 (A2ndH)	40 - -	Straight F.
	Top 6 (A3rdH)	40 - -	Straight F.
	Total	40 - -	Straight F.
	300 - 160 - 200		

C.F. (compound fertilizer)

#43	$N - P_2O_5 - K_2O - MgO$ = 15- 15- 15- 4 (%)
#39	$N - P_2O_5 - K_2O$ = 12- 18- 12 (%)
#1	$N - P_2O_5 - K_2O$ = 20- 5- 10 (%)
Pao-hsiao #2	$N - P_2O_5 - K_2O$ = 21- 0 - 14 (%)

A1stH, A2ndH, A3rdH = after 1st, 2nd and 3rd harvest, respectively.
[c]Applied method: single = banded basal fertilizer in central part of bed, about 20 cm below the top, double = banded in soil 15 cm below plant rows, broadcast = broadcast before bed formation

Potential fruit sizes of Chain Fair and Long Chili are reported to range between 18 and 22, and 20–25 g/fruit, respectively. However, from the data in Table 9, fruit that reached its largest weight were only found in 2nd harvest of Chain Fair and 1st harvest of Long Chili, under similar conditions of treatment. The overall fruit size was apparently more influenced by actual growing conditions of the plants than by genetic factors. No clear differences were observed among treatments. Only double banding of fertilizer produced smaller fruit size.

Table 7. Effect of integrated cultural practices on fruit yield of hot pepper cultivar Chain Fair and Long Chili, spring 1991.

Treatment	Marketable fruit yield (t/ha) at harvest of							Total
	1st	2nd	3rd	4th	5th	6th	Total	yield
1.	0.39 c	3.8 c	10 9 ab	6.7 a	3 9 ab	2.5 a-c	28 1 ab	30.8 ab
2	0.21 c	3.3 c	10 3 a-c	6.9 a	3.5 ab	2.7 a-c	27.0 a-c	29.5 a-c
3.	0.40 c	3.8 c	9 9 bc	7.0 a	4.0 ab	2.5 a-c	27.6 ab	29.8 a-c
4.	0.30 c	3.0 c	8 4 c	5 8 ab	3.7 ab	3 3 ab	24 5 b-d	26 7 b-f
5.	0.37 c	3.4 c	9.1 bc	5.7 ab	3.5 ab	3 6 a	25.7 a-d	27 7 a-e
6.	0.30 c	3.7 c	10.1 a-c	6 0 a	3.8 ab	1.9 a-c	25 8 a-d	28 5 a-d
7.	0.28 c	3.5 c	9.2 bc	6.0 a	3.3 b	2.3 a-c	24.6 a-d	27.5 a-f
8.	0.41 c	3 6 c	12.3 a	6.3 a	4 0 a	1.8 a-c	28.4 a	31.0 a
9.	1.37 ab	7 8 ab	9.5 bc	2.7 c	0 8 cd	1.2 c	23 4 cd	23 8 ef
10	1.75 ab	7.6 ab	8.5 c	3 9 bc	1.1 cd	2.0 a-c	24 8 a-d	25.3 d-f
11.	1.40 ab	6.6 b	9 2 bc	3 5 c	1.2 c	2 6 a-c	24 4 b-d	24.9 d-f
12.	1.29 b	7 0 ab	8.7 bc	3.1 c	0.9 cd	1 7 a-c	22 7 d	23.3 f
13.	1.72 ab	8 7 a	9.8 bc	3.4 c	1.0 cd	1 5 bc	26 1 a-d	26.5 c-f
14.	1.92 a	7 1 ab	9.6 bc	3.2 c	1 0 cd	2.1 a-c	24 9 a-d	25.3 d-f
15.	1 64 ab	8.2 ab	9 9 bc	2.6 c	0 5 d	1.7 a-c	24 6 a-d	25 2 d-f

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

Table 8. Effect of integrated cultural practices on number of dropped fruit and their weight in hot pepper, spring 1991.

Treatment	Dropped fruit no at (no /m²)				Dropped fruit weight at (g/m²)			
	66 DAT	87 DAT	99 DAT	Total	66 DAT	87 DAT	99 DAT	Total
1.	4.8 b	34.9 a-c	12 8 a-e	52 5 b	1 6 b	19 6 a-c	7.1 a-d	28 3 a-c
2.	4 6 b	34 0 a-d	13.1 a-d	51 7 b	2 0 b	20 4 ab	7.2 a-d	29 6 a-c
3.	8 0 b	41.6 a	12 5 a-e	62.1 ab	2 4 b	23.9 a	7 0 a-d	33 3 a-c
4.	4.9 b	32 5 a-d	17 0 ab	54.3 b	1 9 b	18.3 a-c	10.2 ab	30 4 a-c
5.	10 7 b	36.6 a-c	16 0 a-c	63 4 ab	4 9 b	20 1 ab	9.2 a-c	34.2 a-c
6	8 3 b	29.3 a-d	16 4 a-c	54 1 b	3.1 b	16 6 a-d	9 1 a-c	28 7 a-c
7.	6.3 b	38 1 ab	17.6 a	62 0 ab	2.2 b	20.1 ab	11.2 a	33.5 a-c
8.	8 3 b	28 7 a-d	17 0 ab	54.0 b	2 5 b	14.5 a-e	9 5 a-c	26 5 bc
9.	31.4 a	21 9 c-f	8.9 de	62 2 ab	13.6 a	11 8 b-e	5.1 cd	30.5 a-c
10	41.6 a	25 5 b-e	10.6 c-e	77 7 a	18 2 a	12.6 b-e	7 2 a-d	38.1 a
11.	32 0 a	10 1 f	7 0 e	49 0 b	13 4 a	7.6 de	4 4 d	25 4 c
12.	39 2 a	28 5 a-d	10 8 c-e	78 5 a	16 8 a	13.8 b-e	6 4 b-d	36.9 ab
13.	38.2 a	19 5 d-f	8.6 de	66 3 ab	16 8 a	10.2 c-e	7 0 a-d	34.0 a-c
14	41.0 a	25 0 b-e	11.3 b-e	77 3 a	17.7 a	13.3 b-e	7 0 a-d	38 0 a
15	37 6 a	11 9 ef	8 4 de	57 8 ab	16 5 a	6.4 e	7.1 a-d	30.1 a-c

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

Marketable fruit number (i.e. unblemished and > 3 g) of six harvests is shown in Table 10. The fruit number of Chain Fair increased slowly from 1st to 2nd harvest, sharply from 3rd to 4th harvest, and remained moderate at the final two harvests irrespective of most treatments. But treatment 4 set fewer fruits even in the growing peak. On the other hand, Long Chili produced more fruits in the early growing period, number of fruits declined quickly towards 5th harvest, but fruits set again with the formation of new branches at last harvest. The differences in fruit number were greater among the harvest times than among the treatments.

Summer trial. The seedling media greatly affected germination (GR) at 9 and 11 DAS as well as the growth of hot pepper seedlings (Table 12). Linear regression analysis was applied and the following equations were obtained: G (9 DAS) = 98.10–44.08 EC, and G (11 DAS) = 96.69–25.68 EC with r value equal to -0.76 and -0.65, respectively. Nearly 45–60% of the variation in 6 was governed by EC of the

Table 9. Effect of integrated cultural practices on hot pepper fruit size, spring 1991.

Treatment	Ave. marketable fruit yield (g/fruit) at harvest of						
	1st	2nd	3rd	4th	5th	6th	Total
1.	8.0 c	13.0 ab	8.8 a-d	6 1 a-c	4 3 a-c	3.1 a-c	6.4 cd
2.	8.7 c	12.0 ab	9.0 a-c	6 1 a-c	4 1 a-c	3.1 a-c	6 3 cd
3.	8.0 c	12 7 ab	8 5 b-e	6 0 a-d	4 2 a-c	3 4 a	6 3 cd
4.	7.4 c	14.2 a	8.8 a-d	6 3 a	4 3 ab	3.5 a	6.2 cd
5.	7.2 c	10.7 b	7 7 e	5.6 a-d	3.8 bc	3.4 a	5.7 d
6.	8.4 c	12 1 ab	8 5 a-e	5.7 a-d	3 8 bc	3.1 a-c	6.2 cd
7.	7.7 c	12.4 ab	8.4 b-e	5 8 a-d	3 9 bc	3 4 a	6 2 cd
8.	8.4 c	13.1 ab	6.8 a-d	6.2 ab	4 2 a-c	3.3 ab	6.7 bc
9.	16.9 ab	10.9 b	9.5 a	5 3 a-d	4.2 a-c	2 3 d	7 8 a
10.	17.4 ab	11 5 ab	7 8 de	5.0 cd	4 1 a-c	2 6 cd	6 8 bc
11	18.4 a	12 2 ab	9.2 ab	6 3 a	4 7 a	2 9 a-d	7.4 ab
12.	15.7 b	10 2 b	8.0 c-e	5.1 b-c	3 6 bc	2 5 cd	6.8 bc
13.	16 9 ab	11.6 ab	8.8 a-d	5 3 a-d	3 9 bc	2.9 a-d	7 8 a
14.	17.4 ab	10 2 b	7 6 e	4 9 d	3 9 bc	2.7 b-d	6 6 bc
15.	18.4 a	12 0 ab	8 2 b-e	4 9 d	3.5 c	2 6 cd	7.4 ab

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

Table 10. Effect of integrated cultural practices on hot pepper fruit number, spring 1991.

Treatment	Marketable fruit yield (No /m²) at harvest of						
	1st	2nd	3rd	4th	5th	6th	Total
1.	8.0 c	13 0 ab	8 8 a-d	6 1 a-c	4 3 a-c	3.1 a-c	6 4 cd
1.	5.0 b-e	29.6 c	123 4 ab	108.7 ab	90 5 ab	80.8 a	438 1 a-c
2.	2.4 e	27 5 c	114.4 b-d	113 7 a	86.8 ab	86 1 a	431 0 a-c
3.	5.3 b-e	31.0 c	117.2 b-d	117 3 a	94.3 ab	74 0 a	439 1 ab
4.	4.1 c-e	20.9 c	95.8 d	92 1 a-c	84.6 b	96.0 a	393 4 a-d
5.	5.1 b-e	32.0 c	118 1 bc	102 3 ab	91.9 ab	104.6 a	454.0 a
6.	3.6 de	30 3 c	118 8 a-c	105.4 ab	101 4 a	62.4 a	421 9 a-c
7.	3.6 de	28.1 c	109.5 b-d	104.7 ab	85.1 b	66.6 a	397.7 a-d
8.	4.9 b-e	27.7 c	140 2 a	101.9 ab	95.5 ab	55.4 a	425.6 a-c
9.	8.3 a-c	71.0 a	100.6 cd	51 6 d	19 6 c	52 0 a	303.0 e
10.	10.1 a	66.4 ab	108 8 b-d	77.5 b-d	26.3 c	74.4 a	363.5 c-e
11	7.6 a-d	53.4 b	99 8 cd	57.5 d	25.0 c	89.4 a	332.7 de
12.	8.2 a-c	68 5 ab	109 6 b-d	61.3 cd	23 9 c	61.5 a	333.0 de
13.	10.4 a	75.4 a	110.2 b-d	63 3 cd	25.7 c	51.3 a	336.3 de
14.	11.1 a	70.2 a	126 5 ab	65 4 cd	24 9 c	77.7 a	375.7 b-e
15.	8.9 ab	68.1 ab	121.2 a-c	53 4 d	13 3 c	67.9 a	332.8 de

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

media. Previous research (in 1985) also pointed to inorganic N and electric conductivity (EC) as key factors which govern the germination rate of tomato seeds. Based on the earlier media study for tomato and Chinese cabbage, the best composition of media had been predicted for hot pepper. Only minor changes were made among the other media based on locally available materials. Therefore, EC of media were not much different among No. 1–14. In No. 15–17 commercial fertilizer #1 seemed excessively applied. Seedling height and growth before transplanting were best in medium No. 10, followed by No. 7 and 18. Performance in media No. 4–6 and 8 was also acceptable. Application of 100 mg NPK to the medium did not significantly affect seedling growth.

After transplanting to the field, plant height and growth at 21 DAT as measured by fresh and dry weight accumulations were recorded (Table 13). Outstanding plant growth was still achieved in medium 10, but growth in media 6 and 8 improved over media 7 and 18 in which no NPK fertilizer was applied. Light interception of the canopy at 55 DAT was greatest in media 10 and 3, but not much different among all treatments. Seedling quality greatly affected the early field performance of hot pepper. Due to poor seedlings in media 13–17, the initial growth was considerably retarded.

Table 11. Composition of media for raising hot pepper seedlings, summer 1991.

Medium no.	Compositions[a] of seedling medium (volume ratio)								
	Soil	SCC	Sand	RH	SRH	Verm	Corn	OF# 1	NPK
1.	3	1	1	1	-	-	-	-	-
2.	3	1	1	1	-	-	-	-	100
3.	3	1	-	2	-	-	-	-	-
4.	3	1	-	2	-	-	-	-	100
5.	3	1	-	-	2	-	-	-	-
6.	3	1	-	-	2	-	-	-	100
7.	3	1	-	-	-	2	-		-
8.	3	1	-	-	-	2	-	-	100
9.	3	2	-	-	-	-	1	-	-
10.	3	2	-	1	-	-	-	-	-
11	4	1	-	-	-	-	1	-	-
12.	4	1	-	1	-	-	-	-	-
13.	5	-	-	-	-	-	1	-	100
14.	5	-	-	1	-	-	-	-	100
15.	5	-	-	0.75	-	-	-	0.25	-
16.	3	-	1	1.75	-	-	-	0.25	-
17.	3	-	1	1.50	-	-	-	0.50	-
18.	3	2	1	-	-	-	-	-	-

[a]SCC: Sugarcane compost
RH: Ricehusk
SRH: Smoked ricehusk
Verm: Vermiculite
Corn: Corn cob, 5 cm L × 2.5 cm D, was immersed in chemicals for sterilization, and was injected with 5 ml LCF #4 into central part of each cob, and was put into the central part of each seedling pot
OF #1: Organic fertilizer No. 1 produced by Taiwan Fertilizer Company
NPK: Chemical fertilizer, at a rate of 100 mg/l kg soil

Table 12. Effect of seedling medium on germination and seedling growth of hot pepper, summer 1991.

Treatment in seedling medium	Medium EC (mmhos/cm)	Germination (%)		Plant height at 30 DAS (cm)	Plant fresh wt at 30 DAS (g/plant)
		at 9 DAS	at 11 DAS		
1.	0.23 g-i	94.2 a-c	97 1 a-c	9.5 g	1.4 d
2.	0.30 c-e	95 0 ab	97.1 a-c	9.6 g	1.2 d
3.	0.26 d-g	71.3 ef	77.9 ef	11.3 ef	2.0 bc
4.	0.33 c	81.0 c-e	85.4 c-e	11.9 de	2.2 b
5.	0.20 hi	97.5 a	97 7 ab	12.1 cd	1.8 c
6.	0.26 d-h	99.0 a	99.0 ab	12.7 bc	1.9 bc
7.	0.24 f-i	97.5 a	98.8 ab	13 8 a	2.1 b
8.	0.24 e-i	99 6 a	99.6 a	11.9 de	1.8 c
9.	0.31 cd	78.8 d-f	88.3 a-e	6.8 ij	0.7 e-g
10.	0.35 c	83.1 b-e	96.9 b-e	14.3 a	2.7 a
11.	0.22 g-i	66.3 fg	71.3 f	7.3 i	0.9 e
12.	0.24 f-i	74.8 ef	78.8 ef	11.1 f	2.0 bc
13.	0.19 i	75.0 ef	84.0 de	4.9 l	0.5 g
14.	0.21 g-i	77.1 d-f	77.9 ef	6.5 j	0.6 fg'
15.	0.96 b	89.0 a-d	93.8 a-d	8.2 h	0.9 ef
16.	1.01 b	54.4 g	79.2 ef	6.5 j	0.6 g
17.	1.68 a	6.0 h	37.3 g	5.8 k	0.6 g
18.	0.29 c-f	97.1 a	98.8 ab	12.8 b	2.1 bc

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 13. Effect of seedling medium on growth of hot pepper, summer 1991.

Treatment	Plant Height (cm)	Root fresh wt	Leaf fresh wt	Root dry wt	Total dry wt	Light interception at 55 DAT (%)
		g/plant at 21 DAT				
1.	24.4 d-g	1.6 b-e	7 6 b-e	0 17 c-f	1.9 b-f	0.7 ab
2.	26.5 c-f	1.6 c-e	8 9 a-e	0 22 b-f	2.2 b-f	0 7 ab
3.	23.8 d-g	1 8 b-e	5.7 c-e	0 17 d-f	1 5 d-f	0.8 a
4.	26.7 c-f	2 0 a-e	8 6 a-e	0.22 b-f	2.2 b-f	0.7 ab
5.	27.0 b-e	2.4 a-d	8.8 a-e	0 24 b-e	2 2 b-f	0.7 ab
6.	32.7 ab	2.9 a-c	11.7 ab	0.33 a-c	3 2 ab	0.6 b
7.	28.8 a-d	2 3 a-d	7.9 b-e	0.29 a-d	2 3 b-e	0.7 ab
8.	31.7 a-c	2.2 a-d	11 0 a-c	0.30 a-d	3.0 ab	0.7 ab
9.	26 3 c-f	2.7 a-c	11.5 ab	0 30 a-d	2.8 a-d	0 7 ab
10.	34.4 a	3 2 a	13 4 a	0 43 a	3 9 a	0.7 a
11.	25.5 d-g	2.3 a-d	9 5 a-d	0.22 b-f	2 3 b-e	0 7 a
12.	24 7 d-g	1.5 c-e	5 7 c-e	0.17 d-f	1 7 c-f	0.7 ab
13.	20.9 f-h	1.3 de	6.4 b-e	0.16 d-f	1.6 c-f	0.7 ab
14.	19.7 gh	0.7 e	5 6 de	0.11 ef	1 2 ef	0.7 ab
15.	21.1 e-h	1.1 de	6.1 c-e	0.11 ef	1 4 ef	0.7 ab
16.	17.7 h	0.7 e	4.8 de	0.07 f	1 0 ef	0.6 b
17.	17.3 h	0.8 e	4.1 e	0.08 ef	0 9 f	0.7 ab
18.	28.8 a-d	3 0 ab	9.7 a-d	0 35 ab	2 9 a-c	0.7 a

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT)

Yields and yield components of this trial are shown in Table 14. Compared with fruits produced by the same cultivar in the spring trial, potential for summer hot pepper production appeared limited. Fruits in these trials were fewer and smaller than those in spring, resulting in lower yield for all treatments. Medium 7 gave the highest marketable yield, followed by media 18, 10 and 8. All these were adequate media for hot pepper growth in summer.

Among cultural practices tested, plastic mulching, with a basal application of 120-120-120 kg/ha N-P_2O_5-K_2O in a single band, a side-dressing of 40-40-40 kg/ha N-P_2O_5-K_2O at 28 DAT and a second side-dressing of 60-0-40 kg/ha N-P_2O_5-K_2O at 56 DAT, or the standard fertilization method (check - F_4) are all acceptable techniques for spring hot pepper. Straw mulch apparently reduced fruit drop late in the season when ambient temperature rose.

Table 14. Effect of seedling medium on yield and fruit size of hot pepper, summer 1991.

Treatment in seedling medium	Marketable fruit no. (no/m²)	Total fruit no (g/fruit)	Ave. marketable fruit weight	Marketable yield (t/ha)	Total yield (t/ha)
1.	40.4 c-e	48.9 bc	14.2 b-d	5.8 bc	6.1 bc
2.	54.7 a-d	66.5 ab	14 5 b-d	7.9 ab	8.4 ab
3.	48.3 b-e	57.6 a-c	15.4 a-c	7.5 ab	7 9 ab
4.	55.3 a-d	63.3 ab	14.8 a-d	8.2 ab	8.5 ab
5.	58.6 a-c	69 1 ab	14.3 b-d	8.2 ab	8.5 ab
6.	51 9 a-d	57.5 a-c	15.0 a-d	7.7 ab	8.0 ab
7.	70.3 a	78.3 a	14.1 cd	9.9 a	10.2 a
8.	55.9 a-d	65.1 ab	14.5 b-d	8.2 ab	8.5 ab
9.	48.6 b-e	56.5 a-c	14.4 b-d	7.0 bc	7.3 a-c
10.	61.6 ab	67.9 ab	13.6 d	8.3 ab	8.5 ab
11.	44.6 b-e	54.9 bc	15.7 a-c	7.1 bc	7.5 ab
12.	[illegible] b-d	60.5 ab	15.0 a-d	7.6 ab	7.9 ab
13.	44.7 b-e	55.3 bc	14.4 b-d	6.5 bc	6.9 bc
14.	40.8 c-e	50.6 bc	15.8 ab	6.5 bc	6.8 bc
15.	47.5 b-e	58.7 ab	15.1 a-d	7.2 a-c	7.6 ab
16.	29.6 e	36.1 c	14.4 b-d	4.5 c	4.7 c
17.	37.3 de	50.2 bc	16.3 a	6.2 bc	6.6 bc
18.	57.6 a-c	67.1 ab	14.5 b-d	8.3 ab	8.7 ab

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Cultivar Chain Fair yielded slightly more than Long Chili, but the latter matured earlier than the former. Neither of them are heat-tolerant cultivars. Yields were relatively low in summer.

Recommended seedling media are as follows:

a. Soil: SCC: RH = 3:2:1
b. Soil: SCC: Sand = 3:2:1 or
c. Soil: SCC: Verm = 3:2:1

Soil should compose 50% of the media, but should not exceed 70%. Germination rate was mainly governed by EC of the media. Seedling media significantly affected the seedling quality, hence the yield was also greatly influenced by the media. High EC of media containing commercial organic fertilizer for raising seedlings could have been responsible for associated poor seedling performance, and deserves further study.

Establishment of Soil and Crop Data Base for Simulation Model

Summary

Applications of crop models for AVRDC's research have the following benefits:

- Help in the selection of suitable varieties for specific environments;
- Provide interpretations of crop performance for a given environment;
- Help in the establishment of specific breeding objectives;
- Simulate crop responses to specific management practices; and finally,
- Help in the development of expert systems for extension purposes.

Recently, three crop simulation models, SOYGRO, EPIC, and PLANTGRO have been introduced to AVRDC. All these models have been well tested for temperate regions. However, the performance of the crop models under tropical conditions needs to be validated. Many models were designed for field crops, with very little done on vegetable models.

Because of the important role AVRDC plays in vegetable research in the tropics, it is essential for the Center to establish crop and soil data bases as well as develop vegetable models. This project was initiated in 1987 to establish a soil and crop data base for model application and development.

A data base management system at AVRDC was proposed. Minimum data sets of soils, crops, climates, rotation systems and cultural practices have been implemented and are readily available for model validations. Structure of soil data bases and part of the records are presented.

Introduction

Accurate estimates of future soil productivity are important and necessary in agricultural decision-making and planning from the field scale to the national level. People have been predicting plant growth for thousands of years. The study of crop production is complicated by many interactions between the crop and its physical and biological environments. Traditional approaches of many years' replicated experiments or field trials are expensive, and usually location-specific. Applications of the results are difficult and require a long-term commitment of personnel and resources.

Because of the tremendous progress in computer science, development of crop simulation models becomes possible for mechanistic, dynamic and stochastic analysis of soil-crop-climate interactions and for expanding the benefits of research results of field experiments across a wide range of soils, climates, and management practices.

Three crop simulation models, SOYGRO, EPIC, and PLANTGRO were introduced at AVRDC in 1986, 1988 and 1990, respectively. Basically, these are three different application-oriented models.

SOYGRO model was developed by teams at the University of Florida and International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) program groups. It was designed to predict daily soybean growth and development in response to environmental, soil, and pest conditions. Processes of photosynthesis, respiration, transpiration, nitrogen remobilization, tissue synthesis and phenological development are included. The model is sensitive to cultivar choice, planting date, row and plant spacing, and irrigation management.

The Erosion Productivity Impact Calculator (EPIC) model is a comprehensive model developed to determine the relationship between soil erosion and soil productivity, but is potentially useful for other types of analysis. It is a multicrop-based model, several crops can be included in a rotation, and the rotation can be run for any number of cycles up to hundreds of years. EPIC's physical components include hydrology, weather simulation, erosion, nutrient cycling, soil, and tillage, and relates these to plant growth and financial returns. The EPIC model was developed by a US national agricultural research service erosion-productivity modeling team in 1981.

PLANTGRO was designed by Dr.Clive Hackett and other researchers working at CSIRO in Brisbane, Australia. It is a software package for coarse prediction of plant growth for lesser-known species but can be used also for well-known species if more detailed models are not available or are unsuitable for some reasons. This model stores information about plants, soils, and climates, and uses the information to predict plant performance for any soil/climate combinations. A simple suitability ratings system is used from 0 to 9, to describe the relationships between plant and environment factor. People can easily use the model without so much data. The output is also described by a limitation rating with 0 to 9 scale. Unlike the two models mentioned above, this model is ready to be used by any level of users, because it allows people to create their own soil, crop, and climate files easily.

All these models have been well tested for temperate regions. However, the performance of the crop models under tropical conditions has not been well validated. Many models were designed for field crops such as soybean, maize, sorghum, peanut, rice, wheat, etc., but, very little was done on vegetable models, because of constraints existing in vegetable modeling. Some of the problems of modeling are as follows:

- Lack of individual crop data, especially from the tropics;
- Difficulty in obtaining physiological information required for model development;
- Lack of a classification scheme for vegetable-based soil systems.

Materials and Methods

The procedures for vegetable simulation modeling at AVRDC are shown in Figure 1. So far, minimum data sets of climates, soils and crops have been implemented ready to verify the models. Only the soil data base will be reported here.

Soils were collected from more than 90 locations throughout Taiwan. Soil series from major cultivated lands which occupied large areas were chosen and connected to soil mapping units and soil taxonomy. Latitude and longitude were marked on the map so that repeated references to the soil information is possible.

Soil chemical and physical properties related to vegetable growth were analyzed based on "Procedures for collecting soil samples and methods of analysis for soil survey" (Soil Conservation Service, USA 1984).

Results and Discussion

A data base management system (DBMS) at AVRDC is proposed and illustrated in Figure 2. Through the latitude and longitude information of soil data base, and by the software package of GIS, such as ARC/INFO or GRASS, a connection of this data base to the Taiwan Agricultural Resources Data-Base becomes possible. Similarly, it can be extended on a worldwide scale through other GIS systems.

The data base of resources at AVRDC is divided into five categories: soil, climate, crop, cultural practice and rotation system. Climate data bases have daily records of 25 main weather stations of Taiwan over 10 years. They also include weather data of six main District Agricultural Improvement Stations. Weather records at AVRDC were established in 1973.

Crop data bases include AVRDC mandate crops, vegetable performance in gardens, cultivar evaluation and interaction with environment, and physiological analysis for soybean and other crops. Over 6 years, 40 kinds of crops and 300 varieties have been collected in the data base established by the cropping system personnel.

In data base-related cultural practices, crop responses to fertilization, irrigation and other management techniques have been included. In the data base of rotation systems, data sets for 6 years, 7 locations, and 90 plantings have been included with more than 1100 records now available.

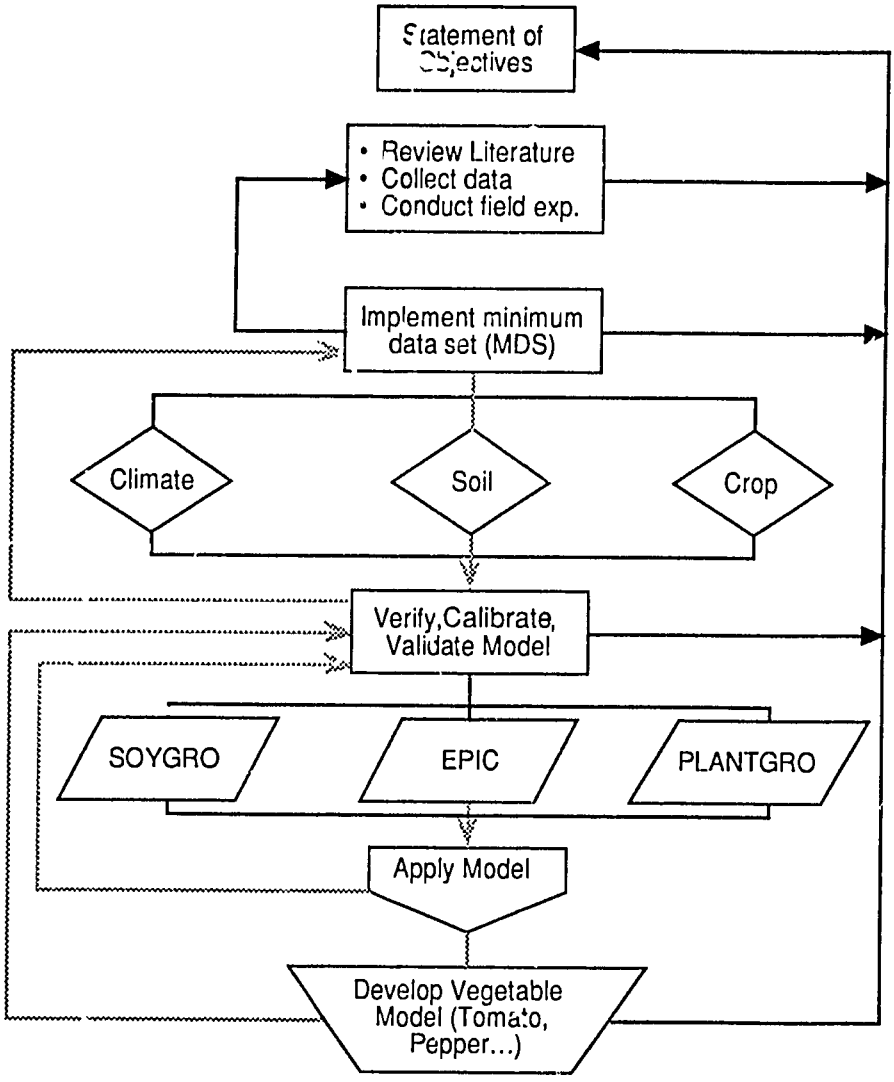

Fig. 1. Flowchart of vegetable simulation modeling at AVRDC.

Examples of relevant chemical and physical properties of latosols, and calcareous and non-calcareous soils are presented in Tables 15a and 15b. Among these, eight locations were selected for field trials of soybean. Soils from 20 locations were planted in pots with soybean. Results of relations between soil and its productivity will be reported later.

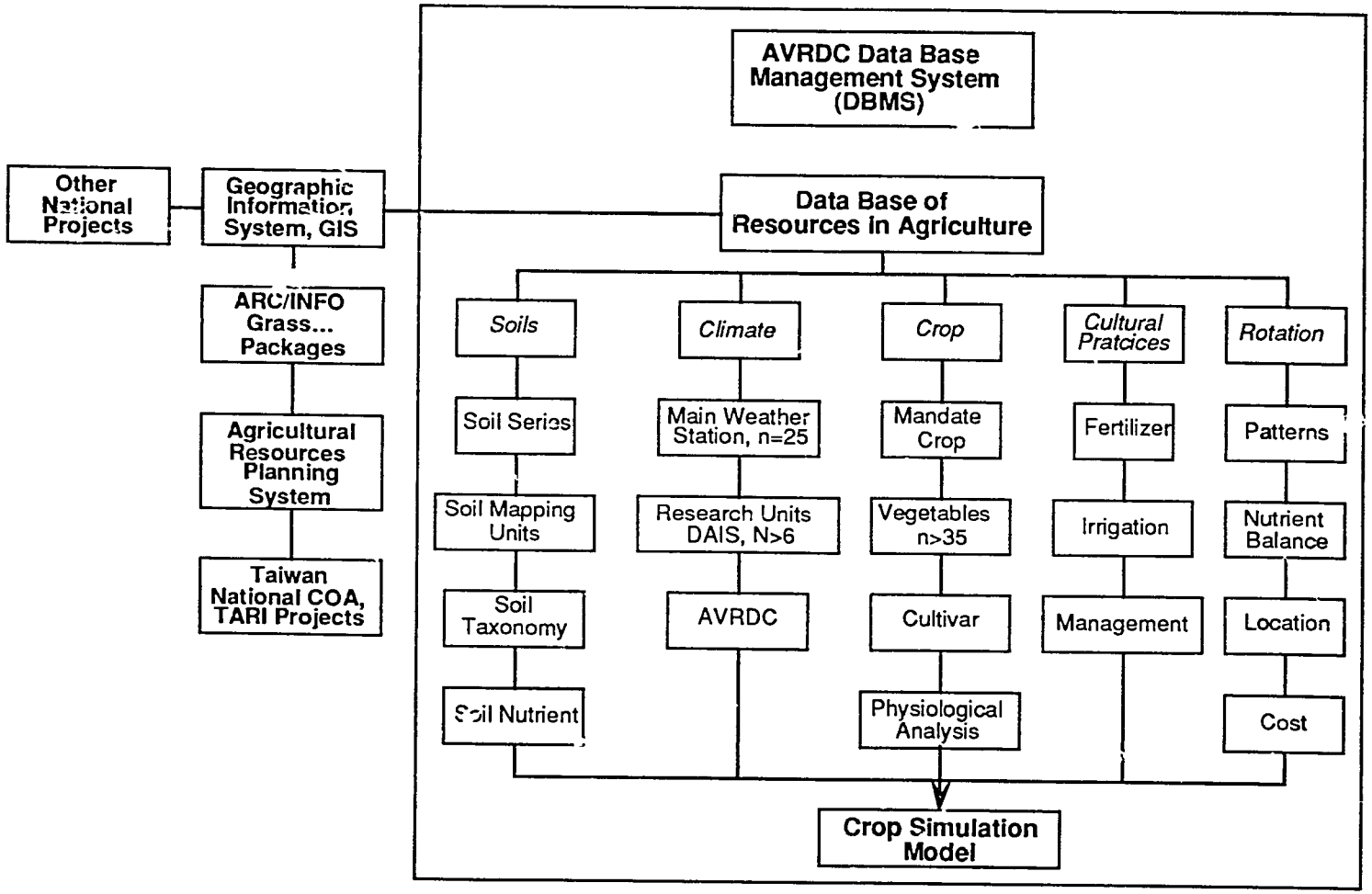

Fig. 2. Proposed data management system for crop cultivation in the tropics (AVRDC, since 1985).

Table 15a. Some examples of chemical and physical properties in soil data base. (n = 20)

Soil No.	pH H20	Organic Carbon (1:2.5)	Total N (%) (%)	Mechanical Analysis Clay	Silt (%)	Sand (%)	CEC (%)	Exchangeable cations K	Na	Ca	Mg
								cmole/kg			
Latosols, n = 6 of 21											
61	5.6	1 7	0.2	45	38	17	10.3	0 56	0.36	4.55	1.29
62	4.3	0.7	0.1	55	33	12	9.2	0 22	0.01	0.36	0 08
63	4.6	0.6	0.1	26	20	54	4.8	0.34	0.03	0.49	0.24
71	5.3	0.9	0.1	30	35	35	7.3	0.36	0 18	3.28	1.03
72	4.2	1.4	0 2	49	36	15	10.1	0.35	0.01	0.20	0.08
73	8.0	0.7	0.1	25	28	47	6.3	0 37	0.05	26.28	2 27
Calcareous soils, n = 8 of 29											
64	6.1	1.4	0.2	42	52	6	16.4	0.25	0 34	11 63	3.66
65	7.5	0.8	0.1	18	28	54	8.7	0 29	0.12	7.25	2.47
66	7.9	0.9	0.1	16	25	59	9 1	0 24	0.29	11.79	2.83
67	7.9	0 6	0.1	18	27	55	9.1	0.12	0 11	10 57	1.65
74	6.3	0.7	0.1	14	15	71	7.3	0.12	0 34	5 90	1.96
75	5.1	0.5	0.1	14	15	71	6.3	0.43	0.12	4.77	1.70
76	7.4	0.9	0.1	21	29	50	10.8	0 19	0.22	13.97	3.35
77	7.9	0 8	0.1	22	34	44	11.3	0 30	0 14	13 06	2.27
Noncalcareous soils, n = 6 of 22											
68	5.6	0.6	0.1	17	26	57	8.6	0.11	0.18	5.10	1.60
69	5.9	1.4	0.2	28	49	23	15.1	0.31	0 26	10.72	2.83
70	8.4	0.5	0.1	18	32	50	10.2	0 12	0.28	13.69	2.22
78	5.8	0.5	0.1	17	27	56	9.1	0.10	0.43	7 25	2.32
79	5.7	0.8	0.1	15	34	51	8.6	0.46	0.10	5.20	2.17
80	5.4	0.7	0.1	17	20	63	6.5	0 34	0.27	3 89	1.29

Table 15b. Some examples of chemical and physical properties in soil data base. (n = 20)

Soil No.	Base Saturation (%)	Exch. Fe[a] (ppm)	Extr. Fe[b] (%)	Inorganic P[c]	Total P	Organic P	Olsen P	Bray P	Resin-Cl P
				(µg P/g)					
Latosols, n = 6 of 21									
61	65.6	0.40	1.76	537.3	735.3	198.0	41.8	29.9	10.4
62	7.1	0.00	2.56	115.9	307.0	161.2	9.5	6.7	0.7
63	23.0	0.55	1.20	138.5	244 4	105.9	24.9	41.4	5.4
71	66.5	0.00	1.88	265.6	434 1	168.5	23.0	33.7	1.4
72	6.3	3.25	2.63	114.5	430.5	315.9	5.3	4.8	1.0
73	100.0	0.00	1.18	389.9	581.5	191.6	49.7	34.7	26.1
Calcareous soils, n = 8 of 29									
64	96.9	-	-	298.8	483 0	184.2	15.1	11.9	6.3
65	100.0	-	-	591.6	734.4	142.8	16.9	23.1	26.4
66	100.0	-	-	506.9	621.1	114.2	7.3	9.7	8.7
67	100.0	-	-	393.6	517.0	123.4	19.9	28.3	22.8
74	100.0	-	-	282.2	375.2	93.0	15 8	23.5	11.3
75	100.0	-	-	498.6	589.8	91.2	26.0	29.7	6.9
76	100.0	-	-	508.7	633.1	124.3	13.2	15.1	10.0
77	100.0	-	-	538.2	696.6	158.4	38 4	63.6	33.5
Noncalcareous soils, n = 6 of 22									
68	80.8	-	-	250 9	337.4	86.6	15.7	13.1	4.5
69	93.5	-	-	659 8	785.1	125.3	44.7	31.2	14.6
70	100.0	-	-	233.4	369.7	136.3	10 3	14.5	10.5
78	100.0	-	-	230.6	319.9	89.3	10.0	5.6	1.0
79	92.4	-	-	344.8	474.7	129.9	20.2	21.1	8.9
80	88.5	-	-	527 2	596 2	69.1	44.5	68.7	10.0

[a]Exchangeable Fe of Latosols were measured by 1N KCl.
[b]Extractable Fe of Latosols were extracted with sodium dithionite and sodium citrate.
[c]Inorganic P was extracted by 1N H_2SO_4.

Variations of P Availability Index Under Different Environments

Summary

As part of a study to predict crop growth and yield based upon the availability index of P in the soil, various experiments were run, initially to define P availability indices based upon P source, P concentration, soil type, incubation period and environment.

Introduction

Conventional soil classification data bases describe physical and chemical components of soils in detail. However, less information on biological aspects is included, especially the relationship to soil productivity. In recent years, soil fertility classification systems were developed to accomplish this goal. More emphases have been put on the nutrient status at the time of crop cultivation, but this may vary from time to time or from one cultivation to the next. Hence, characteristics that represent active components of soils which in turn are related to crop responses will be helpful for estimating soil productivity.

This project therefore attempted to develop a method of evaluating soil available phosphorus and to relate this to soil productivity. Variations of the parameters over soils, incubation time, amount of P application, P forms, moisture status and soybean performance were examined.

Initial Results

Extractable P vs. applied P in different soils

P Availability Index (F) is measured from the slope of the linear relationship between extractable P and added P, and can be expressed as:

Extractable P = a + F × (Applied P).

This linear equation holds true for more than 40 types of soils incubated for various durations with r^2 values > 0.98 (Fig. 3). Since P adsorption involved all reactions relating to active components of soil, i.e. soil surface, organic fraction and amorphous complex, this coefficient (F) reflects not only P adsorption status of the soil, but also the differences between soil properties. The 'a' coefficient (or intercept) represents the P concentration naturally available in that soil.

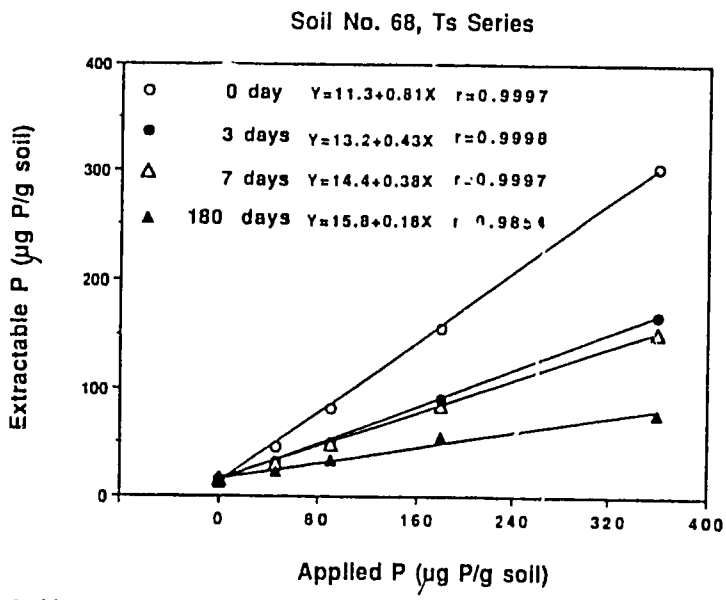

Fig. 3. Linear regressions of extractable P on applied P at different incubation times.

P availability index vs. incubation time in different soils

Multiple regression analyses were applied to P availability index and incubation time (days, T), and the kinetics of P availability index was best fitted to the following equation:

P Availability Index, $F = A + (B \times T) + (C \times \ln(T))$.

This means change of P availability is composed of three different reactions. Adsorption on the soil surface is responsible for the fast reaction, precipitation and rearrangement of surface complexes for the slow reactions. Coefficients of A, B and C can be used to characterize each soil. This equation was applied for more than 30 soils tested with r^2 values > 0.95.

P availability index vs. environments

Variations of P availability index in soils No. 71–80 incubated in the laboratory and in the greenhouse were compared (Fig. 4). Availability of soil P incubated in the greenhouse was generally lower than that measured in laboratory. The differences in the P index ranged from 0.03 to 0.1 over the 10 soils tested. In the greenhouse, temperature was high and soils were incubated in an open system which resulted in drastic changes of soil moisture status. Under rather dry conditions, P concentration in soil solution became condensed, hence P adsorption and precipitation occurred strongly, resulting in a decrease of P availability. Incubation under a constant temperature (25°C) in the laboratory, with soils at optimum moisture, P availability was greater than those in the greenhouse.

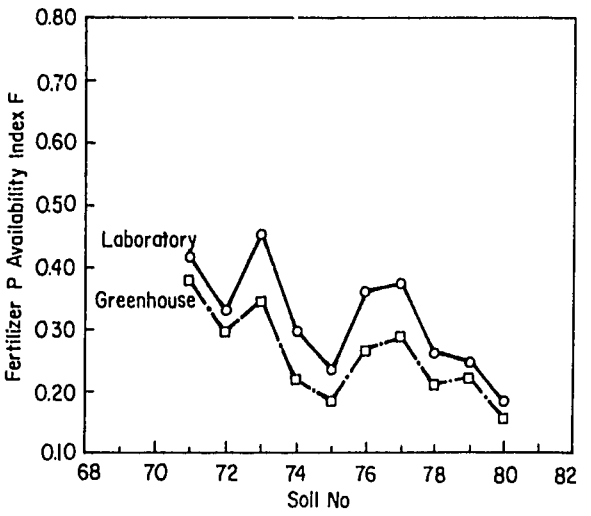

Fig. 4. Differences of P availability index in soils no. 71–80 following 180 days incubation in the laboratory and the greenhouse.

In a comparison of soils incubated in soil bags buried in an experimental field with those in the greenhouse, over the incubation periods similar results were obtained (Fig. 5). Soil P in the buried bags tended to reach equilibrium with the surrounding soil, hence the extractable P in soil bags was less than that measured in the laboratory incubation. Differences between P availability indices in the field and laboratory were usually less than 0.1 unit of the index.

These studies indicated that the P index measured in the laboratory can represent the real P index under field conditions for different soils, although the absolute value of the former will be higher than that measured in the field. The laboratory test will be a practical technique for measuring P index in the soils.

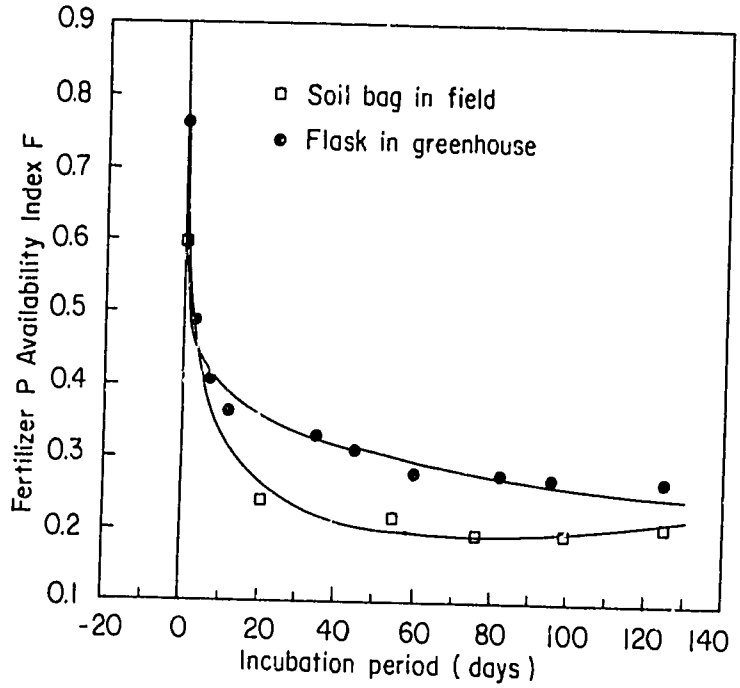

Fig. 5. Differences of P availability in Ts soil, incubated in the field or in a flask in the greenhouse.

P availability index vs. P sources

Two types of fertilizers were applied to soil bags and buried in the field (Fig. 6). For the first 80 days, the P index was higher when P was applied as Ca superphosphate than as di-ammonium phosphate [$(NH_4)_2HPO_4$]. Possibly because of higher solubility of $(NH_4)_2HPO_4$, availability of P in bags was lower than that with Ca superphosphate as a result of greater P fixation in the former. After 100 days of incubation, P source had no effect on P availability index. This result indicated that P index measured for a given soil was eventually similar regardless of the type of fertilizer applied.

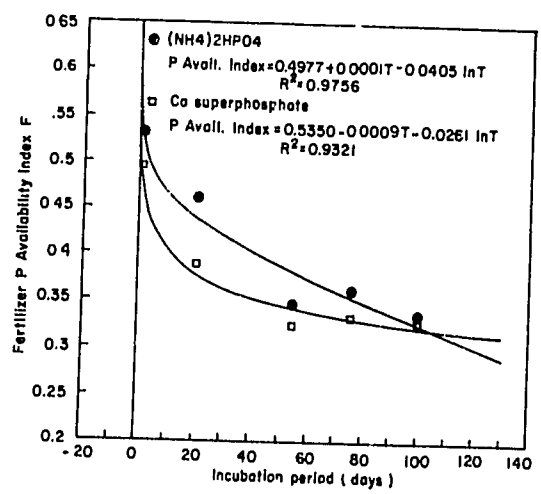

Fig. 6. Differences of P availability index in soil.

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International Cooperation Program

Training

Enrollment

During 1991, AVRDC provided 189.25 person-months or about 16 person-years of training to 51 training scholars from 20 countries in the various training categories (Table 1).

The Southern African countries (Malawi, Tanzania, Zambia and Zimbabwe) represented 18% of the total training scholars making it the largest enrollment of trainees from the African continent in AVRDC's history. AVRDC's enrollment also reached the 1000th mark during the year. Fifty-one percent of all the training scholars were women.

Table 1. Distribution of trainees by country and period of scholarship.

Countries	RF	RS	RI	SPT	SRSTS	UST	VS	Total
Bhutan					1			1
Finland				1				1
Germany		1						1
India					1			1
Indonesia			1	1				2
Japan						1		1
Korea	1		1					2
Malawi					2			2
Mauritius				2				2
Netherlands			1					1
Philippines	2		1	2			1	6
Sri Lanka	1							1
Sudan			1					1
Taiwan	1			1		11		13
Tanzania					4			4
Thailand			4	3				7
Western Samoa				1				1
Vietnam					1			1
Zambia					2			2
Zimbabwe					1			1
Total	5	1	9	11	12	12	1	51

RF = Research Fellow
RS = Research Scholar
RI = Research Intern
SPT = Special Purpose Trainee
SRSTS = Special Research Skills Training Scholar
UST = Undergraduate Student Trainee
VS = Visiting Scientist

Training Specialization

The distribution of training scholars within AVRDC programs and disciplines is shown in Table 2. About 45% of the training scholars were in the Crop Improvement Program with half of them pursuing training in plant breeding. Each training scholar completed a research project, the report of which is deposited at the Center.

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Table 2. Distribution of trainees by program/discipline and training period.

Program / Discipline	RF	RS	RI	SPT	SRSTS	UST	VS	Total	PM
Crop Improvement Program									
Plant Breeding	1		5	4			1	11	43
Plant Pathology	1		2	1		3		7	27.5
Plant Physiology						1		1	2
Entomology			1	1				2	6.5
Seed Technology (GRSU)			1	2				3	6.5
Subtotal	**2**		**9**	**8**		**4**	**1**	**24**	**85.5**
Production Systems Program									
Ag. Chemistry						8		8	16
Crop Management	1	1		3				5	15.8
Subtotal	**1**	**1**		**3**		**8**		**13**	**31.8**
International Cooperation Program									
Publication & Documentation	2							2	24
Training					12			12	48
Subtotal	**2**				**12**			**14**	**72**
Grand Total	**5**	**1**	**9**	**11**	**12**	**12**	**1**	**51**	**189.3**

Training Scholarship

The organizations that sponsored the training scholars are shown in Table 3. AVRDC sponsored 39% of the training participants.

Table 3. Distribution of grantees in each training category by sponsors.

Sponsor	RF	RS	RI	SPT	SRSTS	UST	VS	Total	PM
JSIF			3	2				5	18
AVRDC	3		3	2		11		19	74
SPRADP				1				1	3
COA	1			1				2	7.5
JGP			1	2				3	6.5
SAVERNET					3			3	12
CONVERDS					9			9	36
HU				1				1	3 3
ARETP			1					1	6
IDRC							1	1	1
GTZ	1							1	12
GOM				2				2	1
Self sponsored		1	1			1		3	9
Total	5	1	9	11	12	12	1	51	189.3

JSIF - Japan Shipbuilding Industry Foundation
AVRDC - Asian Vegetable Research and Development Center
SPRADP - South Pacific Region Agricultural Development Project/Western Samoa
COA - Council of Agriculture, Republic of China
JGP - Japanese Germplasm Project
SAVERNET - South Asian Vegetable Research Network
CONVERDS - Collaborative Network for Vegetable Research and Development in Southern Africa
HU - Helsinki University
ARETP - Agricultural Research Extension and Training Project/Sudan
IDRC - International Development Research Centre/Canada
GTZ - German Agency for Technical Cooperation
GOM - Government of Mauritius

Special Research Skills Training Course

Nine training scholars from countries of the Southern African Development Coordination Conference (SADCC) and three from South Asia took part in the Special Research Skills Training Course. This four-month course is among the preparatory activities for the initiation of two new AVRDC networks: the Collaborative Network for Vegetable Research and Development in Southern Africa (CONVERDS) and the South Asian Vegetable Research Network (SAVERNET).

The course objective was to sharpen research skills and broaden the participants' background knowledge on vegetable production practices. This course consisted of lecture series which covered key aspects on vegetable production, laboratory and field practicals and field trips. Delivered by AVRDC scientists and invited guest lecturers, the lectures were intended to upgrade the participants' knowledge of vegetable production and research.

Other components of the course included group field practicals in which participants evaluated vegetable crop varieties of priority in the CONVERDS and SAVERNET regions. This activity was intended to sensitize them to teamwork in the joint planning, data collection and reporting of the results of their field trials. Each participant carried out an independent study, under the guidance of an appropriate AVRDC researcher, on a research problem of priority vegetables in their region. This exercise was intended to sharpen the participants' research skills.

Participants held a Field Day to demonstrate the methods and results of their field trials and conducted a mini-workshop where each made a presentation on the individually guided research.

The four-month course conducted 1 March–30 June has made possible the placement of an initial core of well trained vegetable researchers ready to participate fully in network activities in their national agricultural research systems.

AVRDC has continued with its commitment on the theme of training the trainer. These young researchers, instructors and extension agents return to their home country institutions and carry with them new knowledge, rekindled spirit and a willingness to help teach others new skills. Importantly, these men and women become conduits of AVRDC-improved vegetable varieties and technology which will be tested in the new environment of their regions.

Information and Documentation

Introduction

In 1991, the library acquired 1,814 books and crop documents, and 97 new serial publications. The book collection now totals more than 14,000 titles. Serial publications reached 1311 titles. The crop documents now exceed 31,000 entries. The acquisition of CD-ROM data bases resulted in a dramatic increase in requests for literature searches. Reader services also reported a higher number of library loans and photocopy/document delivery services.

Information Collection

The library ordered 749 books or photocopies, and subscribed to 113 serial publications. The average cost was US$64.92/book and US$160.15/serial. A total of 450 books, 225 photocopies, and 428 serial publications were acquired through exchanges with 553 institutes/organizations in 61 countries. In order to provide more inform ation from external data bases at the lowest cost, three CD-ROM data bases, Agricola, Agris, and CAB International Abstracts, and the floppy disk edition of Current Contents on Agriculture, Biology and Environmental Sciences were purchased.

Documentation and In-house Data Base Development

The library staff catalogued and added to the library collection a total of 1,814 titles of books and crop documents, 97 new serial titles acquired through exchange, and 7 maps. Additions to library collection and in-house data base development are given in Table 1.

Table 1. Status of library collection and retrieval system.*

			Retrieval System	
	Additions	Total holdings	Card-catalog	Online DB
Book (title)	607	14,070	9,655	4,415
Serial publication (title)	97	1,311		1,311
Back volumes	367 (vol.)	12,117 (vol.)		
Map	7	84	77	7
Cassettes		52	52	
Microfilms	11		11	
Documents	(title)	(title)	(titie)	(title)
Chinese cabbage	45	1,496		1,496
Diamondback moth	21	585	340	245
Garlic	47	178		178
Mungbean	86	4,303		4,303
Onion	283	655		655
Peppers	109	953		953
Shallot	17	43		43
Soybean	95	10,051	7,631	2,420
Soybean rust	17	422		422
Sweet potato	15	3,914	2,566	1,343
Tomato	292	7,360	5,257	2,103
Others	180	1,476		1476

*Information Dissemination and Reader Service

Current awareness and SDI services

One issue of Library List (new acquisitions) and 29 issues of current awareness service on different crops or topics retrieved from Current Contents on Diskette were published and distributed.

Eight issues of Tropical Vegetable Information SDI Bulletin were published. The Bulletins, with an evaluation sheet, were distributed to 123 partners and 24 libraries in 36 countries. Feedback was received from 22 recipients.

Bibliographies

Bibliographies on Mungbean Yellow Mosaic Virus (199 entries), Soybean Rust (485), and Bacterial Wilt on solanaceous crops (353) have been compiled.

Reader Services

Literature searching. The acquisition of CD-ROM data bases and Current Contents on Diskette resulted in a dramatic increase of both current and retrospective literature searching. A total of 207 searches were conducted, an increase of 153 over last year. CD-ROM data bases and Current Contents on Diskette will be accessible through campus networking in the near future.

Photocopy/document delivery. The staff copied 1363 document and delivered them to 53 external users and 70 libraries in 20 countries, an increase of 542 titles over 1990.

Library loans. Users borrowed 5937 books and documents in 1991, an increase of 3149 titles over 1990.

Publications and Communications

The Office of Publications and Communications had a highly productive year, setting some new standards both in terms of improved production time for some titles (e.g. the 1990 Progress Report was printed in April), and in developing consistent formats and improved editorial style.

After considerable work and staff discussion, a Publication Policy document was finalized and put on the agenda for approval at the December 1991 Executive Committee Meeting. A companion document, an AVRDC Style Guide, was completed and a copy given to all staff who write or work in English. The intention is to try this guide for a year before formally adopting it as the definitive manual of style.

The Center's Strategic Plan (Vegetables: Research and Development in the 1990s—a Strategic Plan) was printed in October 1991. This document will be widely circulated to our regular collaborators, the donor group, and to the IARCs and national programs.

For most of 1991 the services of a person skilled in personal computers and with skills in typography and computer graphics was contracted. This extra assistance in OPC resulted in faster turn-around of many jobs, and the introduction of new ideas to improve the appearance and readability of Center material.

Despite tight budgets for new equipment, many requests for much-needed new equipment were approved by Center management. The editorial and production staff now have more modern computers and fewer problems of compatibility, resource requirements, etc. The upgrading of OPC equipment is not yet complete; however, the improvements to date have resulted in smoother output and higher staff morale.

The print shop continues to provide a vital function for the Center, and the acquisition of a new press this past year has contributed enormously to this operation. During the year the printery produced close to 400,000 pages of printed materials.

The graphic art unit continued to provide art and calligraphy services to the Center. The artist also prepared all printing and binding specifications, and acted as quality control and liaison person with the printers.

The photographic unit continued a long tradition of providing professional services to Center scientists both in the field, the laboratories, and at conferences and other events. Close to 25,000 slides were prepared for various purposes.

Probably the key to every successful publishing operation is the effectiveness of the distribution system: the maintenance of an accurate mailing list, the prompt filling of orders, the successful promotion of new titles, and the maintenance of stocks and the fast and economical distribution of new titles. AVRDC has managed to score high again this year, despite the growing number of titles and the ever-increasing number of requests. The Center's distribution efforts are aided considerably through a generous annual grant for this purpose from CTA. A mailing list survey sheet was distributed in November to every addressee on the mailing lists. Feedback from this survey will allow the maintenance of an accurate and well-targeted list.

Publications

In 1991 the Center published 25 books and newsletters with a total print run of 37,600 copies. The number of printed pages totaled 1588. A list of new publications is included in this report.

Journal Papers

During 1991, 10 journal papers were published by Center scientists and articles were prepared for submission to international journals and for presentation at international symposia. These are listed in the Publications section.

Public Awareness

Two issues of the Center's newsletter Centerpoint came out. Work continued on the new Center slide show and video following completion of the Strategic Plan. A new Center brochure is in preparation. The Center received more than 100 groups of visitors, and other international visitors, who are briefed on the Center's work and achievements. In 1991 TV crews from two countries came for a visit to record the Center's work.

Publications

Symposium Proceedings

Talekar, N.S. (ed.) 1991. Thrips in Southeast Asia: proceedings of a regional consultation workshop, Bangkok, Thailand, 13 March 1991. AVRDC Publication No. 91-342, 74 p.

Shanmugasundaram, S. (ed.) 1991. Vegetable soybean: research needs for production and quality improvement: proceedings of a workshop held at Kenting, Taiwan, 29 April–2 May 1991. AVRDC Publication No. 91-346, 150 p.

Technical Bulletins

Green, S.K. 1991. Guidelines for diagnostic work in plant virology. AVRDC Technical Bulletin No. 15 (second edition), 63 p.

Green, S.K., and Kim, J.S. 1991. Characteristics and control of viruses infecting peppers: a literature review. AVRDC Technical Bulletin No. 18, 60 p.

Midmore, D.J., Niñez, V., and Venkataraman, R. 1991. Household gardening projects in Asia: past experience and future directions. AVRDC Technical Bulletin No. 19, 28 p.

Monographs

Talekar, N.S. Agromyzid flies of food legumes in the tropics. AVRDC/Wiley Eastern Ltd., New Delhi, 297 p.

Newsletter

Centerpoint, Vol. 9(1) February, 12 p., and 9(2) October, 12 p.

Impact, Vol. 4 January-June 1991, 12 p.

Progress Report

1990 Progress Report, 313 p. (published April 1991)

Working Papers

Jansen, H.G.P. 1991. Prospects for horticultural exports of developing countries in Asia: quality, competitiveness and the environment. Working Paper No. 1. (AVRDC Publication 91-363), 33 p.

Jansen, H.G.P., and Dumsday, R.G. Preliminary impact assessment for AVRDC-improved mungbean varieties in five countries. Working Paper No. 2. (AVRDC Publication 91-366), 15 p.

Others

Black, L.L., Green, S.K., Hartman, G.L., and Poulos, J.M. 1991. Pepper Diseases: A Field Guide. AVRDC Publication 91-347, 98 p.

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Saladaga, F.A., Takagi, H., Cherng, S.J., and Opeña, R.T. 1991. Handling and selecting improved clones from true seed populations of sweet potato. (AVRDC Guidesheet. Publication No. 91-348), 6 p.

Pamphlets

Home composting, 15 p.

Permanent Compost Beds, 14 p.

Simple Seed Storage, 9 p.

Smoked Rice Hull, 10 p.

Tomato Pruning, 10 p.

Slide Scripts

Lal, G., and Shanmugasundaram, S. 1991. No Tillage Rice Stubble Soybean Cultivation, 13 p.

Lal, G., Kim, Doo-Hwan, and Shanmugasundaram, S. 1991. Harvesting High Yield and Quality Mungbean, 13 p.

Shanmugasundaram, S., Talekar, N.S., and Lal, G. 1991. Soybean Production Technology, 14 p.

Lal, G., Lai, S.H., and Shanmugasundaram, S. 1991. Vegetable Soybean Cultivation, 14.

Video Cassette

Harvesting High Yield of Soybean, 9 min.

Training Report

Research Scholars Training Report. 1990, 263 p.

Journal Papers

JP 121 Talekar, N.S., and Yang, J.C. 1991. Characteristic of parasitism of diamondback moth by two larval parasites. Entomophaga, 36(1), 27–36.

JP 122 Hartman, G.L., Yang, C.H., and Wang, J.F. 1990. Races of *Xanthomonas campestris* pv. *vesicatoria* in Taiwan and an inoculation technique to evaluate host resistance. Plant Protection Bulletin, 32, 112–124.

JP 123 Yuen, J.E. 1991. Resistance to *Peronospora parasitica* in Chinese cabbage. Plant Disease, 75, 10–13.

JP 124 Talekar, N.S. 1991. Characteristics of damage by *Ostrinia furnacalis* (Lepidoptera:Pyralidae) in mungbean. Journal of Economic Entomology. (in press)

JP 125 Hartman, G.L., and Yang, C.H. 1990. Occurrence of three races of *Xanthomonas campestris* pv. *vesicatoria* on pepper and tomato in Taiwan. Plant Disease, 74, 252.

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JP 127 Talekar, N.S. 1991. Management of *Anomala cupripes* and *A. expansa* in soybean by using a trap cultivar in Taiwan. Tropical Pest Management (in press).

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Outside Publications

Chen, K.F., Lai, S.H., Cheng, S.T., and Shanmugasundaram, S. 1991. Vegetable soybean seed production technology in Taiwan. In Shanmugasundaram, S. (ed.) Vegetable Soybean: Research Needs for Production and Quality Improvement: Proceedings of a workshop held at Kenting, Taiwan, 29 April–2 May 1991. Asian Vegetable Research and Development Center. Publication No. 91-346, 45–52.

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Shanmugasundaram, S. 1991. Technology packaging in production and protection of FLCG crops–soybean and mungbean. Paper presented at the first working group meeting of the Regional Cooperative Programme for Improvement of Food Legumes and Coarse Grains (FLCG) in Asia (RAS/89/040) held in Chiang Mai, Thailand, 19–24 August 1991.

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AVNET

Summary

The four countries of Southeast Asia—Indonesia, Malaysia, Philippines and Thailand, with support from the Asian Development Bank, have organized themselves into a collaborative vegetable research network called AVNET. AVNET initially formed its set of activities on two main subnetworks: germplasm improvement and disease elimination and integrated pest management. The main results of those collaborative activities for 1991 were as follows:

Cucumber trials for improved germplasm showed that varieties Taeng Ton, Jad-Bai and Pol-lek from Thailand produced small fruits but had higher yield in Indonesia, Philippines and in Thailand itself.

Garlic and shallots are both prone to 100 % virus infection and yield loss from viral diseases can run to as high as 50%. Mass propagation of disease-free materials has become a problem. The Philippines has developed an in vitro culture mass propagation system. Shoot culture was preferred over callus culture because the first has better clonal stability. Eleven garlic and 19 shallot varieties have been cultured in vitro.

Bacterial wilt is one of the most damaging diseases of tomato in the lowland tropics and subtropics. Surveys on this disease conducted in tomato and pepper-growing areas revealed differences in pathogens and environmental conditions which explain inconsistent results among different locations.

Biovar III is predominant in the Philippines while biovar IV is prevalent in Thailand. Biovars are location-specific in Thailand and their virulence vary accordingly. Nine pepper and three tomato lines were found resistant to the most virulent of the biovar III strains in the Philippines and Malaysia.

Anthracnose renders pepper fruits unmarketable. Plant die-back, caused by different species of Colletotrichum was found in Indonesia. Yield loss from this disease could run as high as 60%, aggravated by postharvest yield losses. In Malaysia *C. capsici*, *C. gloeosporioides* and *C. acutatum* were observed. Pepper varieties C2, C3, and C5 from Thailand were resistant in Malaysia, whereas COH72 was resistant and had a high yield in Malaysia and the Philippines. Varieties CO777 and Hp 87-311-5 were resistant to *C. capsici* and *C. gloeosporioides* in the Philippines. In Thailand, the hybrid between Kampaeng Saen and Long chili was highly resistant. Pepper planted as a post rice crop during dry season had no anthracnose in the Philippines. These results suggest that a combination of resistant varieties and adjustments in planting time could be used as a strategy to combat anthracnose of pepper, reduce yield loss and maximize the profit of farmers.

Yield losses due to viruses such as tobacco mosaic virus (TMV) and /or potato virus Y (PVY) can run to as much as 45-75%, whereas from cucumber mosaic virus (CMV) yield loss could be as high as 97% in tropical peppers. A survey of pepper viruses in all four countries suggested the widespread predominance of chili veinal mottle virus (CVMV), CMV, PVY, and therefore, screening for resistance should be focused on these three viruses. In Indonesia, five types of CMV have been identified and all should be screened for resistance. Variety LV-2411 was found immune. In Malaysia, CMV and CVMV mixed infection is common. Twenty CVMV-resistant varieties have been identified. In addition to CVMV, CMV and PVY, tomato mosaic virus (ToMV) and TMV were also predominant in some locations in the Philippines. Viruses were completely absent on pepper plants in Benguet, Isabela and Nueva Vizcaya. These findings should be further investigated to determine factors that limit virus infection. In Thailand, research results point to specific plant parts commonly infected with viruses (bottom leaves of specific sites). Each of the countries has produced antisera for the following viruses; CMV (Indonesia), CVMV (Malaysia), ToMV (Philippines) and PVY and pepper mottle virus (PeMV) (Thailand).

Diamondback moth (DBM), *Plutella xylostella*, is an economically serious pest of crucifers. Excessive use of pesticides to control DBM in crucifers poses the danger of chemical poisoning. A selected group of insects, parasitoids, has been identified to attack and kill DBM, thereby, reducing the damage they cause

on crucifers. In addition to parasitoids, supplementary use of nonchemical pesticides such as *Bacillus thuringiensis* (B. t.) in an integrated pest management (IPM) approach controls DBM effectively. With AVNET's support, all the countries have either renovated their existing facilities or constructed new ones for mass rearing of these parasites. DBM quickly develops resistance to chemical insecticides, therefore, cost and labor on the use of insecticides are ultimately ineffective in controlling DBM. In the Cameron Highlands in Malaysia the establishment of the parasitoids was excellent, and the farmers' cooperation in refraining to use chemical pesticides was remarkable. As a result DBM could hardly be found and the cruciferous vegetables produced from the Cameron Highlands were of excellent quality and were free from chemical pesticide residue. In Indonesia, although both *Diadegma semiclausum* and *Cotesia plutellae* have been well established, a new pest, *Crocidolomia binotalis* has become a serious pest. Farmers started using chemical pesticides and therefore, there is a need to accelerate the identification and mass release of parasitoids to control *C. binotalis*. Earthquakes and typhoons have damaged the parasite-rearing facilities in the Philippines but they have been quickly repaired, and the mass rearing of parasitoids and releases in pilot project sites are progressing satisfactorily. Constant education of the farmers encouraging them to refrain from using chemical pesticides is recommended.

In the lowlands in addition to DBM, there are other pests that attack crucifers. All affected countries mass-produce *Trichogrammatoidea bactrae*, a parasitoid adapted to the lowlands. There is a need to identify heat-tolerant parasitoids for DBM that can be used to control DBM in the lowlands. There is also a need to identify parasitoids for other crucifer pests such as *Hellula undalis*, which is very serious in the lowlands.

Each of the four affected countries have organized an IPM working group to exchange research information and parasitoids.

A monitoring tour was organized from 3-17 March 1991, and completed with a mid-term workshop. The participants included the AVNET coordinator and technical coordinators from each of the four countries and selected staff from the working group for each activity. The four countries reviewed the progress made and observed the facilities and the ongoing activities. All the participating countries also unanimously endorsed the continuation of the AVNET project with redefined objectives. The final workshop is scheduled tentatively for September–October 1992, provisionally, in Indonesia.

Introduction

People in Asia consider vegetables as a major food resource. Advances in vegetable production techniques have to be achieved to support increased vegetable consumption. This puts pressure on research to develop improved genetic materials. The goals are set ultimately towards increased vegetable yield.

In response to this demand, AVNET created two main subnetworks: germplasm improvement and disease elimination, and integrated pest management.

Among others, the subnetworks are tasked to: exchange and share germplasm of priority vegetables, namely tomato, pepper, garlic, yard-long bean, shallot (onion), and cucumber; strengthen the research capability of participating country scientists through research skills training; share valuable research information and transfer mature technologies generated by research to farmers in the regional network.

The activities of the subnetworks and their results are presented in the following report.

Germplasm Subnetwork

The general objective of the germplasm subnetwork is to strengthen the vegetable research capability of the NARS and accelerate the development of improved cultivars in Southeast Asia through special skills training of its personnel, provision of a wide diversity of germplasm, improvement in understanding of major diseases, and identification of new sources of disease resistance.

Specific Objectives

- To assemble, multiply, maintain, distribute and evaluate elite local cultivars (landraces, improved cultivars, and breeding lines) of the approved network commodities, such as tomato, pepper, garlic, shallot, yard-long bean and cucumber;
- To develop a set of potentially useful varieties of the above crops for further evaluation, potential use in breeding, and/or immediate release by the participating NARS of AVNET;
- To enhance the capability of the NARS personnel in carrying out the planned germplasm activities through training;
- To establish a regional gene bank in which the elite and indigenous germplasm of the network commodities collected from the participating NARS are kept and maintained for communal use.

Progress

Experimental results obtained so far reinforced the assumption that the improved varieties developed in one country should prove valuable in the others since the growing conditions in the four AVNET countries are similar.

Indonesia

Cucumber. A cucumber variety trial was conducted at Subang Experimental Farm (100 m a.s.l.) from 15 October to 23 December1990. The objective of the trial was to evaluate the field performance of 12 cultivars for yield, horticultural characteristics, and adaptability to local agroclimatic conditions. Considerable variability was observed for almost all the horticultural characteristics and yield. The best varieties for marketable yield were Jad Bai, Taeng Ton and Pol-lek all of which were from Thailand. However, their fruit size was small, they were late-maturing and they had very short shelf-life (3 days). The eating quality of Pol-lek was not good. Variability identified in the trial enabled the plant breeder to select some of the entries for improving cucumber cultivars for local use. Details of the trials and the results are reported in the AVRDC-Indonesia Vegetable Research Program section of the this Progress Report.

Tomato. A tomato trial was conducted at Kramat Tegal Experiment Farm (Central Java). The trial was planted in December 1990. Thirty-one tomato varieties from AVRDC were evaluated against two local check varieties, Ratna and Mutiara. Two weeks after planting almost all the plants were attacked by viruses. Infection by bacterial wilt (*Pseudomonas solanacearum* and Fusarium wilt (*Fusarium oxysporum* pv. *lycopersici*) were observed on a few plants. The trial is in progress.

Hot pepper. Seed multiplication was conducted at Lembang (1250 m) in the screenhouse to prevent outcrossing by insects. Germination of seeds of three varieties, Kulai, Matikas, and Hot Shot, was poor in two sowings. Seeds of the following six cultivars were distributed: Tit, Jati laba, Paris, Keriting, MC 4 and MC 5. Additional seeds of the following varieties were requested from different countries for multiplication and distribution: Kulai from Malaysia; Hot Shot, Matikas and Kawit from the Philippines; and Huey Sithon, Mun, Luang and Yuak from Thailand.

Yard-long bean. Seeds were distributed to all network partners from Malaysia.

Malaysia

Sixteen promising yard-long bean cultivars were evaluated. These cultivars were observed for 11 horticultural characteristics including yield according to AVNET procedures agreed upon by all countries.

Five cultivars (KP#5, K.U. #8, DOA, CSL 19 and CSD 4) significantly out-yielded the local check (and Taiwan White which is similar to the local check).

Number of pods per plant is quite variable (based on coefficient of variation). Phenotypic correlation indicated that pods per plant, weight per pod and pod length are relatively more important to pod yield.

At present the seeds of the local check cultivar are imported from Taiwan. The results of the trial suggest that there are cultivars that perform better than this local check. Since yard-long bean is a self-pollinated crop, seed production of promising cultivars can be done locally.

Some of the cultivars that possess desirable traits can be used for further breeding. The trials have also shown that a selection program should be based on number of pods per plant, pod weight and pod length, since these characters are significantly correlated to yield.

Philippines

Cucumber. The evaluation trial was planted on 9 August 1990 at BPI - National Crop Research and Development Center (Economic Garden), Los Baños (15 m a.s.l.). Fourteen elite cultivars received from four countries were evaluated during the 1990 wet season.

Observations were made according to the agreed AVNET Germplasm Improvement Network guide. Variety Taeng Ton produced significantly more marketable fruits (57/9 m^2) and marketable yields (10.3 t/ha). Varieties Jad Bai, UPL Cu-4 and BPI Cu-22 were also high yielding; Bukit Mertajam and BPI Cu-22 had large fruit size; BPI Cu-22 and UPL CU-6 had longer shelf life; for eating quality UPL Cu-4, UPL Cu-8, LV 1043 and BPI Cu-22 were the best. MTi-1 was resistant to downy mildew. UPL Cu-4, UPL Cu-6 and UPL Cu-8 were resistant to powdery mildew. Such information on different traits will be useful not only to other breeders within the country but also to other network partners.

Germplasm Maintenance and Evaluation and Rapid Multiplication of Garlic and Shallot

Germplasm Evaluation and Maintenance

Garlic (*Allium sativum* L.) and shallot (*Allium ascalonicum* L.) are two of the most important cash crops of vegetable growers in Asia. A number of strains, cultivars and elite lines exist in Indonesia, Thailand and the Philippines. However, they are not properly maintained and exchanged. Therefore, AVNET set out to identify a mechanism for maintenance and multiplication (free of diseases) so that they can be exchanged for use. This task has been charged by the network to the Philippine researchers.

Two varieties from Indonesia, Kuning and Sumenep, have been multiplied.

Rapid Propagation

Garlic and shallot are propagated by asexual means—by single cloves for garlic or by bulblets for shallot. Such standard asexual propagation is slow, seasonal and encourages the transmission of virus diseases. The yield reduction due to virus diseases could be as high as 45%. The objective of this AVNET project is to develop micropropagation techniques for rapid propagation and meristem culture to obtain virus-free planting materials. Shoot culture was chosen over callus culture due to better clonal stability in the former.

Plant material. Eleven strains of garlic and 19 strains of shallot were initially cultured in vitro (Table 1). Bulbs were surface-sterilized with 20% commercial bleach for 10 min and 4 to 6-mm shoot tip explants were excised and cultured onto the medium. For specific experiments, selected strains of garlic and shallot were used.

Nutrient media. For initial in vitro culture, two-base media (MS and R) were tested for garlic and one-base medium (MS) for shallot. For the succeeding experiments, MS-base medium was routinely used. The growth regulators used were BAP, kinetin (Ki), 2-ip and NAA at different concentrations.

Culture conditions. Cultures were grown in tubes or 125-ml flasks with the specific medium and incubated in an air-conditioned room at 24±2°C under 10-hour photoperiod provided by fluorescent light.

Among the strains of garlic and shallot initially cultured in vitro, no differences in the rate of growth were observed during the first 3 weeks (Table 2). After the third week when the cultures were first subcultured, garlic strain LV 1611 (Acc. 89-17012 from Indonesia) and one shallot strain (Acc. 90-16015 from the Philippines) showed a much slower growth than the rest of the accessions.

Using garlic strain Ilocos White (Acc. 89-17003 from the Philippines), initial results showed that shoots grown in MS and R base media with 4 mg/l BAF exhibited more vigorous growth than those grown

Table 1. In vitro germplasm maintenance of garlic and shallot.

CMPB Code	Accession No.	Description	Country
Garlic			
1G	89-17005	Batangas	)
2G	89-17020	Lemery	)
3G	89-17019	Cale, Tanauan	)
4G	89-17005A	Laguna	) Philippines
5G	89-17022	Bayog	)
6G	89-17003	Ilocos White	)
7G	89-17001	Tan Bolter	)
8G	90-17023	Ilocos Norte	)
9G	89-17007	LV 1020	)
10G	89-17012	LV 1611	) Indonesia
11G	89-17014	LV 2025	)
Shallot			
1S	89-16008	Sri-saket 1	) Thailand
2S	89-16009	Sri-saket 2	)
3S	88-16004		) Philippines
4S	88-16006	Bangkok	)
5S	88-16007	Bima	)
6S	90-16011	Sumenep	)
7S	90-16012	Kuning	) Indonesia
8S	90-16019	Ace, 5290	) Laos
9S	89-16010		)
10S	90-16013		)
11S	90-16014		)
12S	90-16016		)
13S	88-16001	Multiplier regular	)
14S	88-16002	Multiplier purple	) Philippines
15S	88-16003	Multiplier dark purple	)
16S	90-16015		)
17S	90-16018 a		)
18S	90-16016		)
19S	90-16017 b		)

Table 2. Effect of 6-benzylaminopurine (BAP) and two kinds of base media on shoot length using 5 to 6-mm shoot tip explants of garlic, strain 'Ilocos White' (Acc. 89-17003 from the Philippines).

Base Medium[a]	BAP (mg/l)	Mean length (mm)
MS	0	9.4
R	0	15.0
MS	4	17.2
R	4	15.4

[a]Murashige and Skoog's (MS) medium (Murashige and Skoog 1962) and R medium (Pateña et al. 1978).

in both media without BAP (Table 2). In terms of multiple shoot induction, Garlic favored the medium containing 0.5 mg/l NAA in combination with 1-2 mg/l 2-ip (Table 3), while shallot favored the medium containing 0.5 mg/l NAA in combination with 2 mg/l BAP (Table 4). These results indicate that garlic and shallot differ in their media requirements for multiple shoot induction.

Shoots established in vitro were subcultured every 3 weeks. Subculture was limited to three passages, after which the cultures died or formed bulb in vitro as in shallot strain 'Kuning' from Indonesia and garlic strain LV 1020 also from Indonesia. These observations show that garlic and shallot also undergo their normal cycle of plant development in culture as they do under field conditions.

Table 3. Effect of BAP, 2-ip and KI with or without NAA on multiple shoot induction in garlic strain 'Ilocos White' (Acc. 89-17003 from the Philippines).

Treatment No	Media					Total No Cultures	Ave No Axillary Shoots
	Base	BAP	2-IP (mg/l)	KI	NAA		
1	MS	0	0	0	0	26	0
2	MS	0	0 5	0	0	24	0
3	MS	0	0 5	0	0 5	27	1.2
4	MS	0	1.0	0	0 5	30	2 2
5	MS	0	2.0	0	0 5	30	2 3
6	MS	0 5	0	0	0	30	0
7	MS	0 5	0	0	0.5	25	0
8	MS	1 0	0	0	0.5	30	0
9	MS	2.0	0	0	0.5	29	0
10	MS	0	0	0.5	0	20	0
11	MS	0	0	0 5	0 5	30	0
12	MS	0	0	1 0	0 5	28	0
13	MS	0	0	2 0	0.5	28	0

Table 4. Effect of BAP, 2-ip and KI with or without NAA on multiple shoot induction in shallot strain 'Multiplier purple' (Acc. 88-16002 from the Philippines).

Treatment No	Media				NAA	Total No. Cultures	Ave. No. Shoots	
	Base	BAP	2-IP (mg/l)	KI			Axil.	Adv.
1	MS	0	0	0	0	14	1 3	0
2	MS	0	0 5	0	0	17	1 8	0
3	MS	0	0.5	0	0 5	12	1.6	0
4	MS	0	1.0	0	0.5	12	1.8	0
5	MS	0	2.0	0	0 5	12	1.6	0
6	MS	0.5	0	0	0	14	1.9	0
7	MS	0 5	0	0	0.5	18	2.3	0
8	MS	1.0	0	0	0.5	14	1.8	2
9	MS	2.0	0	0	0.5	14	2.8	3.7
10	MS	0	0	0.5	0	13	1.7	0
11	MS	0	0	0.5	0.5	14	1.9	3.0
12	MS	0	0	1.0	0.5	16	1.5	1.0
13	MS	0	0	2.0	0.5	12	2.1	1.0

Subculturing of shoots of both garlic and shallot has to be done every 3 weeks because of rapid elongation of the leaves. Experiments using mannitol showed that 1–2% mannitol added to the medium effectively controlled the rapid growth of leaves.

This study aims to develop a micropropagation technique for different strains of garlic and shallot via the multiple shoot induction technique. Research results in 1989–1990 showed that this technique is feasible. The two problems encountered in vitro, i.e. 1) limited subculturing of shoots due to the death of shoots after the third passage of bulbing in vitro, and 2) rapid elongation of leaves, are currently being addressed and alternate strategies are being undertaken.

Tomato. Seeds of tomato have been received.

Yard-long bean. The trial was planted on 12 December 1990. However, all the entries were severely infested by leaf roller and the data were discarded.

Hot pepper. A complete set of entries is yet to be received from Indonesia.

Thailand

Cucumber. Seeds of 13 varieties were obtained, multiplied and distributed to all participating countries. Seed multiplication was continued in the second year. Seeds of 12 varieties available for 1991 trial were distributed to all the participating countries during the monitoring tour.

Thirteen cucumber varieties were grown in June–July 1990. Due to flooding in the experimental field there was water-logging and the plant stand was poor. As a result the yield performance was also poor. Since it is an off-season such results were not unexpected. LV1043 gave nine fruits per plant while the local varieties had only one to seven fruits. AVNET trials therefore, enabled the selection of off-season types.

In November–December 1990, 13 entries were again evaluated. These are dry season entries. Variety Pol-lek and Taeng-Ton had the highest number of fruits. However, yield differences by weight between the varieties were insignificant.

A third cucumber trial was conducted during May–July 1991. Results suggested that the long-fruited varieties such as LV1043 (Indonesia) and LV308, LV2276 and Jad Bai gave significantly higher yield than the small-fruited cultivars.

Yard-long bean. The trial was conducted at Kasetsart University, Kamphaeng Saen, from 22 January to 17 May 1991. Sixteen cultivars were evaluated: CSD4, KU#8 and CSD5 gave the highest yields.

Tomato. Some 22 determinate and 14 indeterminate lines were included in two independent trials, which were planted in May 1991. The details of the trials and the types of entries used are reported in the AVRDC-TOP section of the AVRDC 1991 Progress Report.

Bacterial Wilt Screening

Bacterial wilt (BW), caused by *Pseudomonas solanacearum* (Smith) is one of the most damaging diseases of tomato in the lowland tropics and subtropics. Estimates of yield loss due to bacterial wilt range from 15 to 95%. The destructiveness of the pathogen is attributed to its widespread occurrence, broad host-range, its exceptional abilities to survive in the soil and in the roots of nonhost plants and the existence of different races, biovars, or strains. Varieties resistant to bacterial wilt have been identified at AVRDC but were later noted to be susceptible in some locations. Apparently, the differences in variety reaction to the pathogen is influenced by the presence of different pathogenic races as well as environmental conditions. It is essential that the screening techniques be standardized so that the results obtained from each country can be useful to others. Therefore, the objective of the international bacterial wilt disease nursery (IBWDN) study is to understand the variability in the host, pathogen and their interaction with the environment. By using selected resistant lines and planting them in IBWDN with a known local, resistant, and susceptible check varieties using a commonly agreed screening procedure, the collaborating countries hope to have a better understanding of the host-pathogen-environment relationships. To accomplish the above objective, a uniform BW screening procedure was agreed upon by the collaborating countries. An international bacterial wilt disease nursery using 22 varieties was proposed.

Progress

Philippines. A second IBWDN was established to screen pepper varieties. A susceptible tomato variety L390 was used as a check and it was inoculated with virulent biovar III pepper isolate of *P. solanacearum.*

- Survey and collection— In Luzon 12 tomato- and pepper- growing provinces were surveyed for bacterial wilt. Tomato samples were collected from five provinces and pepper samples from eight provinces.
- Isolation of the pathogen—Forty-six pure culture isolates are currently being maintained at IPB, UP at Los Baños. All the 46 isolates infected the tomato and pepper test plants.
- Biovar classification—Twenty-one tomato isolates and 20 of the 30 pepper isolates of *P. solanacearum* utilized both sugars and the hexose alcohols confirming that they belong to biovar III. However, 10 pepper isolates oxidized the hexose alcohols but not the sugars indicating that they belong to biovar IV.

- Screening for resistance—Of the 22 local pepper collections screened for resistance using BW pathogen biovar III in the greenhouse, the following were rated as resistant: PP67, A127, A99, A116, PP71, A137, PP4 74-61-15-1, PI 173877-3-2-N-4, A95 and A125. Variety Matikas and A160 were rated as moderately resistant.

Second International Bacterial Wilt Disease Nursery. The following seven tomato lines and varieties were sent to AVRDC on 16 January 1991 for seed increase and distribution to other countries: Tm-L114-48-5-N spreading, R 3034-3-10-N-UG, Tm-L46-N-12-N-early H.T., Tm-L114-42-N-H.T.P. early, F7-80-465-10-Pink, Improved Pope, and Marikit.

Thailand. In a disease survey and pathogen identification and characterization, a total of 19 strains of *P. solanacearum* was obtained from tomato and pepper plants collected from three provinces (Nakorn Pathom, Nong Khai, and Khon Kaen). Biovar III and IV were identifed among 19 strains. Biovar III was found only for Zeka (Table 5). Biovar IV is widely prevalent in Thailand.

Table 5. Biovar and virulence of *Pseudomonas solanacearum* strains obtained from infected tomato and pepper plants showing wilt symptoms.

Location	Strain	Host	Biovar[a]	Virulence[b]
Khon Kaen				
Muang	KK1	Tomato	IV	M
	KK2,3	Tomato	IV	L
Nong Khai				
Sichiang Mai	SR11,12,22,23	Tomato	IV	M
	SR21	Tomato	IV	H
Zeka	ZA21-ZA23	Tomato	III	M
Nakorn Pathom				
Bang Len	PAI, PA3-PA6	Tomato	IV	M
	PA2	Tomato	IV	H
Kamphaeng Saen	P1,2	Pepper	IV	H

[a]Biovar of *P. solanacearum* was determined according to Hayward (1964) based on utilization of sugars and sugar alcohols.
[b]Virulence was evaluated by percentage of wilting from artificial petiole-clipping inoculation of Dr. Valdez on cv. Seeda after 15 days of inoculation, H=71–100%, M=31–70%, L=1–30%.

Greenhouse screening for BW resistance. Ten tomato accessions/lines from AVRDC were screened with Seeda as susceptible check. Three pathogen strains were used either alone or as a mixture of three. All lines were 100% susceptible to strain T6 suggesting T6 is highly virulent. Except for BL341 and Seeda none of the others were wilted by strain KK1. Strain SR21 was intermediate. Mixture of strains produced variable infection. The results suggested that variation in host reactions to BW pathogen may be due to strains or mixture of strains attacking the host.

Malaysia

Screening for BW resistance in tomato. Eight AVRDC accessions were evaluated for two seasons. There was high, uniform inoculum in the soil. The local check MT1 was highly resistant to bacterial wilt. AVRDC lines CLN 65-247D5-2-0 and BL355 were completely resistant to the local strains of *P. solanacearum*. The results of resistance screening in two seasons were similar. It appeared that seasonal difference in Serdang does not seem to influence drastically the disease development in different varieties. Details of this evaluation procedure are reported in the AVRDC-MARDI section of this Progress Report.

Anthracnose of Pepper

Anthracnose of pepper, caused by *Colletotrichum* spp., primarily affects the fruits in the field and causes losses to producers and retailers. The fungus is carried on the infected seed and residues of infected plants. It occurs throughout the pepper production areas in Indonesia, Malaysia, Philippines, and Thailand. Anthracnose disease surveys have not been fully conducted in the past in any of the above four countries

except for a few places in Indonesia and Malaysia. There is a need to conduct a disease survey to understand the severity of the disease and variability in the pathogen in different pepper-growing areas in each of the countries.

In all countries, primary losses are due to fruit infection; plant die-back has also occurred in Indonesia. Estimates of yield losses in Java vary from 40 to 60% in both lowland and highland production areas. In Thailand and Malaysia, the estimated overall losses were 50% and up to 60%, respectively. Furthermore, postharvest losses due to anthracnose disease could be as high as 25%.

The pathogen species varied between locations within a country and between countries. To design effective control measures, basic knowledge on the species of the pathogen will be valuable.

The general control procedure involves the application of fungicides, which increases the cost of production and the risk of pesticide residue. Therefore, screening and identifying varieties resistant to the disease will result in savings to the farmers and greater safety to consumers.

Progress

Malaysia

Survey. A survey of the chili farms was conducted in various states in Peninsular Malaysia including Kelantan and Terengganu in the East Coast and Selangor and Malacca in the Central Region. Three pathogenic species of *Colletotrichum* (*C. capsici*, *C. gloeosporioides* and *C. acutatum*) have been isolated and preserved for further studies.

Disease resistance screening. Evaluation of 12 lines selected from 18 initial batches showed that line C01172 produced the highest yield of 33 kg for 60 plants. The same line had only 2% anthracnose incidence. Through collaborative effort it has been possible to select anthracnose-resistant lines with high yield potential for the lowland tropics. From F_6 and F_7 generation, 73 individual lines were selected as either resistant or moderately resistant. Based on other horticultural characteristics, nine lines were selected. Five were chosen for multilocation trials in 1991. Another disease, *Choanephora* shoot blight, was observed on the plants which interfered with the evaluation for anthracnose.

Philippines

Survey. A pepper anthracnose survey was conducted in 14 provinces of Luzon. The disease incidence varied from 0 to 25% depending on location. In Laguna, Cavite and Batangas, where pepper is grown throughout the year, the anthracnose occurrence was the highest, especially during the rainy season. Even though there were large pepper plantings in Pangasinan, La Union, Ilocos Norte, Ilocos Sur, Benguet, Nueva Vizcaya and Isabela, anthracnose was not observed since the pepper was grown following rice during the dry season which is not favorable for disease development. These observations suggest that one way of overcoming the disease is to adjust the planting time to avoid the disease.

In the infected fruits *C. capsici* alone was observed from samples received from Pampanga, Tarlac, Zambales and Nueva Ecija. *C. gloeosporioides* predominated in Laguna, Cavite and La Union.

Isolation and identification of *Colletotrichum* sp. A total of 42 isolates of *Colletotrichum* spp. from pepper are being maintained in the laboratory. Of them 25 are *C. capsici* and 17 are *C. gloeosporioides*.

Pathogenicity tests. Only five out of 18 *C. capsici* isolates and three out of 11 *C. gloeosporioides* were highly pathogenic causing 100% fruit infection. Red fruits were infected more severely than the green fruits (Table 6).

Screening for resistance. A total of 34 pepper lines—three from AVRDC, one each from Thailand, and Malaysia and 30 from the Philippines—were screened for resistance to *C. capsici* and *C. gloeosporioides*. The lowest percent fruit area infected by *C. capsici* and *C. gloeosporioides* was in C01777 and Hp 87-311-5, respectively. All the entries had 100% infected fruits by both *C. capsici* and *C. gloeosporioides*.

Thailand

Twenty-five pepper varieties were screened for anthracnose. The hybrid between Kamphaeng Saen and Long Chili had the best resistance. Resistance is based on the diameter of the lesion as shown in Table 7.

It appears that Long Chili, as one of the parents, confers resistance to the hybrid. An understanding of inheritance of resistance and the mechanism of resistance to anthracnose in Long Chili will facilitate breeding anthracnose-resistant peppers.

Table 6. Pathogenicity tests of 18 isolates of *Colletotrichum capsici* and 11 isolates of *C. gloeosporioides* using green and red ripe fruits of hot pepper accession P36.

		% Area infected on fruit type[a]			
		Red		Green	
Isolate No.	Place collected	Cc	Cg	Cc	Cg
C. capsici					
Pp11-1	Zambales	100	100	100	66
11-2	Zambales	100	100	100	47
12-2	Lipa, Batangas	100	100	100	39
12-1	Lipa, Batangas	100	100	90	72
6-5	Sta. Rita, Pampanga	100	100	–	–
6-4	Sta Rita, Pampanga	100	95	90	71
12-5	Lipa, Batangas	100	90	70	12
7-1	Kawit, Cavite	100	79	100	26
6-1	Sta. Rita, Pampanga	100	76	89	37
7-3	Kawit, Cavite	100	73	100	37
6-3	Sta. Rita, Pampanga	100	31	90	25
6-2	Sta. Rita, Pampanga	90	29	80	23
12-4	Lipa, Batangas	80	80	10	3
7-2	Kawit, Cavite	80	26	80	18
5	Los Baños, Laguna	70	14	44	13
1	Bay, Laguna	50	21	10	15
4	Bay, Laguna	30	11	40	10
2	Bay, Laguna	10	9	40	7
C. gloeosporioides					
Pp13-2	Lipa, Batangas	100	80	40	11
13-1	Lipa, Batangas	100	75	80	21
14-1	Gen. Frias, Cavite	100	75	80	17
14-3	Gen. Frias, Cavite	100	60	70	5
8-3	Labo, Camarines Norte	100	53	10	5
8-1	Labo, Camarines Norte	80	21	90	40
14-2	Gen. Frias, Cavite	80	25	40	6
3	Los Baños, Laguna	80	20	30	2
9-1	Vinzons, Cam. Norte	60	27	30	11
9-2	Vinzons, Cam. Norte	60	23	50	10
10	Guimaras, Iloilo	40	17	40	5

[a]Average of 10 fruits per isolate

Table 7. Resistance of 25 hybrid peppers to artificial inoculation with anthracnose fungus *Colletotrichum dematium*.

Pepper variety	Lesion diameter (cm)[a]
Passion × Mundang	3.1
Mungdang × Bangchang	3.0
Mundang × Kamphaeng Saen	2.8
Bangchang × Kamphaeng Saen	2.8
Long chili × Maeklong	2.7
Long chili × Passion	2.7
Maeklong × Bangchang	2.6
Passion × Bangchang	2.6
Bangchang	2.6
Maeklong × Passion	2.6
Mundang	2.2
Kamphaeng Saen × Maekolng	2.1
Passion, MC-4	2.0
MC-5, Bangchang × Long chili	1.8
Maeklong × Mundang	1.8
Passion × Kamphaeng Saen, C. 01777, C. 01227	1.7
Mundang × Long chili, C. 01807, C. 01826	1 6
C. 01172	1.5
Kamphaeng Saen × Long chili	1.1

[a]Symptom diameter was averaged from 30 fruits of each variety after 7 days of incubation in moist chamber at room temperature.

Pepper Viruses

Diseases caused by plant virus complexes are considered as a major constraint in pepper production. The yield and quality losses due to viruses in tropical peppers are high. For example, in Indonesia viruses such as TMV and/or PVY can cause a yield loss of 45–75% whereas CMV can reduce yield by 97%. There is very little information available on the identity of these viruses. Techniques to identify these viruses are also not well developed.

Objectives

The major objectives of the pepper viruses research are:

- Collection and sharing of germplasm, landraces, most important cultivars and resistant sources, with a view to screening them for resistance to major viruses of pepper.
- Identification of viruses by surveying the pepper-growing areas and using the available modern techniques to better understand the focus needed for controlling them.
- Production of antisera which could be shared by different countries and AVRDC.
- Identification of strains using serological methods and/or differential hosts.
- Screening for pepper virus resistance by using standardized screening methodology and rating method.
- Exchange of resistant lines between the collaborating countries so that their usefulness in different countries for different viruses can be established.

Progress

Indonesia

Cucumber mosaic virus was multiplied on *Nicotiana tabacum* Xanthi and 2 weeks later tobacco leaves were harvested. The method of Lot et al. (1972) was used in the purification procedure. About 80–120 mg purified CMV could be obtained from 1 kg tobacco tissue. Antiserum of CMV was produced by injecting purified virus into healthy male rabbits. Antiserum is available for any network partners. A survey showed that CMV, CVMV and PVY are probably the most important viruses.

Malaysia

Antiserum production. Chili veinal mottle virus (CVMV) has been successfully purified and the immunoglobulin G (IgG) and enzyme conjugate of the virus have also been produced and will be distributed to the participating countries of the AVNET program.

Screening for resistance. In breeding for CVMV resistance, 10 resistant breeding lines which derived their resistance from Cili Padi 6 and Serrano Huasteco have been identified. In F_8 generation these resistant plants were selfed for fixing genes and for further selection. From the planting, a total of 13 resistant pedigrees were selected and further crossed with Lorai, BG1 (India), C14a (France), Szechuan (Taiwan) and Mexico, LS 1621/2 (Mexico). These genotypes were known to have resistance to both CVMV and CMV. Fourteen resistant genotypes received from AVRDC were screened for CVMV and the results were similar to those obtained at AVRDC.

Philippines

Most field-grown peppers in the Philippines are infected with two or more viruses exhibiting complex symptoms of mosaic, mottling, leaf distortion, vein banding, yellowing and stunting.

Survey and detection of pepper viruses. A survey for pepper viruses was conducted in 14 provinces of Luzon. The use of DAC indirect ELISA resulted in the detection of the following viruses, in decreasing order of occurrence: ToMV/TMV, CMV, TEV, CVMV, PVY and PeMV (Table 8). The incidence of viruses on pepper was either negative or 0 in Benguet, Isabela, and Nueva Vizcaya. The significance of the result during this survey needs to be assessed.

Table 8. Pepper viruses found in a survey of 13 Luzon provinces by DAC-Indirect ELISA.

Provinces surveyed	No. localities sampled	Incidence (s) of virus detected					
		TMV/ToMV	CMV	PVY	CVMV	TEV	PeMV
Laguna	2	100	6	32	83	97	nt
Cavite	4	15	2	–	–	–	–
Zambales	5	40	22	1	18	–	36
Pampanga	1	–	–	6	–	17	–
Tarlac	1	–	–	–	–	17	–
Pangasinan	2	33	13	–	–	–	–
La Union	1	33	–	–	67	–	–
Benguet	2	–	–	–	–	–	–
Ilocos Sur	2	15	25	–	–	–	nt
Ilocos Norte	3	–	–	–	–	–	nt
Isabela	1	0	0	0	0	0	0
Nueva Vizcaya	7	0	0	0	0	0	0
Nueva Ecija	3	–	–	–	13	–	–

nt = not tested; – = negative

Virus isolation and characterization. The virus isolates detected by ELISA in the survey were characterized using differential hosts. CMV, CVMV and TEV are currently being isolated. Host range and transmission tests are also in progress.

Screening for resistance. Forty-nine hot pepper germplasm accessions were screened for resistance to ToMV and TMV. Nine entries (A99, A139, A144, A146, A155, A156, A157, C01172 and PP6-5258) were resistant to both viruses. Nineteen entries were resistant to ToMV but susceptible to TMV. Resistance was confirmed by ELISA test. Seeds of resistant entries are collected for further tests. Identification of resistance sources for TMV and ToMV should facilitate the study of the genetics of resistance and pave the way for breeding for resistance to the above two viruses into otherwise adapted varieties.

Purification and antiserum production. The Philippines has the responsibility to purify and produce antiserum for ToMV and other tobamoviruses.

Thailand

From November 1989 to January 1990 the pepper viruses research work was conducted collaboratively by researchers from Kasetsart University and the Department of Agriculture (DOA). From February 1990 the research for AVNET was exclusively undertaken by DOA.

Germplasm collection. During the survey of major pepper-growing areas for pepper viruses, seeds were collected from plants that had apparent resistance/tolerance to viruses in the field. The following seven tolerant cultivars were collected: "Yuak" and Huey Sithon from the Central Plain; "Hua Rua" and "See Som" from the Northeast; and "Noom", "Mundang" and "Duey Kai" from the North. Evaluation of these lines using ELISA tests will provide information on their resistance to different pepper viruses.

Seeds from two apparently healthy plants from "Kee Noo Chinda" cultivar from Kanchanaburi and four from Prajuabkirikhan provinces were collected. No virus could be detected in four out of six plants. In the other two plants PVY was observed by using the double antibody sandwich (DAS) ELISA.

Although four plants of cultivar "Chee Pha Mun" collected from Kanchanaburi province exhibited mosaic and ring spot symptoms, the plant height was normal and the yield was high and, therefore, it is likely that they may be tolerant. It is necessary to conduct further tests to learn the stability of tolerance in different environments so that they will be valuable for production.

Seeds of sweet pepper varieties 1949 and 1960 which had no virus symptoms were collected at Lertpan Seed Production Farm of the East West Seed Company in Chiang Mai. DAS ELISA test later found these plants to be virus-free.

Pepper virus disease survey. The second survey for pepper viruses was conducted in six locations. The data are presented in Table 9.

Table 9. Detection of viruses of pepper in six locations of central and northern Thailand from August to December, 1990 by ELISA tests.

Location (Provinces)	A[a]	B[b]	Viruses									
			AMV	CMV	CVMV	PVY	TEV	TMV	ToMV	PeMV	PMMV	TSWV
Chiang Mai	Aug	40	10	13	18	10	6	0	3	–	–	–
	Dec	40	0	10	6	4	0	4	0	2	0	4
Sukhothai	Aug	80	40	40	68	36	16	0	12	28	4	12
Tak	Dec.	88	0	4	52	40	0	24	0	0	0	0
Kanchanaburi	Dec	90	0	26	80	24	14	8	0	–	–	–
Prajuabkirikhan	Sep	74	40	12	40	52	28	0	0	–	–	–
Total		412	90	105	264	166	64	36	15	30	4	16
% infection			21 84	25 49	64 08	40 29	15.53	8.74	3.64	14 42	1 92	7.69

[a]Time of Collection
[b]No. of Samples
Notes. – = not tested, AMV, CMV, CVMV, PVY, TEV and ToMV were detected by double antibody sandwich ELISA; PeMV, PMMV and TSWV were detected by direct antigen coating ELISA

CVMV was the most prevalent virus (264 out of 412 samples) affecting peppers in northern and central regions during August to December 1990. It is present either alone or in combination with other viruses. PVY and CMV were the second and third most important viruses. AMV, TEV, PMV, TMV, TSWV, ToMV and PMMV were other viruses observed in the samples in decreasing order of importance.

From the first and second year surveys it was apparent that CVMV was consistently the predominant virus. It was noted that the prevalence of one virus over others varied with geographic area, pepper cultivars grown and sample collection times (Table 10). Due to their high incidence regardless of location, season and cultivars, CVMV, PVY and CMV should be regarded as the most important viruses of peppers in Thailand.

Table 10. Detection of viruses of pepper in central, north and northeastern Thailand from November 1989 to December 1990 by DAS ELISA.

Locations	Pepper cultivars	Number of samples	Viruses						
			AMV	CMV	CVMV	PVY	TEV	TMV	ToMV
Central	Chinda, Kaset, Yuak, Huey Sithon, Mun	408	86	132	245	188	66	31	42
North	Duey Kai, Kaset, Noom, Mundang, Sweet Pepper	366	60	48	218	76	53	10	0
Northeast	Hua Rua, See Som, Huey Sithon	160	11	71	88	12	17	8	0
Total		934	157	251	551	276	136	49	42
% infection			16 81	26.87	58.99	29.55	14 56	5.25	4.50

Antiserum production. PVY and PeMV isolates received from AVRDC were purified from the frozen tissue of *N. tabacum* Xanthi. The yields of PVY and PeMV obtained from the purifications were 4 and 7mg/100g respectively.

Screening for resistance to pepper viruses. Leaves from the bottom area or the area below the top two fully expanded leaves got the most concentration of CVMV after inoculation.

Status of Tomato Yellow Leaf Curl Virus (TYLCV) as a Causal Agent of Pepper Disease in Thailand

Tomato yellow leaf curl virus is one of the most important virus diseases of tomato in Thailand. It can cause almost total yield loss in some tomato fields. Although the virus has not been reported to infect pepper

naturally or artificially in Thailand, a leaf curl virus has been reported to infect pepper and cause serious yield loss in Malaysia and Indonesia.

The transmission of TYLCV from tomato to pepper and back to tomato was studied. Results confirmed that TYLCV could be transmitted via viruliferous whiteflies from tomato to pepper but the symptoms on pepper were only mosaic, whitish flecking or spotting on the leaves. Back inoculation from pepper to tomato via whiteflies produced typical TYLCV symptoms.

Some Properties of an Isolate of CVMV from Thailand

CVMV-Thailand isolate consists of filamentous flexuous particles, 725–760 nm in length. It infects nine plant species in the Solanaceae family including *Capsicum annuum*, *C. frutescens*, 'Tabasco', *D. metel*, *D. stramonium*, *Lycopersicon esculentum*, *N. clevelandii*, *N. tabacum* 'White Burley', *Petunia hybrida* and *Physalis floridana*. The following hosts are immune to this virus: *Brassica alboglabra*, *B. napus*, *B. pekinensis*, *Chenopodium amaranticolor*, *C. murale*, *C. quinoa*, *Citrullus vulgaris*, *Cucumis sativus*, *Cucurbita moschata*, *Glycine max*, *Gomphrena globosa*, *Ipomoea aquatica*, *Ocimum basilicum*, *O. sanctum*, *Mentha arvensis*, *Phaseolus vulgaris*, *Raphanus sativus*, *Tetragonia expansa*, *Vigna radiata*, *V. unguiculata* and *Zea mays*.

Integrated Pest Management Subnetwork

IPM of DBM in Crucifers

Cruciferous vegetables such as cabbage, cauliflower, broccoli, and radish are economically important to many countries. In recent years, however, crucifer production has been seriously affected by a steady increase in the infestation of insect pests, especially the diamondback moth (DBM), *Plutella xylostella*. Farmers in Southeast Asia use large quantities of chemical insecticides to control DBM. As a result of injudicious use of pesticides, DBM has developed resistance to practically all chemicals now being used. Since no other practical control measures are yet available, farmers are using ever-increasing quantities of insecticides. Indiscriminate use of pesticides not only gives poor control of DBM, but also kills the natural enemies of DBM such as predators and parasites which otherwise help check the natural population of DBM and other pests.

Scientists have found a bacterium, *Bacillus thuringiensis*, which kills DBM but is not harmful to parasites, predators and humans. A synthetic sex pheromone which attracts DBM males has also been developed. More recently, the chemical industry has developed selective chemicals which are safe for the natural enemies of DBM. AVRDC has also worked with several parasites on DBM.

The NARS of Southeast Asia have unanimously agreed during the Strategy Planning Workshop to accord high priority on transfer of IPM technology.

The goal of the IPM-DBM subnetwork is to transfer the concept and the technology of IPM to vegetable scientists in Southeast Asia with particular emphasis on DBM.

The following are the specific objectives:

- Low-cost control of DBM with a concomitant reduction in health hazards associated with excessive use of pesticides which have harmful environmental effects;
- An updated assessment of DBM and other vegetable insect pest problems, and national research and development effort to combat these pests;
- Insights into pesticide registration and use for vegetable crops, and environmental assessment programs of concerned NARS;
- The enhancement of capabilities of the NARS research personnel through training at AVRDC and incountry training; and
- Application by researchers of the concept of IPM for the control of other major pests of horticultural commodities.

Progress

Indonesia

Parasite-rearing facilities. Although the permanent greenhouse at LEHRI, Lembang, is equipped with air conditioning units, the temperature during daytime is high due to glass ceilings and insect proofing (no ventilation). Modifications are being made to reduce the temperature so that the rearing of parasites can proceed satisfactorily.

At Segunung, mass production of *C. plutellae* and *Diadromus collaris* (pupal parasitoid of DBM) is progressing satisfactorily.

Field release of parasitoids. In the highlands, *D. semiclausum* was fairly well established. In locations where *C. plutellae* has been released they have also been recovered suggesting that *C. plutellae* has also established well. In the highlands *Crocidolomia binotalis* has become a serious pest and the farmers were using chemical sprays to control it. Such chemical insecticides exterminated *D. semiclausum* and *C. plutellae* which exacerbated the DBM problem in the highlands. There is a need to emphasize the identification and introduction of parasites to control *C. binotalis*.

Furthermore, in midlevel elevations and in the lowlands *D. semiclausum* and even *C. plutellae* did not survive well. There is a need, therefore, to make selections among *D. semiclausum* and *C. plutellae* populations for adaptation to the lowlands so that they can be used with maximum efficiency.

Malaysia

Mass rearing of *C. plutellae* for release in the lowland areas. Renovation and improvement of the insect-proof screenhouse has just been completed at MARDI, Serdang. In this facility the mass production of DBM and *C. plutellae* will be undertaken using the two-cups seedling technique.

Another facility for mass production of *C. plutellae* has been constructed at Kelantan by the Department of Agriculture with AVNET funds. The parasite *C. plutellae* produced in Kelantan will be used for release in the East Coast States of Kelantan and Terengganu where large quantities of lowland crucifers are grown.

Mass rearing of *T. bactrae* for release in lowland areas. With the help of AVNET funds the laboratory space for mass rearing of *T. bactrae* was renovated at MARDI in Jalan Kebun. A staff member has been sent to Thailand specifically to be trained in the mass rearing of *T. bactrae* utilizing the *Corcyra cephalonica* eggs. The mass rearing is now progressing satisfactorily.

IPM Committee. An IPM committee composed of representatives of MARDI, Universiti Pertanian and DOA was set up to promote the IPM approach in vegetable production. Extensive extension work was initiated and implemented by MARDI and DOA for the adoption of the IPM approach by farmers to control DBM. AVNET linkage has strengthened the national IPM program. Specifically, training on many aspects of biological control was essential. Provision of facilities for mass production of parasitoids, exchange of parasitoids and information and collaboration with other neighboring countries have facilitated and encouraged the promotion of IPM in Malaysia. A recent survey in the Cameron Highlands has shown that the IPM approach has been adopted by more than 54% of the remaining vegetable growers and 46% were willing to adopt IPM. And in spite of insecticide use the parasites were well established in the Cameron Highlands with parasitism ranging from 10 to 40%.

Philippines

Field release of parasitoids in the highlands. After the earthquake and the typhoons which hampered the mass rearing of *D. semiclausum*, the facilities at Benguet State University were repaired and the damages were rectified facilitating the resumption of mass-rearing of parasites.

In November 1990 *D. semiclausum* were released in five farmer-cooperators fields—two in La Trinidad, one in Atok and two in Buguias with a total land area of 3,900 m². The disease infection on cocoons of *D. semiclausum* reduced the harvest of the parasites. Therefore, sufficient numbers of parasites could not be released at all sites. La Trinidad received adequate releases with an average of 400 cocoons per release.

Based on the DBM larvae sampled in Atok and La Trinidad during the resumption of release after 4 months of disruption it was found that *Diadegma* was parasitizing DBM at the rate of 33% in Atok and 10% in La Trinidad. It appears that a combination of released and natural parasitoids are able to establish themselves and parasitize the DBM.

Economics of *D. semiclausum* + *B. thuringiensis* + (IPM). An experiment on the economics of using organic insecticides versus IPM [*D. semiclausum* + *B. thuringiensis* + (IPM)] was conducted in a farmer-cooperator field in La Trinidad. Results suggest that IPM is much cheaper (Table 11) than using organic insecticides alone. Farmers and consumers also recognize the additional benefits of IPM, namely absence of toxic compounds from the produce, avoidance of health hazards for laborers and maintenance of ecological balance in the environment.

New strategy in releasing *D. semiclausum* and choice of cooperators. The farmers were educated on IPM of DBM including the use of parasitoids. Seminars on the use of parasitoids for farmers were conducted in Atok (16 January 1991), and Buguias (3 February 1991). The cost of the seminars was borne by the insecticide companies which produce selective insecticides which work well with *D. semiclausum*.

Table 11. Comparison of expenses following the use of *Diadegma* + *B. thuringiensis* + (IPM) and the conventional method (organic insecticides) in the control of DBM.

Cooperator: DEL AMEN	Site: La Trinidad IPM	Area 420 m² Previous Practice (Organic I)
Control method	*Diadegma* + Dipel	Sole use of insecticide such as Garvox + Malathion + Tamaron
Rates	4 tbs/16 l water	2 tbsp + 2 tbsp + tbsp/16 l water
Spray Interval	5 days	5 days
Spray Loads	18 spray loads	18 spray loads
Volume of I Product Used	720 g	360 g + 360 ml + 360 ml
Cost/unit I	US$15 02	$18.36 + $2 16 + $6.55 = US$27.07
Yield	Normal yield	
(Class A harvest)	Normal yield (Class A harvest)	

Current prices of:
a. Dipel - US$10 40/500 g
b. Garvox - US$10 20/200 g
c. Malathion - US$6 00/1000 ml
d. Tamaron - US$18 20/100 ml

At present there are six cooperators in Atok, three in Buguias with a total area of 18,000 m² (Table 12). Since the *D. semiclausum* supply is scarce many other farmers were encouraged to use selective insecticides alone to enable the establishment of *D. semiclausum*.

All the cooperators in Atok received 3–4 releases of *D. semiclausum* while in Buguias parasites were released twice.

The farmer-cooperators were briefed on the economics of DBM control using *D. semiclausum* and the advantages and safety of using parasitoids. The following information will be collected from the cooperators: spread of *D. semiclausum* from the release sites, rate of *D. semiclausum* parasitism, and resistance of *D. semiclausum* to organic insecticides.

Table 12. Farmer cooperators in Atok and Buguias who use IPM using *D. semiclausum* from 1991 onwards.

Toludan Atok	Date of Planting	Area Size	Natubleng Buguias	Date of Planting	Area Size
R. Kaasi	December 1990	500 m²	A. Chan, Jr.	February 1991	3000 m²
T. Alivs	February 1991	1500 m²	R. Llcdan	February 1991	1000 m²
S. Popeo-o	December 1990	3000 m²	A Cabansay	February 1991	2000 m²
L. Dipnag	January 1991	1000m²			
D. Dipnag	January 1991	5000 m²			
R. Dipnag	January 1991	1000m²			

Combination of *D. semiclausum* and Dipel. Results of an experiment conducted to determine the usefulness of Dipel with *D. semiclausum* suggest that Dipel is harmless to the adult parasite. This was evidenced by a higher rate of parasitization in both *Diadegma* as well as Dipel treatments (25–54%). However, Dipel is toxic to DBM larvae. DBM adults are unaffected by Dipel. Such information is useful in the preservation of parasites which try to reduce the pest populations.

Field release of DBM parasitoids in the lowland areas in the Philippines

Survey and selection of release areas. Cabbage/petchay-growing areas in Laguna (Nagcarlan, Liliw, Majayjay, Los Baños, Cabuyao and Calauan), Cavite (Silang and Tagaytay), Misamis Oriental (Claveria) and Bukidnon (Lantapan) had heavy populations of DBM. Generally crops planted in May–September were less infested with DBM than those planted from November to March.

Parasites *D. semiclausum* and *C. plutellae* were not observed in the above area. Most of the farmers use one insecticide spray per week while some sprayed two to three times a week if the DBM population was very high. With such heavy application of insecticides the parasites have no chance for establishment.

Mass rearing of parasitoids. *T. bactrae* was reared using *Corcyra* eggs and maintained in the laboratory at room temperature. *T. bactrae* were released only when the population of DBM adult was high.

Cotesia plutellae was reared in the second instar larvae of DBM. The developmental period of *C. plutellae* in the laboratory ranges from 7 to 10 days (egg to pupae). The mass production capacity at present was 1000–2000 cocoons/week. Mass production capacity will be increased to expand the release.

D. semiclausum was also reared in the second instar larvae of DBM. The production, development and survival of this parasitoid was very poor due to high temperature. Under high temperature cocoons were small; emergence of males was higher than females, and the overall emergence was 20–30%.

The rearing of parasitoid *Thyraella collaris* commenced.

Field releases. A total of 21,250 parasitoids were released in seven areas. *C. plutellae* and *D. semiclausum* were released in Nagcarlan and Liliw in Laguna whereas *T. bactrae* was released in Nagcarlan; Continuing Education Center, College; and Lipa, Batangas. The DBM population was lower in all the fields with parasitoids than in the farmer's field. Release of *C. plutellae* at the rate of 3500/release/ha and 3–4 releases plus 1–3 sprayings by *Bacillus thuringiensis* Krustaki reduced the DBM population. The average parastism was 17.4 and 36.5% in the first and second plantings. With additional extension and continuous release of large numbers of parasitoids, the establishment of parasitoids can be assured. This will ensure safety and the quality of produce and will likely reduce the cost of production.

Although *D. semiclausum* was also released in the demonstration plot the parasitism due to the parasitoid was of 2–7% and parasitoids could not be recovered 2–3 weeks after release. It is likely that long dry season is unfavorable for the establishment of this parasitoid.

In Liliw, Laguna, with four releases of *C. plutellae* about 25–40% parasitism was observed. Microbial insecticide (B.t.) was provided to the farmers. The combination of parasitoid and this microbial insecticide reduced the DBM in the area. In Cabuyao, Laguna, two releases of *C. plutellae* was done in a kale/petchay farm. Since the farmer used heavy insecticide sprays, in spite of the AVNET team's advice, mortality of parasitoids was noted and the DBM population was heavy, resulting in severe damage to the crop. In Calauan, Laguna, 2 weeks after the release of *C. plutellae*, 3–4% parasitism was observed.

Two releases of *C. plutellae* and *T. bactrae* were made in a cabbage farm in Lipa, Batangas. Prior to the release of the parasitoids the number of DBM was 20–30 larvae/plant. The farmer was advised to use Dipel after the release of the parasitoid. In the first monitoring *C. plutellae* gave 40-50% parasitism and the number of DBM went down to 4-6 larvae/plant. The farmer used to spray chemical insecticides 2–3 times per week, which was reduced to only one spray of B.t./week during pre-heading stage, and no sprays at all at heading stage. The total number of sprays that farmers did in the past was 16 for one cropping season at a cost of Pesos 10,000–12,000/ha. With the release of parasitoids, the number of sprays and the cost was reduced to 8 and Pesos 6000–7000/ha, respectively. The farmer was able to save money and thereby increase his profit, and the produce was safe to consumers. Environmental pollution was also avoided.

C. plutellae was also released in the seed production area of petchay at the Institute of Plant Breeding. About 3-10% parasitism was observed in the released field. The neighboring fields were also being monitored.

In-country training. From 17 February to 20 March 1991 at the University of the Philippines at Los Baños and at the Continuing Education Center, College, Laguna, the first in-country training on IPM of DBM was conducted. The training was jointly organized by PCARRD, UPLB and Benguet State University (BSU), and was funded by AVRDC through the Japan Shipbuilding Industry Foundation Grant. Participants were trained on the mass production and utilization of DBM parasitoids.

The course was designed to enable the participants to:

- Understand the principles of IPM biological control.
- Understand the importance and role of parasitoids in the management of DBM.
- Know the techniques of mass rearing the parasitoids for field utilization.
- Know the technique of field releases and assessment of parasitism for DBM management.
- Understand the development of resistance to insecticides in DBM.
- Understand the principles of chemical selectivity in IPM.

After the training, the 12 participants from nine institutions are expected to initiate and work on the developmental activities of IPM of DBM. The sponsoring agencies involved are expected to commit support and sustain the promotion of IPM of DBM as part of their research and development program. As a result of such training the area covered by IPM of DBM is expected to expand substantially assuring safety to vegetable consumers and safeguarding the environment.

Thailand

Mass rearing of *T. bactrae*. The technique to mass-rear the parasite *T. bactrae* and its host *Corcyra cephalonica* has been described in detail and aimed to benefit participating countries in mass producing the parasite. The mass rearing of the host *C. cephalonica* requires rice bran (media); the temperature of the rearing room should be around 30–38°C and the relative humidity should be 80–100%. A slideset and a detailed pamphlet on mass rearing technique for *T. bactrae* will be produced with the help of the Thailand group. Mass rearing of *D. semiclausum* from the DBM host is also progressing satisfactorily. In crucifer fields in Thailand (lowlands) the naturally existing enemies of DBM are being surveyed. After identifying these, attempts will be made to rear them artificially so that they can serve as the starting point for IPM work in the lowlands for crucifers since the parasites adapted to the highlands cannot survive well in the lowlands. Such newly identified parasites could be valuable in other AVNET countries for lowland crucifer fields.

Training/visit for a Malaysian partner. In Malaysia difficulties were encountered in rearing the parasite *T. bactrae*. Since Thailand has made excellent progress in rearing *T. bactrae* one of the scientists from Malaysia was selected to undergo hands-on special training in rearing *T. bactrae* in Thailand.

Ms. Siti Asma binti Dzayanddin from MARDI, Jalan Kebun, was trained by Mrs. Piyarat Keinmeesuke in the Department of Agriculture parasite rearing laboratory from 21 April 1991 to 6 May 1991. She is now able to successfully mass-rear the parasite *T. bactrae* in Malaysia. This is an excellent example of intercountry sharing of expertise and materials so that the research capacity of all countries can be strengthened to make rapid progress in IPM.

There is no significant crucifer cultivation in the highlands in Thailand and almost all crucifer cultivation is located in the lowlands. Therefore, work on *Diadegma* was discontinued and greater emphasis was placed on *Cotesia* and *Trichogrammatoidea bactrae*. Since these parasites may not control DBM effectively there is a need to identify other new parasites. Such new parasites could be shared by other scientists.

Monitoring and Evaluation Tour: Results and Recommendations

A monitoring and evaluation tour of the project was carried out to observe the progress made by the different participating NARS. The joint monitoring tour included selected AVRDC staff, four technical coordinators (one from each of the four NARS); an IPM specialist from each of the four NARS was also included to promote scientific interaction and exchange of information and materials. The tour began on

3 March and ended on 17 March 1991. The results and recommendations of this tour, and the workshop in Malaysia are reported in this section.

The objectives of the monitoring tour are: 1) to observe the progress of research in the germplasm subnetwork and in the IPM-DBM subnetworks in each of the NARS (all NARS were requested to present the progress of each AVNET component); 2) to discuss and exchange research findings of value with a view to strengthen the ongoing research project; 3) to determine the constraints encountered and ascertain ways and means to minimize or overcome the constraints so that research progress could be assured; 4) to assess the progress and impact and discuss future plans; 5) to ascertain the lessons learned from network partners including the benefits of the monitoring tour.

The various ongoing research activities observed during the monitoring tour are given below.

Indonesia

Bacterial wilt of tomato. Mr. Hanudin, trained through the AVNET project, performed commendably with his diligent and systematic implementation of bacterial wilt screening program at the Subang Horticultural Station. AVNET screening technique for bacterial wilt resistance was implemented in eggplant (*Solanum melongena*).

Simultaneously, at the time of the visit an identical set of tomato varieties was being screened in the greenhouse where the inoculation and plant growth were regulated.

Pepper viruses. Research activities are conducted at the Horticultural Research Institute in Lembang and Segunung; Horticultural Experimental Station of LEHRI-ATA in Subang, Tegal and Sukamandi.

In Lembang, the construction of an insect-proof screenhouse with AVNET funds has already commenced. For laboratory research, excellent facilities are available and the laboratory is fairly well-equipped with funds from Japan, USAID and AVNET.

IPM of DBM. At Lembang Horticultural Research Institute (LEHRI), a new parasite-rearing facility with air conditioners and proper ventilation has been constructed with AVNET funds. Since it is a glasshouse the temperature and relative humidity are high for rearing *Diadegma semiclausum*. Therefore, a few minor modifications on ventilation and shading were made to reduce the temperature and relative humidity.

In Bandung, the farmers are well experienced in growing cabbages. However, the farmers frequently apply a variety of insecticides such as Sumicidin and Padan to control DBM and Ambush to control *Hellula undalis*. DBM population in general was very low. Some native *Cotesia plutellae* were found in a neighboring field which was not sprayed. In spite of insecticide application, it appears that there is a naturally established parasite population that keeps the DBM under control. The monitoring group felt the need to organize demonstration plots without chemical insecticides but only with bacterial insecticides to control DBM. This is to convince the farmers that they are wasting their money on insecticides that are ineffective and polluting the environment, and rendering the vegetables harmful to consumers.

At the Segunung experiment station, the parasite mass-rearing screenhouse has been completed. As in the case of Lembang the temperature inside the screenhouse was higher than outside. As a result there is some problem in rearing *Cotesia plutellae*. The facilities will be modified to enable mass-rearing of parasites.

Malaysia

The yard-long bean trial has already been completed at Universiti Pertanian Malaysia (UPM). Another trial planted at Jalan Kebun was well managed.

The screenhouse for anthracnose screening of pepper becomes very hot during the day for lack of proper ventilation. The researcher was using humidifiers and providing exhaust fans for pepper to grow normally.

The laboratory facilities for bacterial wilt, anthracnose and virus research are in very good condition. They are, however, in need of data processing equipment which they hope to obtain through the AVNET funds instead of other planned equipment which have been purchased through national program funds.

Pepper varietal screening trial was well laid out; however, the plants were still short and too young for observation. Screening procedures have been streamlined.

The cabbage plants with DBM in the greenhouse and the mass-rearing facilities for *Trichogrammatoidea bactrae* at MARDI, Jalan Kebun were observed. They encountered problems with rearing *T. bactrae*, and therefore sent the researcher from MARDI for training in Thailand where AVNET cooperators were successfully mass-rearing the same parasite. Now the mass-rearing of *T. bactrae* is proceeding successfully at Jalan Kebun.

At the MARDI station in the Cameron Highlands, the mass-rearing facilities for DBM parasitoids are maintained and the activities are well established. The researchers used parasites such as *Cotesia* and *Diadegma* so that the farmers no longer use pesticides indiscriminately. They released parasitoids continuously in selected pilot project sites and refrained from using any pesticides that are harmful to the parasitoids.

In some farmers' fields where cabbage production is intensive, high levels of parasitism on DBM caused minimum damage to cabbage. However, in some areas where the parasite has not yet become established or where the farmers continue to spray chemical insecticides, high levels of DBM activity were observed. Ineffectiveness of insecticides was quite apparent, indicating that DBM has already developed resistance to the pesticides. Educating the farmers on the DBM strategy was recommended.

Philippines

PCARRD. The monitoring group visited the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and was briefed by the Executive Director. A slide story of PCARRD gave an overview of PCARRD and its activities.

BPI-NCRDC. The team visited the BPI National Crop Research and Development Center (Economic Garden). The germplasm evaluation subnetwork studies are conducted primarily by the Bureau of Plant Industry, Economic Gardens.

Encouraging initial results were observed in identifying higher yielding varieties of AVNET commodities with superior quality. Several varieties resistant to specific diseases in each crop have also been identified.

IPB. Under the germplasm subnetwork, the Philippines was entrusted with germplasm maintenance and evaluation, disease elimination and rapid multiplication of garlic and shallot.

In the Institute of Plant Breeding (IPB), a large number of shallot germplasm accessions from the participating AVNET countries and the indigenous germplasm from the Philippines are being evaluated and multiplied.

Disease elimination and rapid propagation of garlic (*Allium sativum* L.) and shallot (*Allium ascalonicum* L.) are two of the major objectives.

Bacterial wilt, anthracnose and pepper viruses research. Isolates of bacterial wilt and anthracnose pathogens are maintained as specific cultures. Twenty-one tomato and 30 pepper isolates of *Pseudomonas solanacearum* were biochemically classified based on their ability to oxidize two hexose alcohols; mannitol and sorbitol, and two disaccharides lactose and maltose.

Specific methods to isolate, identify, characterize and maintain different viruses have been streamlined by the virologist. In the greenhouse, the monitoring group was shown different kinds of mottling, yellowing and mosaic symptoms caused by a mixture of different pepper viruses. AVNET's national partners have developed the capability to identify viruses through AVNET training.

IPM of DBM subnetwork. At the University of the Philippines at Los Baños, the entomology laboratory is mass-rearing three parasites of DBM in the newly constructed screenhouses. The screenhouse is equipped with air conditioning and cages similar to those at AVRDC and other participating countries.

Under field conditions, DBM is highly destructive on common cabbage. Parasitoids of DBM mass-reared in the laboratory were released in the experimental cabbage plots at Los Baños and parasitism was monitored. There was excellent parasitism by some parasites like *Cotesia plutellae*; up to 70% after 5 months was observed.

Benguet State University (BSU), La Trinidad, Benguet. The highlands in the Philippines are the major vegetable production areas especially during summer. Vegetable production areas can be found in

the rolling hills and valleys of Atok in Benguet. Since irrigation is an important requirement for successful vegetable production, an ADB-supported Highland Irrigation Project has established irrigation facilities through pipes linking remote areas of the mountains. One of the major vegetable crops grown in Atok using ADB irrigation facilities is common cabbage. Large areas of common cabbages are intensively cultivated.

The AVNET project appropriately complements the ADB Irrigation Project. Vegetable farmers are using large quantities of different pesticides to control diamondback moth which is a serious pest of crucifers. As a result, DBM has already developed resistance to a wide range of insecticides. In spite of this, farmers continue to spray. Increased pesticide application increases cost of production and reduces profit. Pesticide residue poses serious health and environmental problems.

At the Benguet State University in the highlands, a screenhouse for mass-rearing of parasites was constructed through the AVNET project. The strong earthquake of 1990 damaged part of the structure. However, all damage has been partially repaired. The screenhouse is now equipped with two air conditioners. Mass production of parasites had initial problems due to diseases, but after the installation of air conditioners, humidity has been reduced and production of parasites has increased.

In general, parasitism was low in fields where parasites had been observed. Damage to cabbage plants by DBM was also low. The fields that were visited were sprayed with biological pesticides such as Dipel and Thuricide, which could have accounted for the low parasitism. It takes some time for the parasite population to build up.

Some of the farms used methamidophos and as a result, the population of parasitoids was low. Farm areas within 1 km of the release site had no parasitoids.

Thailand

Germplasm evaluation. Thailand is responsible for multiplying and distributing the seeds of elite cucumber varieties. Each country coordinator has already been provided with the multiplied seeds for the AVNET trial.

The rainy season trial encountered too much rain and most varieties had poor plant stand and low yield. Considerable variability in fruit color, fruit length, fruit size, fruit shape, spine type and number of fruits per vine were observed.

In general, the variety trials for cucumber and yard-long bean at Kampaengsaen were well-managed.

Bacterial wilt screening. The bacteriology laboratory is well equipped to obtain information on the biology of the bacterial wilt pathogen viz. races, biovars, virulence, host range and survival mechanism. These information could strongly support the development of bacterial wilt-resistant tomato.

The IBWDN research showed that sufficient differences between the susceptible and resistant check varieties exist. The inoculum distribution in the nursery appeared to be fairly uniform.

Pepper anthracnose screening. A training scholar from Indonesia was trained at the AVRDC/ Thailand Regional Training and Outreach Programs in screening for anthracnose resistance. Pepper varieties from different countries were planted in the field as well as in the screenhouse and the fruits were harvested and incubated to determine the reaction to anthracnose. Plant establishment of some varieties was poor in the field. Since all the varieties were also planted in the greenhouse, all of them could be screened for the disease.

Pepper viruses. A number of insect-proof screenhouses have been constructed using AVNET funds at the Kasetsart University in Bangkok. These screenhouses have been used to screen the peppers for virus diseases. Similar screenhouses were used for screening for disease resistance in other crops.

IPM of DBM. The IPM/DBM facility at the Kasetsart University campus in Bangkok has been remodelled, and refurnished. There were four air-conditioned rooms used for rearing different parasites and hosts. There was a large glasshouse area where the hosts can be multiplied in large numbers to raise the parasites. In Thailand the egg parasite of DBM *Trichogrammatoidea bactrae* is mass produced.

Participants visited the farmer's field in Khaokhor highland. Very few cabbages and other crucifers were being grown in the farmer's field. The consensus was that the IPM group in Thailand should focus on lowland crucifer pests and their control through IPM. Aside from DBM, other lowland pests should also receive attention. The parasites for lowland DBM and other pests need to be identified.

Midterm Workshop in Cameron Highlands, Malaysia: Recommendations

Germplasm Enhancement Subnetwork

Germplasm evaluation

Hot pepper. Thailand and Malaysia will have sent their seeds to AVRDC by April for redistribution to the other partners. The variety Matikas will be dropped and AVRDC will supply two other varieties, Yangiao and P8C388, from the region to the set.

Garlic and shallot. The Philippines will continue to multiply clones by meristem culture and will request antiserum from the Netherlands to proceed with virus-indexing. After indexing, the Philippines will distribute virus-free clones to the other AVNET partners. AVNET will secure antisera to be exchanged among all members.

Tomato, cucumber and yard-long bean. Variety trials for these crops will be continued to complete two trials at each country in locations which have not finished their trials. Malaysia will not conduct cucumber trials because it is not a priority crop for them.

Future considerations. Quality traits and nutrition will be given priority for the second phase of variety evaluations.

Bacterial wilt of tomato

Current phase. a) Some participants have nearly completed the second trial of the IBWDN. The third trial will evaluate a standard set consisting of two lines from Indonesia, two lines from Malaysia, six lines from the Philippines, two lines from Thailand, and six from AVRDC. b) Data will be collected on environmental conditions related to the trial, especially soil temperature and moisture in regard to management of the trials. c) Records on how each trial was established will be completed, i.e. more complete materials and methods. d) Biovar testing of strains collected will be completed.

Second phase. a) Strains of known biovars will be tested for virulence under controlled conditions using a predetermined panel of host plants. b) Experiments on integrated control using amendments, antagonistic organisms, and other cultural or chemical controls will be carried out. c) Population dynamics of the bacterium in soil and plants (wilted and nonwilted plants) will be studied. d) Epidemiology of the disease to determine the source and spread of inoculum, and to determine the survival capacity of the pathogen, will be investigated. e) Collection and isolation of strains will be deposited at a central location that will pathotype the strains.

Anthracnose of peppers

First phase. a) Data from standard set of lines that were screened for resistance using the same scoring method and screening protocol will be accumulated so that results from all the countries can be compared. Five more entries from Indonesia and two more from the Philippines were added to make a total of 25 test lines. b) Only one method of screening of fruit (pin prick) will be used; five lines (C01172, C1, C5, C01780, and C02676) will be tested by all participating countries. c) Testing of seed transmission by extracting seed from field-infected fruit with 1) > 50% fruit infected, 2) about 50% of the fruit infected and 3) <10% of the fruit infected, will be carried out.

Second phase. a) More studies about the variation of the pathogen, the predominant species, the virulence within species and existence of races will be conducted. b) The best method to establish disease nurseries for uniform field screening will be determined. c) Research schemes to study integrated control practices such as the use of crop rotations, intercropping, delay planting, etc. will be developed. d) Significance of seed-borne pathogens at the grower level (those who save seeds) and at the commercial production level will be determined and techniques to rapidly detect and treat the seed will be developed.

Pepper viruses

First phase. a) CMV and CVMV resistance screening have been agreed upon or prioritized by all participating countries. The Philippines will screen against these two viruses aside from tobaco mosaic virus. b) Collection of seeds of pepper landraces will be continued and the seeds will be sent to AVRDC for multiplication and distribution to all participating countries. c) Common differential host range for different viruses will be developed and information will be exchanged among the participating countries. d) Survey of viruses will be continued and resistant sources will be sought. Literature on this aspect will be explored and shared with other countries. e) Difficulties in the identification of the leaf curl viruses was brought out. The scientists recommended that a short course for this aspect be given priority by AVNET. f) Screening procedures will be standardized as follows:

- Number of plants to be used will be set to a minimum of 30 seedlings per entry.
- Inoculation of the pepper seedlings at 4-leaf stage.
- Inoculation should be done once and then a reinoculation if the plants do not show symptoms after 10–14 days. Resistance should be confirmed by ELISA. In case cooperators have no access to ELISA facilities, plants can be ratooned.
- Source of inoculum should be standardized using infected leaves from 3-week old inoculated plants. The use of pepper as source of inoculum has been agreed upon.
- Disease rating or scoring should be done. Plants should be classified as to whether they are segregating or behaving uniformly. For segregating populations, scoring of resistance and susceptibility will be applied. For uniform populations, the rating scale of Dr. Atie (Indonesia) for disease severity will be adopted. Dr. Atie will provide the rating scale. Inclusion of virus indicator plants for screening test will be strictly followed.
- Exchange of antisera among participating countries has been agreed upon. Each country will send antisera in liquid form with the addition of $NaNO_3$. The amount of $NaNO_3$ to be added will be determined by Dr. Atie.

Second phase. a) CVMV- and CMV-resistant lines will be field-evaluated. b) Integrated management of pepper viruses will be studied. c) Leaf curl viruses will be studied.

Diamondback Moth Integrated Pest Management Subnetwork

Indonesia

Highlands. *Diadegma* is established in all the highland areas of the country where the potential for its establishment exists. There is no need to rear this parasite. The rearing facilities should be used to rear *Diadromus collaris* and release it in all areas where *Diadegma* is established. This parasite will complement *Diadegma*.

Midlevel highlands. As many *Cotesia plutellae* as possible should be released at all locations where crucifers are grown. *Crocidolomia* occurs both in the highlands and the midlevel highlands. All available information on this pest will be collected. In collaboration with AVRDC, these parasites are to be introduced.

There is a need to set up a crucifer IPM task force within the country to handle the problem as was done successfully in Malaysia.

Philippines

Highlands. This region is most suitable for *Diadegma*-based IPM. Immediate and intensive efforts are needed to release as many *Diadegma* as possible. This should be supplemented with several IPM demonstration plots in the region. Extension service of the region should be fully utilized to set up demonstration plots. Baguio State University (BSU) should intensify its rearing of *Diadegma*.

Lowlands. Release of *Cotesia* (*Apanteles plutellae*) in all crucifer-growing areas of the Philippines should be intensified. One or two demonstration plots should be set up near UP College of Agriculture to understand the interaction of *Bacillus thuringiensis* application and *Cotesia plutellae* parasitism. These plots are meant for researchers. If possible, policymakers should be invited to see these plots. *Crocidolomia*

occurs throughout the lowland areas of the country. All available information on this pest in the Philippines should be collected and compared with the information from Indonesia. In collaboration with AVRDC, these parasites should be introduced in the lowlands.

There is a need to set up a DBM-IPM task force within the country to handle the problem as was done successfully in Malaysia. DBM-IPM in the highlands should be the top priority of this task force.

Malaysia

Highlands. Both *Diadegma* and *Diadromus* are established in the highland areas and are giving good control. However, many farmers are still continuing to use insecticides. There is need to set up more DBM-IPM demonstration plots to wean these farmers away from habitual insecticide use. There is no need to rear either *Diadegma* or *Diadromus*. However, Malaysia should act as source of these parasites for the region.

Lowlands. *Cotesia* is established in most of the lowland areas of Malaysia. *Hellula* is a problem in the lowlands. The present shoot-tip treatment to control *Hellula* should be supplemented with introduction of parasites. AVRDC will collaborate with Malaysia in the introduction of the parasite Malaysia should expand production of *Trichogrammatoidea* immediately. AVNET has agreed to send one Malaysian researcher to Thailand for training and to gain more experience. It is essential to demonstrate the utility of *Trichogrammatoidea* in Malaysia to fully justify setting up a joint Malaysia-Thailand egg parasite production facilities. Demonstrations on the use of this parasite, shoot treatment for *Hellula* control and judicious use of insecticides should be conducted in lowland areas.

Thailand

Highlands. There are no true highland areas in the country where crucifers are grown. Small patches of such areas probably exist in the north but they are not economically important. Thai scientists surveyed these areas (1000 or more m a.s.l) to test their potential for the release of *Diadegma*. It was decided that after one release of 2000 cocoons, *Diadegma* mass-rearing should be discontinued. If additional potential highland fields are found at a later date, AVRDC will supply the parasites for direct release in the field.

Lowlands. Practically all crucifer-growing areas of Thailand are lowland areas. *Cotesia plutellae* should be introduced in all areas where crucifers are grown. Thai scientists should increase rearing of *Trichogrammatoidea bactrae*. Demonstration trials using this parasite should be conducted in as many locations as possible throughout the country. There is a need to set up joint mass-rearing facilities to produce this parasite for Malaysia and Thailand. Because labor cost in Thailand is low, the facilities should be located in Thailand. Private sector should be encouraged to participate in the venture after initial demonstration in the public sector.

There is a need to set up a national task force to handle the DBM-IPM problem using a similar pattern as Malaysia's.

AVRDC-Indonesia Vegetable Research Program

Introduction

The long-standing collaboration in vegetable research between Indonesia and AVRDC continues. The major areas of activity are:

- Evaluation of germplasm collections;
- Screening tomato lines for resistance to bacterial wilt;
- Screening tomato lines for resistance to pepper viruses; and
- Biological and integrated control of diamondback moth on cabbage.

Collaboration between Indonesian researchers and other scientists in Southeast Asia and other countries was continued with activities such as exchange of vegetable seeds, exchange of parasitoids, exchange of information, training, attending seminars/workshops, etc. These have been made possible through the support of ADB, AVRDC and ATA-395 (Dutch) Project.

The proceedings of the National Vegetable Workshop held at Lembang from 22 to 24 November 1990 have been published in two versions viz. English and Indonesian. This workshop was supported by AVRDC through Japan Shipbuilding Industry Foundation funds and ATA-395 Project.

Indonesian researchers joined the AVNET monitoring tours and attended a workshop from 3 to 17 March 1991. Visits were made to vegetable-growing areas in the Philippines, Indonesia, Thailand and Malaysia.

Germplasm Evaluation

Germplasm evaluation aimed to evaluate varieties of cucumber, yard-long bean, tomato and hot pepper recommended by countries of the network. In 1991, evaluations were carried out in the dry season on cucumber (14 accessions), yard-long bean (20 accessions) and tomato (37 accessions).

Cucumber Variety Trial

In the first cucumber variety trial of AVNET, 12 varieties were tested in the lowlands from June to August 1990. LV-1043, LV-308, LV-2276 and MTi-1 were found promising based on the shelf life, size, color and the taste of the fruit. In the second trial, another two varieties were added originating from the Philippines and Thailand. The latter trial was carried out under dry season condition.

Fourteen promising cucumber cultivars from Indonesia (4), Malaysia (3), Philippines (3) and Thailand (4) were evaluated in the field at Subang Experimental Farm (elevation 100 m) of the Lembang Horticultural Research Institute, Indonesia (Table 1). The trial was carried out from 5 June to 3 September 1991.

The aim of the trial was to evaluate the field performance of the 14 cultivars for yield, agronomic characteristics and their adaptability to local agroclimatic conditions. Thirteen of the cultivars and their country of origin were:

Indonesia: (1) LV-1043, (2) LV-308, (3) LV-1723, (4) LV-2276.
Malaysia: (5) MTi-1, (6) MTi-2, (7) bukit Mertajam.
Philippines (8) UPL Cu-4, (9) UPL Cu-6, (10) UPL Cu-8.
Thailand (11) Taeng Ton, (12) Jad-Bai, (13) Zinza.

Table 1. Field performance of cucumber varieties at Subang Experimental Farm.

Variety	Days to maturity	Marketable fruits/plot	
		Number	Weight (kg)
LV-1043	32	99 0 bcde	10.4 ab
LV-308	32	88 8 bcdef	9.9 ab
LV-1723	34	101 8 bc	10.3 ab
LV-2276	32	67.5 efg	8.6 ab
MTi-1	37	85.5 bcdefg	8.7 ab
MTi-2	37	64.0 fg	8.3 ab
Bukit Mertajam	32	54.8 g	7.9 ab
UPL Cu-4	34	100.3 bce	9.5 ab
UPL Cu-6	34	69 3 defg	7.5 b
UPL Cu-8	34	113.3 ab	12.2 a
Taeng Ton	37	135 3 a	11.4 ab
Pol-lek	37	134 0 a	9.9 ab
Jad-Bai	34	84.3 bcdefg	10.7 ab
Zinza	37	73.5 cd	9.4 ab

The trial was carried out in a well drained Latosol soil. The soil was plowed and harrowed to produce a fine soil tilth and stable manure was applied 3 days before planting at the rate of 15 t/ha while NPK (15:15:15) fertilizer at the rate of 500 kg/ha was applied two times as basal along with stable manure and as sidedress 3 weeks after planting.

The seed was planted in a randomized complete block design with four replications. The plot consisted of two rows of eight plants per row, 50 cm between and in the rows, and 75 cm between plots and blocks. Plot size was 1.25 m × 4 m. Cultural practices such as weeding, cultivation and trellising, and periodic spraying with pesticides were applied.

Results

Maturity. Four varieties matured early, 32 days after planting, viz. LV-1043, LV-308, LV-2276 and Bukit Mertajam, and the other five were late at 37 days after planting, viz. MTi-1, MTi-2, Taeng Ton, Pol-lek and Zinza.

Marketable fruit yield. Number of marketable fruit was significantly different among cultivars. The highest number of marketable fruit was produced by Taeng Ton and Pol-lek but did not differ significantly with UPL Cu-8. The lowest number of fruit was produced by Bukit Mertajam.Weight of marketable fruit was also significantly different among varieties. The highest weight of marketable fruit per plot was produced by UPL Cu-8 but did not differ significantly with Taeng Ton, Jad-Bai, LV 1043, LV-308, Pol-lek, UPL Cu-4, Zinza, MTi-1, LV-2276 and MTi-2. The lowest weight of fruit was produced by Bukit Mertajam and UPL Cu-6.

Fruit size. There were significant differences between cultivars in terms of fruit length. Zinza had the longest fruit length (22.6 cm), but it did not differ significantly with Bukit Mertajam (30.4 cm) or MTi-2 (18.2 cm). The shortest fruit was produced by Pol-lek (7.1 cm). The range of fruit width was 2.7–3.9 cm; MTi-1 (3.9 cm), UPL Cu-8 (3.8 cm) and UPL Cu-4 (3.6 cm) did not differ significantly with MTi-2 (3.5 cm), Bukit Mertajam (3.2 cm), UPL Cu-6 (3.4 cm), LV-1043 (3.4 cm), Pol-lek (3.4 cm), LV-1723 (3.4 cm), Jad-Bai (3.5 cm), LV-308 (3.3 cm), LV-2276 (3.2 cm) and Zinza (2.7 cm), respectively.

Fruit color. Skin color ranged from whitish green to dark green. LV-2276, MTi-1, UPL Cu-4, Taeng Ton, Pol-lek and Zinza were dark green and MTi-2 was whitish green; the rest were green.

Bitterness and eating quality. Only Bukit Mertajam tasted bitter and had poor eating quality. Although Pol-lek had no bitter taste, it had poor eating quality. The rest of the cultivars were not bitter and had fair to good eating quality.

Flesh thickness. Bukit Mertajam, Jad-Bai, Mti-2 and UPL Cu-6 had relatively thick fleshes. The others had medium thick flesh.

Shelf-life. Short shelf-life (3 days) was shown by MTi-2, Bukit Mertajam, Taeng Ton, Pol-lek and Jad-Bai, while the rest had sufficiently long shelf-life (10 days after harvest).

Disease rating. During planting period viruses were more dominant than other diseases. LV-1043, LV-308, LV-1723 and UPL Cu-4 had medium infection and the rest had mild infection levels. Symptoms of powdery mildew infection were absent in all cultivars.

Based on the marketable fruit yield, UPL Cu-8 showed the best yield, heaviest fruit weight and longest shelf-life (10 days), although it did not differ significantly from the other 11 varieties. Zinza and Bukit Mertajam produced the longest fruit (22.6 and 20.4 cm); Bukit Mertajam had poor eating quality and very short shelf-life (3 days). Zinza, LV-1043, LV-308, LV-2276, UPL Cu-4 and UPL Cu-6, UPL Cu-8 had good eating quality and shelf-life but were semi-hollow.

Compared to the first trial in 1990, LV-1723 showed a drastic jump in the volume of fruit yield, whereas Taeng Ton, Pol-lek and Jad-Bai declined sharply in both number and yield of fruit. In the first experiment in the rainy season eight cultivars appeared to be susceptible to powdery mildew, and the other four cultivars resistant. However, in the second experiment in the dry season none of the cultivars had any symptoms of powdery mildew infection. This was probably because of the unsuitable conditions for growth of the fungus.

Large variabilities were shown in several characters: fruit yield, size, shelf-life, color, etc. These variabilities permit plant breeders to improve the cultivars according to their own goals, which might be different from consumer preferences. For instance, for fresh consumption, shelf-life should be long with good eating quality and appropriate size. On the other hand, the fruit for pickles should be short and slender, the color should not be too dark, and the yield should be high. Based on this trial the promising cultivars were: for yield—UPL Cu-8, although it did not differ significantly with the other 11 cultivars; for maturity—LV-1043, LV-208, LV-2276 and Bukit Mertajam; for eating quality—all cultivars except MTi-1, MTi-2, Bukit Mertajam and Pol-lek; and for shelf-life—LV-308, LV-1043, LV-2276, MTi-1, UPL Cu-4, UPL Cu-6 and Zinza.

Yard-long bean variety trial

Yard-long bean cultivars from Malaysia, Philippines, Thailand, and Indonesia, were tested in Subang (elevation 100 m) from May to September 1991. Another five new promising cultivars from Indonesia were added to this trial.

The experimental design was a randomized complete block with two replications. Plot size was 1.5 × 3 m; plant distance, 75 × 30 cm, with 20 plants per plot. Soil type was Latosol and pH 5.6. Data on some characters are as follows:

1. Days to harvest
   - a. early (40–44 dap) = LV-265
   - b. mid-early (45–49 dap) = LV-2316, Usus Hijau, LV-232, KP-1 and LV-1630
   - c. medium (50–54 dap) = KP-2, KP#5, CSL. 19, Taiwan White, KP#8 and ML#30
   - d. mid-late (55–59 dap) = KU#7, RW#24, Rajburi, CSD4, CSD5
   - e. late (>60 dap) = PS1
2. Number of pods/plant = LV-217, KP-1, LV-265, DOA
3. Yield potential = LV-1630, DOA, LV-217, LV-265, KU#8, LV-2316
4. Crispiness = ML#30, Rajburi, KU#7, KP#5, PS1, LV-2316
5. Taste = LV-2316, Rajburi, PS1, LV-265.

Tomato variety trials

Tomato trials were carried out in Subang (Latosol soil type) and Kramat/Tegal (5 m, Alluvial soil type). Thirty-six cultivars in Subang and some in Kramat were evaluated.

Subang. The experimental design was randomized complete block with two replications. The plot consisted of two rows of eight plants/row with plant distance of 60 × 70 cm. Results of this trial are presented in Table 2.

Table 2. Growth habit, days to flower, fruit shape and weight of fruit/plant of tomato cultivars at Subang experimental garden.

Accession and place of origin	Growth habit	Fruit shape	Fruit color	Weight of fruit/plant (g)
BL-651 (Thailand)	Semi det.	plum	cream	156
BL-652 (Thailand)	Semi det.	pear	green	869
BL-653 (Thailand)	det.	pear	cream	510
BL-654 (USA)	semi det.	plum	green	815
BL-655 (USA)	det.	square	green	367
BL-694 (Malaysia)	semi det.	oblate	light green	1.7
BL 695 (Malaysia)	semi det.	oblate irreg.	light green	2.1
BL-700 (Philippines)	indet.	pear	light green	634
BL-701 (Philippines)	det.	oblate	white	1.6
BL-702 (Philippines)	det	cylindrical	light green	1.6
BL-703 (Philippines)	semi det.	plum	light green	1.3
BL-704 (Philippines)	semi det.	cylindrical	light green	661
BL-705 (Philippines)	det.	elong sq	white	193
BL-706 (Philippines)	semi det.	deep oblate	green	1.1
BL-708 (Philippines)	semi det.	elong sq	light green	1.3
BL-707 (USA)	semi det.	plum	light green	743
CL 591-206D4-2-2-0 (AVRDC)	indet.	square	light green	1.3
CL 591-206D4-2-5-0 (AVRDC)	indet.	square	light green	1.1
CL 591-206D4-2-2-0-4 (AVRDC)	indet.	plum	light green	1.3
CL 657 BC1F2-274-0-15-0 (AVRDC)	indet	deep oblate irreg.	white	1.0
CL 657 BC1F2-274-0-15-4 (AVRDC)	indet.	deep oblate	white	1.3
CLN 657 BC1F2-274-0-15-7 (AVRDC)	indet.	deep oblate	light green	1.1
CLN 657 BC1F2-285-0-20-0-24 (AVRDC)	indet.	pear	light green	726
CLN 657 BC1F2-285-0-20-0 (AVRDC)	indet.	square	light green	1.1
CL 6046 BC2F2-51-0-20-5-15-14-1 (AVRDC)	indet.	cylindrical	light green	1.3
CL 6046 BC2F2-51-1-1-20-5-10-13 (AVRDC)	indet.	cylindrical	light green	1.2
CLN 475 BC1F2-265-4-19 (AVRDC)	semi det.	oblate irreg	light green	1.2
CLN 475 BC1F2-265-12-9-1 (AVRDC)	det.	oblate irreg.	light green	1.2
CLN 657 BC1F2-267-0-3-12-7 (AVRDC)	semi det.	square	light green	921
CLN 698 BC1F2-358-4-13 (AVRDC)	det.	square	light green	1.2
CL 5915-93d4-1-0-3 (AVRDC)	det.	plum	white	829
TK-70 (Kagome)	det.	oblate irreg.	white	270
FMTT-138 (AVRDC)	indet.	square irreg.	green	1.9
L-4783 (AVRDC)	indet.	square irreg	green	587
BL-697 (AVRDC)	det.	deep oblate	light green	1.6
BL-699 (AVRDC)	semi det.	square	light green	1.9
Intan (Indonesia)	det.	oblate	white	1.4

Kramat. The experimental design was RCB with two replications. The plot consisted of two rows of eight plants/row with plant distances of 60 × 70 cm. Statistical analysis is still ongoing. Based on the yield the following cultivars were promising:

FMTT-138	: 59.0 kg/6.7 m²
CLN5915-203D4-2-5-0	: 48.0
CLN 5915-203D4-2-5-0-4	: 43.8
BL-694	: 44.3
BL-695	: 45.7
BL-702	: 53.0
BL-703	: 38.3

Adaptation and Screening of Tomato Lines for Resistance to Bacterial Wilt in the Lowlands of Indonesia

Introduction

At present, the only effective way to control bacterial wilt of tomato and potato (caused by *Pseudomonas solanacearum*) is by means of resistant varieties. The sources of resistance are known in several countries, e.g. Venus and Saturn in the United States (Henderson and Jenkins 1972) [1] Rao and Tikko (1975)[2] tested 23 accessions including 11 from Hawaii, 7 from the Philippines, 4 from North Carolina and 1 from Ceylon to bacterial wilt race 1. They found resistance in all lines except CRA-66A.

Research on bacterial wilt resistance in Indonesia has been carried out since 1970, but efforts were mainly concentrated in the highlands. From 1974 to 1976, Boesro (1982)[3] conducted two field experiments, at Segunung (highland), and found resistance in varieties HBWR-72, VC-11, Saturn, Kemir (local variety), VC-33, VC-22 and VC-15. After individual selection, three accessions from AVRDC—VC-11, VC-15 and VC-33—were released under the names Ratna, Berlian and Intan.

The purpose of this trial was to select promising AVRDC tomato accessions that have a high degree of resistance to bacterial wilt and good adaptation to lowland areas of Indonesia.

Materials and Methods

The trial was conducted at the Subang Horticultural Research Station (elevation 110 m) from November 1990 to May 1991. A randomized complete block design with three replications was used. The treatment included 30 accessions of tomato (Table 3).

Table 3. AVRDC accessions/lines used in the bacterial wilt nursery, Subang 1991.

L-390	CL 5915-93 D4-1-0
BL-350	CL 5915-206 D4-2-2-0
BL-342	Berlian (local variety)
BL-323	Cln 475-BC1 F_2-265-4-19
BL-341	Mutiara (local variety)
BL-355	Cln 65-349-2-0
BL-312	LV-2100 (tomato Tumpang/local variety)
BL-410	LV-1646 (tomat Rembang/local variety)
BL-333	Intan
L-285	LV-1051 (tomat Rampay/local variety)
CL 1131-0-0-13-0-6	LV-1450 (tomat Jepara/local variety)
CL 143-0-10-3-0-1-1-10	LV-1823 (tomat Laban/local variety)
CL 8d-0-7-1	LV-1498
CL 9-0-0-1-3	LV-1513
CL 11d-0-2-1	LV-2099

Before screening for bacterial wilt resistance could be conducted, the disease nursery had to be established. After the land had been prepared, 15-day old seedlings of susceptible tomato variety L-390 were planted in beds. The distance between the rows was 20 cm. Thirty days after sowing (DAS), all top leaves were cut with scissors that had been dipped in a suspension of *P. solanacearum* race 1 biovar 3 (1×10^9 cfu/ml). The land was rototilled 15 days after plant infection.

[1] Henderson, W. R., and Jenkins, S. F. Jr. 1972. HortSci., 7(3), 346.
[2] Rao, M. V. B., and Tikko, S. K. 1975. Plant Dis. Rep., 59, 734-736.
[3] Boesro, A. 1982. B. J. Penel Hort., 9(1), 1-7.

The accessions to be tested were seeded and after 21 days transplanted to the disease nursery. All accessions were planted next to the susceptible check L-390 and resistant check Intan at distances of 20 × 30 cm. Rice straw mulch was used on the beds to preserve soil moisture.

Observations on bacterial wilt were made every week. The Thaveechai et al. (1989)[4] method was followed to rate and classify resistance:

80–100% survival = Resistant (Rs);
60–70% survival = Moderately Resistant (MR);
30–59% survival = Moderately Susceptible (MS);
0–29% survival = Susceptible (Ss).

Results and Discussion

The symptoms of wilt appeared about 7 days after planting. The analysis of variance of the reactions of 30 tomato accessions to bacterial wilt were highly significant.

Screening for resistance in Subang showed that none of the lines tested was resistant to *P. solanacearum* The only exceptions were BL-33 and Berlian with moderately susceptible reactions. On the other hand, all accessions were resistant to *P. solanacearum* in Taiwan (Hartman 1989).[5]

A type of resistance to bacterial wilt in tomato was interpreted as recessive polygenics (Acosta et al. 1964)[6]. Reports from Hawaii indicate that the bacterial wilt resistance was not as stable during warm weather (31–33°C) at low elevations, as in cooler, higher elevations or during cool weather (21–26.7°C) at the lower elevations (Krausz and Thurston 1975).[7] High temperature is probably the main reason for susceptible reaction in the experiments. At the location of testing, air temperatures ranged from 23.7–33.6°C. The average relative humidity was 81.47 and precipitation 15 mm.

Differences in resistance may also be due to the pathogenicity of bacterial wilt, determined by its races. Race 1 attacks solanaceous plants and other plants living in the lowland tropics. Race 2 attacks bananas and heliconias, and race 3 attacks potato and sometimes tomato. Besides, the breakdown of resistance in tomato may also be due to the synergism with parasitic nematodes. Widjaja (1979)[8] reported that the infection of *P. solanacearum* will be accelerated if parasitic nematodes are present. The populations of parasitic nematodes in this trial are as follows: *Meloidogyne* sp., 18; Rotylenchus, 163; Helicotylenchus, 2; Criconemoides, 2; and Xiphinema, 1.

Varieties and lines that tested resistant to bacterial wilt in Taiwan and Indonesia were susceptible under Subang conditions (lowland elevation, 110 m, and *P. solanacearum* race 1 bi var 3). Accessions BL-333 and Berlian were moderately susceptible to *P. solanacearum*.

Pepper Viruses

Introduction

The pepper virus working group of AVNET is concerned with a collaborative research program among AVRDC, Indonesia, Malaysia, the Philippines and Thailand. The ultimate goal is to obtain more varieties of pepper with resistance to important viruses. Sharing of activities depends on the importance of virus incidence and intensity in member countries. Indonesia will be responsible for cucumber mosaic virus (CMV), Malaysia for chili veinal mottle virus (CVMV), Philippines for tomato mosaic virus (ToMV) and Thailand for potato virus Y (PVY). AVRDC will be dealing with all viruses mentioned.

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[4]Thaveechai, N., Kostratana, W. and Hartman, G. L. 1989. Kasetsart University, Bangkok, 40 44
[5]Hartman, G. L. 1989 Kasetsart University, Bangkok, 6
[6]Acosta, J. C., Gilbert, J.C. and Quinion, V. L. 1964. "Heritability of bacterial wilt resistance in tomato." Proc. Am. Soc. Hort. Sci. 84: 455–461.
[7]Krauz, J. P., and Thurston, H. D. 1975. Phytopathology, 65, 1272-1274.
[8]Widjaja, A. W. 1979 B. J. Penel Hort., 7(2), 27-33

Besides studies of varietal screening, other activities related to pepper virus disease are under way. Since chili leaf curl virus (CLCV) is important in some countries, and found in Indonesia, this virus is also being studied.

Recent Status of Pepper Virus Disease

Some fields were visited in the pepper-growing areas of high and low elevation regions in Central and West Java. Incidence of infected plants was recorded based on the visual symptoms grouped into mosaic complex and leaf curl.

The mosaic complex was invariably found at every observation site. The incidence and intensity of infection was higher on older plants. In some locations, symptoms were difficult to recognize due to sucking insect damage (mites, thrips and leafhopper).

Leaf curl symptoms (Kerupuk disease) were not found at every site, but symptoms have been found on any bird pepper and hot long pepper varieties, at both young and older growth stages and in the highlands and lowlands (Tables 4 and 5).

Table 4. Virus incidence on pepper in the highlands, West Java, November 1991.

Location	Variety	Age (days)	Virus symptoms	
			Mosaic	Leaf curl
Bandung				
Cibodas-1	Keriting	50	25	0
Cibodas-2	Keriting	200	60	5
Pangalengan	Keriting	200	80	5
Garut				
Tarogong	Cabai Besar	60	11	0
Samarang	Cabai Besar	240	Cmp*	0
Kuningan				
Cisantana	Cabai Besar	60	20	0
Majalengka				
Cikijing-1	Rawit	100	80	3
Cikijing-2	Rawit	90	90	5
Cikijing-3	Rawit	100	87	5
Argalingga	Keriting	50	30	0
Cicalung-1	Cabai besar	100	70	1
Cicalung-2	Cabai besar	80	50	2
Cianjur				
Pacet-1	Keriting	250	Cmp	0
Pacet-2	Cabai Besar	100	70	0
S. Negara-1	Keriting	90	15	0
S. Negara-2	Keriting	240	50	15
Sukabumi				
Wanasari-1	Hot beauty	90	50	5
Wanasari-2	keriting	120	20	0

*Cmp = Complex. virus symptoms mixed with insect damage.

An interesting observation in the field was pepper mixed with tomato in which pepper showed good growth, less insect infestation and less virus incidence. This cropping system was found widely in Cianjur area, West Java.

Virus Identification

The most common symptoms of virus in pepper in the field was the mosaic complex, but these were not tested for causal pathogens. Based on previous serological testing, these symptoms showed positive reactions to antisera of CMV, CVMV, PVY, TEV, AMV and ToMV. The virus occurring in each tested sample could be one or a mixture of several viruses.

Table 5. Incidence of leaf curl disease on pepper in lowlands of Central Java, March 1991.

Location	Variety	Age (days)	Symptom of leaf curl	
			Mild	Severe
Tegal-1	Jatilaba	110	1.98	8.91
Tegal-2	Cipanas	92	2.68	6.43
Tegal-3	Tit Paris	30	0.25	0 00
Tegal-4	Tit Super	30	0 68	0.12
Tegal-5	?	60	0.14	0.46
Brobes-1	Jatilaba	40	1.40	1 30
Brebes-2	Jatilaba	45	3 80	1 51
Brebes-3	Jatilaba	45	3 80	1 51
Klampok	Tit Super	30	0.05	0.05
Cirebon-1	Jatilaba	60	0.20	1.35
Cirebon-2	Jatilaba	55	0 00	0.40
Cirebon-3	Jatilanba	60	0.60	0.40

More attention was paid to CLCV due to its importance during the current season. A biological study on transmission with suspected vectors and its identification by using indicator plants has been implemented. All tests were carried out in a new screenhouse provided by ADB under the AVNET project.

Samples of infection were collected from Tegal, Ciranjang and Segunung. Transmission to indicator plants was done by means of mechanical inoculation and grafting. Transmission by suspected vectors was done by use of aphids (*Myzus persicae* and *Aphis gossypii*) and whitefly (*Bemisia tabaci*). Fasting period of aphids was 3 hours and acquisition feeding was 1 hour. Healthy young pepper plants were inoculated by 10 viruliferous aphids per plant for 36 hours. Both the acquisition and inoculation feeding times of whitefly were 48 hours. After inoculation feeding all insects were killed by an insecticide.

Based on transmission testing, the Kerupuk disease or leaf curl could not be transmitted by mechanical inoculation and grafting. Inoculation from Tegal was supposed to be via a mixed infection with other viruses. This supposition was drawn, because symptoms on inoculated pepper plants were not similar to the initial symptoms (mosaic or chlorosis instead of curling).

Transmission studies using aphids and whitefly were also not successful. Aphids were not reported as a vector of CLCV, but *Bemisia tabaci* was.

Field Testing of Nine Promising Varieties

A completely randomized block design was used for field testing of the nine promising varieties, namely: Keriting Hitam, Keriting lurus, Jatilaba, Cipanas, LV-1559, LV-2320, LV-1603, LV-2175 and LV 1689. Blocks were repeated four times. The source of infection was virus-inoculated tobacco plants planted in the borders of the observation field.

The collected data were on disease incidence and intensity, and fruit yield. The formula for determining the disease intensity is as follows:

$$I = \frac{Z\,(n \times v)}{N \times V} \times 100\%$$

in which:
- I = disease intensity
- n = number of plants showing a certain symptom
- v = score of symptom of each plant
- N = total number of plants observed, and
- V = highest score of symptom

Field observations showed that pepper plants were infected with more than one virus. The virus incidence increased as the plants aged. Nevertheless LV-2175 showed the lowest virus incidence. The lowest disease intensity was found on LV-2175, LV-1689 and Keriting Hitam. The highest fruit yields were

obtained from plots with LV-1689, Keriting Hitam and LV-2175. These three were considered to have a relatively high level of field tolerance.

Based on the studies during this period the following conclusions were drawn:

- The status of pepper viruses in the field was different from the previous year, as the incidence of leaf curl disease was much higher in 1991. The incidence of mosaic complex was similar to 1990, as it was spread widely in the growing areas and mainly occurred in a complex rather than in single infection.
- Transmission studies of the leaf curl disease are not yet successful. Further investigation should be continued to obtain more reliable information.
- The pepper varieties LV-1689, LV-2175 and Keriting Hitam seemed to have field tolerance.

Other Activities

- Three milliliters (2 vials) of CMV antiserum (titer 1:12, 800) assessed by means of ELISA was delivered to the group members: Malaysia, The Philippines and Thailand in mid-June 1991.
- Antisera of CVMV from Malaysia, PVY from Thailand and ToMV from the Philippines had been received. Antiserum of PVY and ToMV was sent by country members via AVRDC.
- Five grams of chili pepper tabasco seed was received from Malaysia (Mr. Roff) for CVMV investigation.

Diamondback Moth Parasitism by *Diadegma semiclausum* and *Cotesia plutellae*

Summary

Cotesia plutellae reared in large cages (90 × 90 × 90 cm) were much better in quality than those from a smaller cage (50 × 50 × 50 cm). The rate of parasitism in the large cage was 91%, and was 81% in the smaller cage. Competition between *Diadegma semiclausum* and *C. plutellae* was studied under laboratory conditions to investigate its effect on larval parasitism of DBM. The rate of parasitism by *D. semiclausum* (80.4%) was higher than by *C. plutellae* alone (62.6%). When both parasitoids were placed together in the same cage, the total parasitism was higher (94.4%).

Introduction

Diamondback moth (DBM, *Plutella xylostella* L.) is the most destructive insect pest of economically important cruciferous vegetables in Indonesia. Biological control of DBM by the ichneumonid parasitoid *Diadegma semiclausum* Hellen has become a key component of integrated pest management (IPM) of DBM in the highland areas during the last 20 years. A braconid parasitoid *Cotesia plutellae* Kurdj. was introduced from AVRDC and MARDI in 1987 to strengthen the biological control program of DBM in Indonesia. Two studies were conducted to investigate the effect of cage size and the presence of both parasitoids on the parasitism of DBM.

Materials and Methods

Effects of cage size on parasitism. The experiment was conducted using "paired treatment comparison". The treatment tested was the cage size: A. 90 × 90 × 90 cm and B. 50 × 50 × 50 cm. Sixteen cabbage seedlings (5 weeks old, grown in plastic pots) were placed in Cage A, and four cabbage seedlings were placed in Cage B. Four hundred DBM adults were released into Cage A and 100 DBM adults into Cage B. After about 1 week, 2400 *C. plutellae* were released into Cage A and 600 *C. plutellae* adults into Cage B. The parasitized larvae were reared in plastic bottles and maintained in the laboratory.

When all the insects turned to pupae/cocoons, their number and that of the parasitoids were recorded, and the percentage of parasitism and their sex ratio were computed.

Parasitism of two parasitoids. A randomized complete block design was used with six treatments and four replications. Five cabbage seedlings with 300 second instar DBM larvae on their foliage were placed in a cage (50 × 50 × 50 cm). The treatments tested were: A. 6 pairs of *D. semiclausum*; B. 10 pairs of *C. plutellae*; C. 66 pairs of *D. semiclausum* + 10 pairs *C. plutellae*; D. 3 pairs *D. semiclausum* + 5 pairs *C. plutellae*; E. 2 pairs *D. semiclausum* + 6 pairs *C. plutellae*; F. Check (300 DBM larvae). The parasitoids were released into the cage and allowed to parasitize the DBM larvae for 1 week. Then the cabbage seedlings with larvae were transferred to other cages to allow larvae to become pupae/cocoons. When all the larvae pupated, the number of parasitoid cocoons and DBM was recorded, and the percentage of parasitism calculated. After emergence, the sex ratio was computed.

Results and Discussion

Effects of cage size on parasitism. The results of the rate of parasitism by *C. plutellae* in different cage sizes (8'%) and their sex ratio are summarized in Table 6.

Table 6. Parasitism of diamondback moth larvae by *C. plutellae* in different cage sizes.

	Cage A* (90 × 90 × 90 cm)	Cage B* (50 × 50 × 50 cm)
No. DBM larvae	1172.1**	370.0
No. *C. plutellae* cocoons	1060.0**	241.6
% parasitism of DBM larvae	91.0**	80.9
C. plutellae adults	1056 0**	237.4
No. males	495.1**	119.0
No. females	590.9**	118.4
%emergence of *C. plutellae* cocoons	99.6**	118.4
% emergence of *C. plutellae* cocoons	99.6**	98.3
Sex ratio (males. females)	1.00:1.13**	1.00.0.99

*Data are means of nine replicates
**Highly significant different at 5% level by t-test.

C. plutellae parasitism of DBM larvae in the larger cage was significantly higher (91%) than in the small cage (80.9%). The sex ratio in the larger cage is also slightly better (1.00:1.13) than in the small cage (1.00:0.99). Hence, rearing of *C. plutellae* in the large cage is better than in the small cage in terms of the number of cocoons produced, sex ratio and efficiency of the process.

Parasitism of two parasitoids. *D. semiclausum* parasitism of DBM larvae was significantly higher than that of *C. plutellae*. The total parasitism by both parasitoids together was 94.4% and significantly higher than either *D. semiclausum* or *C. plutellae* alone. Competition between the two parasitoids occurred, but it seems that multiple parasitism and super parasitism did not exist. *D. semiclausum* is superior to *C. plutellae*. Nevertheless, both parasitoids may complement each other in parasitizing DBM larvae.

Selective Insecticides with Parasitoids in IPM

Summary

The use of selective insecticides in IPM of DBM is very important. To support this program, selectivity testing was conducted under laboratory conditions. All formulations of *Bacillus thuringiensis* (Dipel WP, Delfin F, Florbac FC), and abamectin (Agrimec) were not toxic to *Cotesia plutellae*. In addition, cartap hydrochloride was less toxic to *C. plutellae*.

Introduction

The introduced parasitoid, viz. *Cotesia plutellae* Kurdj., has been released in some lowland and mid-elevation areas since 1989. Cabbage farmers in those areas tend to use different kinds of insecticides which may be harmful to *C. plutellae*. Therefore, it is very important to find selective insecticides and to support the biological control program of DBM in warmer areas.

Materials and Methods

Diamondback moth larvae strains in Lembang and *C. plutellae* were raised in the greenhouse of LEHRI using cabbage seedlings. Second instar larvae of DBM and *C. plutellae* adults were used. The microbial insecticides, viz. *Bacillus thuringiensis* (Dipel WP, Delfin F, Florbac FC) and abamectin (Agrimec), and chemical insecticides, viz. deltamethrin, permethrin, cartap hydrochloride and profenofos, were evaluated by dipping method. Pieces of cabbage leaf (5 × 5 cm) were dipped for 30 sec into an aqueous solution of appropriate concentration of each tested insecticide. After drying, the treated leaf pieces were fed to 2nd instar larvae of DBM (20 larvae for each concentration) and placed in a petri dish.

Toxicity of insecticides against *C. plutellae* was evaluated using free feeding method. A mixture of appropriate concentration with honey solution (30%) was dropped on a piece of cotton and stuck on the mouth of a test tube. Ten *C. plutellae* adults were released into the test tube and the mouth part of the test tube was covered with nylon screen. After 24 hours the parasitoids were removed to a clean test tube and fed with honey solution.

Treatments, including control, were replicated four times. All mortality data were taken 72 hours after the treatment and corrected for natural mortality. With Abbott's formula the LC_{50} was determined and analyzed using probit analysis.

Results and Discussion

The toxicity of the tested insecticides is shown in Table 7. Microbial insecticides such as *B. thuringiensis* formulations and abamectin were not toxic to *C. plutellae* adults. A chemical insecticide, cartap hydrochloride, was slightly toxic to *C. plutellae* adults, while deltamethrin, permethrin and profenofos were toxic to *C. plutellae* adults. In addition, an indication of DBM resistance was shown with the application of deltamethrin, permethrin and profenofos.

Table 7. Toxicity of several insecticides to DBM larvae and adult *C. plutellae*.

Insecticide	LC-50 (ppm)		Selectivity (SR)*
	P. xylostella	*C. plutellae*	
Microbial insecticides.			
B. thuringiensis var. k-1 (Delfin F)	23.69	>4000	very low
B. thuringiensis var. k-2 (Dipel WP)	402.86	>4000	very low
B. thuringiensis var aiz. (Florbac FC)	122.35	122,645.90	0.001
Abamectin	0.93	2.929 50	0.00013
Chemical insecticides:			
Deltamethrin	5,465 30	15.187.17	0 36
Permethrin	1.896.84	2.326 26	0.81
Cartap hydrochloride	308.04	1 763.70	0.17
Profenofos	2.148.89	3 061.33	0.70

*Selectivity ratio = LC_{50} *P. xylostella*: LC_{50} *C. plutellae*.

Field Trial with Sex Pheromone of the Diamondback Moth and Yellow Sticky Trap

Summary

Sex pheromone and yellow sticky trap were tested in the field on diamondback moth, *Plutella xylostella*, from November 1990 to March 1991 at Lembang. Sex pheromone PX was more attractive than yellow

sticky trap to DBM males. Population of DBM larvae on cabbage was related to sex pheromone trap catches. Insecticide application based on trap catches over 20 months was effective, with sustained cabbage yield and a 60% reduction in insecticide sprays.

Introduction

Population measurement is essential for development of a pest management program. The discovery of potent sex pheromone PX as an attractant for male DBM has opened the way for practical monitoring of DBM.

The present control threshold for DBM larvae was found to be 0.5 caterpillar/plant. The relationship between moth catches by sex pheromone PX and the population of DBM larvae is not known. In addition, the use of yellow sticky trap for monitoring green peach aphids and other insects has been reported to be very useful. This field trapping was undertaken to determine the performance of sex pheromone PX and yellow trap , and to release seasonal moth populations on DBM larvae and determine their effect on yield of cabbage.

Materials and Methods

A field trial on a 0.2 ha field of cabbage was conducted at LEHRI, Lembang from November 1990 to March 1991. All agronomical aspects followed LEHRI recommendations. A split plot design with three replicates was used. Plot size was 6.0 × 8.4 m (144 plants/plot). The main plot was: A0. Sex Pheromone PX; and A1. yellow sticky trap. The subplot was control threshold of DBM: B0. 0.5 caterpillar/plant; B1. 10 months/trap; B2. 20 months/trap; B3. 30 months/trap; B4. routine sprays (1/week); and B5. check. The trap was placed in the middle of each plot (1 trap/plot). Numbers of moths caught, DBM larvae, and cabbage damage were recorded every week, starting from 2 weeks after planting. The yield of cabbage plot was recorded at harvest. Insecticide application was initiated when the population of moth/trap and or larvae surpassed the control threshold. A selective insecticide, *Bacillus thuringiensis* (Dipel WP), was used in this experiment.

Results and Discussion

DBM larval population increased from 14 days after planting (DAP) and reached its peak at 42 and 63 DAP. The population of DBM moths in sex pheromone traps was positively correlated with the population of DBM larvae on cabbage plants. Similar trends were also shown in yellow sticky traps. The DBM larval population reached a peak at 49 and 56 DAP in the cabbage plots.

Statistical analysis indicated that there is no interaction between the type of trap and control threshold against the population of DBM larvae, damaged plants and cabbage yield. Insecticide applications based on moth catches and larval populations were effective and did not significantly differ with calendar system. The frequency of insecticide spray was reduced 50–70% in sex pheromone trap catches and 50% in control threshold (0 5 caterpillar/plant) plot.

The use of insecticide based on control threshold of either moth catches or larval populations (0.5 caterpillars./plant) gave better yield than the calender system.

Development of Biological Control Measures for Diamondback Moth in Farmer's Field in Warmer Areas

Summary

Attempts were made to control diamondback moth (DBM) by releasing introduced parasitoid *Cotesia plutellae* on farmers' fields in Majalengka (West Java) and Magelang (Central Java). About 150 parasitoids were released in each area, combined with the use of *Bacillus thuringiensis* when the DBM population surpassed control threshold (0.5 caterpillar/plant). The population of *C. plutellae* cocoons in Majalengka was low (0.1-0.6 cocoon/plant). However, the parasitoids seemed to temporality get established in this area. No indication of establishment was observed in Magelang.

Introduction

Statistical data in 1987 had shown that the cabbage-growing area in the lowland and mid-elevation areas of Java was about 5000 ha. As indicated elsewhere in Indonesia, the diamondback moth is the most important insect pest in warmer areas. Therefore, farmers tend to use insecticides intensively to overcome the DBM problem and other insect pests.

A braconid parasitoid *Cotesia plutellae* Kurdj. was introduced several times in Indonesia since 1987 to overcome the DBM problem. Since *C. plutellae* is more suitable for warmer areas (20–35°C), this parasitoid will be released in the lowland/mid-elevation areas.

Materials and Methods

Two experiments were conducted in the districts of Majalengka and Magelang. About 0.15-0.2 ha of cabbage were grown in Majalengka (variety: Green Coronet) and in Magelang (variety: KK-Cross). All agronomical aspects followed local recommendations. The treatments tested in each area were:

- integrated pest control plot (release of *C. plutellae*, control threshold of DBM 0.5 caterpillar/plant and the use of *B. thuringiensis*)
- Biological control plot (release of *C. plutellae*)
- Farmer's plot (calendar system).

About 75 *C. plutellae* adults were released in plots A and B, respectively. Starting from 2 weeks after planting (WAP), observations on DBM larval populations were made at weekly intervals. Numbers of parasitoid cocoons were also recorded starting from 3 WAP. The yield was recorded at harvest time.

Results and Discussion

Cocoons of *C. plutellae* were found on cabbage in Majalengka (elevation 700 m) at 2 weeks after parasitoid release. In addition, many *D. semiclausum* cocoons were found in Majalengka. This was probably due to some cocoons of *D. semiclausum* brought back from Pangalengan where the cabbage seedlings came from. In Magelang, no parasitoid cocoon was found on cabbage. One possible reason could be that the population of DBM larvae was low. In addition, the cabbage-growing area was surrounded by rice and secondary food crops. The yield of cabbage in the two areas was quite low. The average yield per crop was only 0.7–0.8 kg in Majalengka and 0.2–0.6 kg in Magelang.

AVRDC-MARDI Vegetable Research Program

AVNET Germplasm Improvement Subnetwork

Summary

Seventeen yard-long bean cultivars were evaluated. Five cultivars (KP #5, K.U. #8, DOA, CSL 19, CSD 4) significantly outyielded the local check and these high-yielding cultivars will be used for further breeding work in Malaysia. At least three pathogenic species of *Colletotrichum* have been identified as the causal pathogens of anthracnose fruit rot of chili. Eighteen pepper lines were tested for anthracnose incidence and severity. Five lines were found to be more susceptible to infection by *C. gloeosporioides* than by *C. capsici*. Nine breeding lines of chili were found resistant to anthracnose fruit rot disease. AMV, CVMV, CMV, PVMV, PVY, TEV, TMV, ToMV and TSWV have been detected on chili in eight states in Malaysia. CVMV was the most prevalent virus on chili followed by CMV. The immunoglobulin G (IgG) and enzyme conjugate of the CVMV virus have been produced and distributed to the participating countries of the AVNET program. Resistant breeding lines for CVMV have been identified and resistant gene types from AVRDC and local sources have also been screened against CVMV and CMV.

Germplasm Enhancement

In the yard-long bean germplasm evaluation study, two field trials were conducted in Universiti Pertanian Malaysia Research Farm at Serdang and one in the Malaysian Agricultural Research and Development Institute (MARDI) Research Station at Jalan Kebun. At the beginning of this project, Indonesia, Malaysia, Philippines and Thailand contributed four promising yard-long bean cultivars. These seeds were multiplied at UPM and later redistributed to the coordinators of the participating countries for evaluation as part of AVNET activity.

In all the trials, a randomized complete block design with four replications were used. Two trials were conducted at UPM Research Farm in 1990 and 1991 and one trial in MARDI Research Station in 1991. For the first trial conducted in UPM Research Farm in 1990, the general procedures and agronomic practices together with the collection of data were in accordance with the standard methods outlined in the training course held in Lembang, Indonesia, from 29 January to 3 February. All the parameters measured are reported here. However, in the latter two trials, only pod yield and pod length were reported as these were the two characters important for evaluation purposes. In this report, only results of the trials conducted in Malaysia are reported.

Among the 17 cultivars, including the local check, six were conical and the rest were cylindrical in branching habit (based on the evaluation of the first field trial conducted in UPM Research Farm). From this trial, there was no clear indication that showed which type of branching habit would give a higher pod yield.

Results of the first trial conducted in the UPM farm at Serdang are shown in Table 1.

Every year, a large amount of seeds of the local check has to be imported from Taiwan to meet the local demand. Nevertheless, from this study, it was noted that the agronomic performance of the crop grown from the imported seeds was similar to that of the crop grown from locally produced seeds such as Taiwan White. Taiwan White, however, was not the best yielder, as five cultivars (KP #5, K.U. #8, DOA, CSL 19, CSD 4) significantly outyielded it.

Since yard-long bean is a self-pollinated crop, it can be multiplied locally for seed production purposes. Therefore, it is recommended that the popular cultivar imported form Taiwan be produced locally to save foreign exchange. The coefficient of variation (CV) and the phenotypic correlation values between pod yield and other agronomic characters are shown in Table 2.

Table 1. Mean values of the characters measured in 17 cultivars of yard-long beans evaluated at UPM farm, 1990.

Cultivar	Pod length (cm)	Pods/plant	100-seed wt. (g)
KP1 1018	32.0 g	21.9 b	14.3 efg
KP2 1019	60.2 abcd	14.8 efg	19.1 a
USUS Hijau	62 5 ab	15.7 efg	18.3 ab
LV 801	62.0 ab	17.3 bcdef	16.8 bcd
DOA	56.1 cd	19.7 bcde	16.7 bcd
KP #5	56.5 cd	20.9 bc	19.0 a
Taiwan W.	50.0 e	12.6 gh	12.9 g
ML #30	40.1 f	19.3 bcde	14.9 def
CSD 4	56.3 cd	20.8 bcd	16.2 bcd
CSD 5	56.5 d	16.4 cdefg	16.0 cde
CSL 19	56.2 d	21.9 b	16.3 cd
PS1	48.4 e	13.8 defg	19.1 a
K.U. #7	59.1 bcd	5.1 efg	17.3 abc
K.U. #8	60.6 abc	27.0 a	13.0 g
R.W. #24	64.5 a	8.5 h	17.7 abc
Rajburi	58.1 bcd	18 0 bcdef	16.7 bcd
Check	50.6 e	13 2 fg	13 2 fg

Mean values in the same column followed by the same letter are not significantly different based on the 5% new Duncan's Multiple Range Test.

Table 2. The C. V. values and simple correlation coefficients between pod yield and other agronomic characters.

Character	C V.	Correlation
Pod yield	17 87	1 00
Pod length	5.73	0.26*
Pods/plant	16.93	0 71**
100-seed weight	7.12	0.01
Height of 1st flowering node	13.19	0.15

*P< 0 05 **P<0.01

The results of this study showed that pod yield, number of pods per plant and height of the first flowering node are more varied compared to other characters. The number of pods per plant, weight per pod and pod length are relatively more important.

Since pod yield per unit area and pod length are the main concern in this evaluation trial, these characters in the three trials are summarized in Tables 3 and 4.

Based on the present findings in Malaysia, some of the cultivars such as K. U. #8 from Thailand, CSD 5, CSD4 and CSL 19 from the Philippines, KP #5 and DOA from Malaysia were found to be high yielders with long pods and these cultivars can be used for further breeding work. In a selection program, more attention should be paid to the number of pods per plant, pod weight and pod length since these characters are significantly correlated to pod yield.

Anthracnose of Chili

Disease survey. A study of chili farms was carried out in seven states in Peninsular Malaysia, including Kelantan and Terengganu in the East Coast; Selangor, Malacca and Negri Sembilan in the Central Region and Perak and Penang in the West Coast. Altogether, 35 sites have been surveyed.

At least three pathogenic species of *Colletotrichum* have been identified. These are: *C. capsici*, *C. gloeosporioides*, and *C. acutatum*.

Distribution maps have been constructed showing the frequency distribution of *Colletotrichum* species in various locations in Peninsular Malaysia. This will help in planning for the management of the disease.

Table 3. Mean pod yield (t/ha) for the yard-long bean cultivars evaluated at MARDI and UPM farm in 1990 and 1991.

Country of origin	Variety	MARDI	UPM I	UPM II	Mean
Indonesia	KP1 1018	8 9 e	7.9 g	4.4 h	7.1
	KP2 1019	15 2 b	14.1 deg	8.3 gh	13.5
	USUS Hijau	10 0 ed	14.5 deg	7.4 h	10.6
	LV 801	15 2 b	16 4 cde	11.2 defg	14.3
Malaysia	DOA 1	14.2 bc	21.6 ab	13 8 cd	16.5
	KP#5	14 1 bcd	23.4 a	15.4 bc	17.6
	Taiwan W.	12.7bcde	14 0 def	8.8 fgh	12.2
	ML #30	14.6 bc	16.2 cde	12.9 cde	14.6
Philippines	CSD 4	14.6 bc	20.2 abc	12.6 cde	15.8
	CSD 5	14 2 bc	18.7 bcd	18.0 ab	17.0
	CSL 19	14.8 b	21.6 ab	12.8 cde	16.4
	PS 1	8.9 e	14.9 def	19.2 a	14.3
Thailand	K U #7	10.5 cde	13.4 ef	9 9 efgh	11.3
	K U. #8	19.5 a	23 2 ab	11.9 defg	18.2
	K U #8	19.5 a	23 2 ab	11 9 defg	18.2
	R.W. #24	9.1 e	11.1 fg	8.3 fgh	9.5
	Rajburi	13 9 bcd	11 9 efg	12.6 cde	12.8

Mean values followed by the same letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

Table 4. Mean pod length (cm) of the yard-long bean cultivars evaluated in 1990 and 1991.

Country of origin	Variety	MARDI	UPM I	UPM II	Mean
Indonesia	KP1 1018	8.9 e	7.9 g	4.4 h	7.1
Indonesia	KP1 1018	31.3 i	32.0 g	33.0 i	30.0
	KP2 1019	51.8 ef	60.2 abcd	50.0 efg	54.2
	USUS Hijau	51.8 ef	62.5 ab	44.1 h	51.8
	LV 801	53.5 cdef	62.0 ab	54.3 cde	56.6
Malaysia	DOA 1	53.9 cdef	56.1 cd	54.9 cd	55.0
	KP #5	53 2 cdef	56.5 cd	54.0 cde	54.6
	Taiwan W.	52.2 cdef	50.0 e	48.8 fg	50.3
	ML #30	42 3 h	40.1 f	40.6 h	41.0
Philippines	CSD 4	53 4 cdef	56.3 cd	51.4 deg	53.7
	CSD 5	56 8 b	56 5 d	58 8 ab	57.4
	CSL 19	51.0 f	56.2 d	51.3 defg	52.8
	PS1	48.4 g	48.4 e	47.6 g	48.1
Thailand	K.U. #7	46.6 g	59.1 bcd	43.9 h	49.9
	K.U. #8	59.7 a	60.6 abc	54.8 c	58.4
	R.W. #24	54.6 bcd	64.5 a	52.3 cdef	57.1
	Rajburi	55.6 bc	58.1 bcd	55.7 bc	56.5

Mean values within the same column followed by the same letter are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

Germplasm resistance. Eighteen pepper lines exchanged for in-house testing of anthracnose incidence and severity were multiplied for a proper replicated trial under Malaysian conditions. Twelve lines were put into a replicated trial to further determine disease resistance, yield and agronomic characters. Local checks MC4 and MC5 were included in the trial. Line C 01172 gave the highest yield of 32.5 kg for 60 plants. It also had low anthracnose incidence of 1 9%, making it a potential variety for large-scale cultivation in the lowlands.

As was agreed in the AVNET Monitoring Workshop in the Cameron Highlands, Malaysia, on 14-16 March 1991, five selected varieties of chili were assessed for resistance to anthracnose fruit rot under in

vitro conditions. Inoculation was carried out using the pin-prick method with an inoculum suspension of 1×10^6 spores/ml. Ten chili fruits from each of these varieties were screened for resistance to the two most commonly occurring *Colletotrichum* species, i.e. *C. capsici* and *C. gloeosporioides*.

All the five varieties tested were found more susceptible to infection by *C. gloeosporioides* than to *C. capsici*. Varieties C1, C5 and C 01172 were not infected by *C. capsici* but C 01789 and C 2676 were highly susceptible to this pathogen. C 2676 and C1 were highly susceptible to *C. gloeosporioides* infection but C 01780, C5 and C 01172 were only moderately susceptible. The results from Malaysia will be compared with those obtained from other participating countries to compare the virulence of local strains of *Colletotrichum* with those present in other countries.

Genetic studies. From the breeding lines of F_6 and F_7 generations, 63 resistant and 10 moderately resistant individual lines were selected. Based on their agronomic characters, nine resistant lines were identified as potential varieties. From these nine lines, five will be identified for seed bulking for multi-locational trials.

Bacterial Wilt of Tomato

The IBWN was set up in MARDI, Serdang in April 1990 and since then, 16 AVRDC tomato accessions and three local varieties have been evaluated for disease reaction under local environmental conditions.

In the first trial, eight AVRDC accessions and two local checks were screened over two seasons in 1990. In 1991, another eight AVRDC accessions and three local checks were screened over two seasons with the second trial completed only in November 1991. Results of the first trial are shown in Table 5.

Table 5. Percentage wilt of tomato accessions from AVRDC and local checks screened in the IBWN.

Variety	1st season	2nd season
MT 1 (local check)	2 5	2.5
MT11 (local check)	9.2	6.7
L 390 (susceptible check)	98.0	99.0
L 285 (resistant check)	1.00	4.8
CL 143	1.7	8.3
CL6047	1.7	1.7
CLN 65	0	0
CLN 475	0.8	0.9
BL 350	2.5	0
BL355	0	0
BL 410	0.8	3.3
BL 342	0.8	1.7

Virus Diseases of Chili

Survey of virus diseases on chili. A total of 30 locations in eight states, namely Johore, Kelantan, Malacca, Pahang, Penang, Perak, Selangor and Terengganu were surveyed for the presence of chili viruses. Leaves were collected from hot chili. Leaves of bell pepper were collected only in the Cameron Highlands.

Results from the field surveys showed the presence of AMV, CVMV, CMV, PVMV, PVY, TEV, TMV, ToMV and TSWV on chili in Peninsular Malaysia. Among the viruses detected, CVMV was the most prevalent and was detected in 51.8% of the samples. This was followed by CMV, TSWV, TEV, PVMV, PVY, TMV, ToMV and AMV with mean percentages of 25.7, 6.9, 6.6, 5.0, 4.5, 2.9, 1.2 and 0.2% respectively.

Six types of viruses were detected in three states: Kelantan, Perak and Terengganu. Three types were detected in Johore and Malacca and two in Pahang and Penang. Chili veinal mottle virus (CVMV) and cucumber mosaic virus (CMV) were the two most prevalent and devastating viruses infecting chili in all states in Peninsular Malaysia. CVMV was the most prevalent in Kelantan and Penang with an average percentage incidence of 83.6 and 83.3% respectively while CMV was most frequently detected in Terengganu and Selangor with an average percentage incidence of 70.2 and 63.7% respectively. Generally,

symptoms expressed by CVMV were veinal mottling, puckering and vein banding while symptoms of CMV included mottling.

Antiserum production. Chili veinal mottle virus has been successfully purified. The immunoglobulin G (IgG) and enzyme conjugate of the virus have also been produced and have been distributed to the participating countries of the AVNET program.

Screening for resistance. In the program on breeding for CVMV resistance, 10 resistant breeding lines which derived their resistance from Chili Padi 6 and Serrano Huasteco have been identified. These resistant plants were selfed in the F_8 generation for further fixing and selection. From the planting, a total of 13 resistant individuals were selected and further crossed with Lorai, BG I (India), C41e (France), Szechuan (Taiwan) and Mexico, LS 162-/2 (Mexico). These genotypes were found to possess resistance to both CVMV and CMV. Another additional 14 resistant genotypes received from AVRDC were screened against CVMV and the result confirmed that of AVRDC's.

A total of 70 CMV isolates have been collected from chili farms in Peninsular Malaysia for strain identification and comparative studies.

Training for IPM of DBM

Summary

Some 100 persons including 30 farmers were trained for the implementation of the IPM for DBM program. Mass production of *Diadegma semiclausum* and *Diadromus collaris* was carried out in the Cameron Highlands. Production of *D. semiclausum* is now 5,000–10,000 adults/week and *D. collaris* 2,000–3,000/week. These parasitoids were sent to the Philippines, Thailand and Indonesia for mass production and release. The mass rearing facilities for *Cotesia plutellae* at Serdang started operations at the end of 1991. Another facility in Gelantan now produces 500–1,000 *C. plutellae* for release locally. The mass rearing facilities for the egg parasitoid *Trichogrammatoidea bactrae* in Jalan Kebun is now producing 18cc of *Corcyra* eggs per cycle. The egg parasitoids will be released in the field in early 1992. Trials in 1991 showed that the IPM package was superior in terms of yield, net profit and reduced application of insecticides. Great success in IPM for DBM has been achieve[illegible] in the highlands of Malaysia.

Overseas Training

Ms. Siti Asmah Dhiauddin from M[illegible] [illegible]nded a training program (31 April–6 May 1991) at DBM Research Laboratory at DOA, Bangk[illegible] [illegible]k. The training was on the mass rearing and production of *Trichogrammatoidea bactrae*. The [illegible]rogram was sponsored by AVRDC and MARDI. Siti [illegible]smah is actively involved in the mas[illegible] [illegible]on of *T. bactrae* at MARDI, Jalan Kebun.

In-country Training

MARDI and DOA successfully organized a nine-day in-country training on IPM for DBM at Serdang Malaysia from 15–23 July 1991. A total of 30 participants comprised of DOA technicians and extension agents attended the training course. The extension agents and technicians will in turn train the farmers and implement the IPM program in the various states and counties in the country.

Three in-state training programs were also conducted in 1991. Two training programs were held in the state of Terengganu for 30 farmers from 13 to 17 October 1991.

A training program was held on 21 October 1991 in Kelantan for 15 farmers. The farmers were trained to identify the DBM parasitoids and to implement the IPM in cabbage plots in the state.

Mass Rearing of *Diadegma semiclausum* and *Diadromus collaris* in the Cameron Highlands

The mass rearing of *D. semiclausum* was initiated in October 1989 and that of *D. collaris* in February 1990. The mass-rearing facilities included a mass-rearing laboratory and modified screenhouse for mass production of potted cabbage plants. The facilities were funded by AVRDC/ADB and MARDI.

Due to problems of high relative humidity in the rearing houses a heater and an air-conditioner were installed. Production of *D. semiclausum* is now 5000–10,000 adults per week and *D. collaris*, 2000–3000 per week. These parasites were also sent to the Philippines, Thailand and Indonesia for mass production and release.

Mass Rearing of *Cotesia plutellae* for Release in the Lowlands

MARDI mass-rearing facility. The IJORU method is still being used for mass rearing of DBM. However, this method is now beset with problems due to microsporidian infection in the laboratory cultures. To overcome this problem, the DBM eggs are currently treated at 40°C for about 12 days so that healthy DBM larvae could be used for mass-rearing of the parasitoid *C. plutellae*.

Interim experiments were initiated to mass-rear the DBM larvae using Shelton's artificial diet. In a test to find suitable cups for mass-rearing DBM, the emergence of adults was found to be relatively higher in the 80-oz plastic cups than in the styrofoam cups.

DOA mass-rearing facility. This mass-rearing facility is at Kelantan (northeast of Peninsular Malaysia). The facility was completed in February 1991 with AVRDC/ADB funds and has been producing 500-1000 *C. plutellae* per week. This facility will be expanded to produce 5000–10,000 parasitoids per week.

Mass Rearing of *Trichogrammatoidea bactrae* for Release in the Lowlands

The mass-rearing facility for *T. bactrae* at MARDI, Jalan Kebun has been completed. The facility includes a room for mass production of *Corcyra cephalonica*, egg exposure room and a room for emergence of *T. bactrae*. The staff trained in Thailand is now involved in the mass production of *T. bactrae*. In March 1991, the *Corcyra* cultures were infected by diseases. After sterilizing the rooms, the culture was started again in July 1991 Eggs of *Corcyra* were obtained form Perlis Sugar Research Station. Egg production of *Corcyra* is now approximately 18 cc per cycle. Mass production of *T. bactrae* was initiated in September 1991. The egg parasitoid was obtained from BPI, Philippines.

Integrated Pest Management of DBM on Cabbage in the Highlands and the Lowlands

Highlands. The IPM package trials for the Cameron Highlands from 1988-1990 had the following results:

- Yields were higher in the IPM plots than in the prophylactic plots.
- IPM plots need 0-3 sprays of B.t. and/or insecticides per crop cycle, while in the prophylactic plots the number of insecticide applications was between 8 and 10.
- Increased levels of parasitism by DBM parasitoids in the IPM plots.
- There was no insecticide residue on harvested cabbage in IPM plots.
- Net profit was higher in IPM plots.

In 1991, three IPM packages were evaluated based on the age of the cabbage crop. The following results indicate that IPM I is superior to IPM II and IPM III.

	IPM I	IPM II	IPM III
Total yield (kg)	1324	1231	1210
Net Profit (US$)	226.00	198.00	192 00

Lowlands. The IPM package for the lowlands is similar to that for the highlands except for the weekly treatment for *Hellula undalis* for the first 30 days after transplanting. The treatment was done with *Bacillus thuringiensis* as a shoot treatment to prevent damage of shoots by *H. undalis* which results in total loss of the cabbage crop.

In 1991, the IPM I package was tested in farmers' field at Sepang Selangor. Initial observations indicate superiority of the IPM package compared to prophylactic plots.

AVRDC-Philippines Outreach Program

Mungbean

Preliminary Yield Trial

Summary

Forty-two mungbean lines were evaluated in two sets of preliminary yield trials (PYTs) to identify lines with high yield potential, desirable agronomic characters and disease resistance, particularly against Cercospora leaf spot (CLS) and powdery mildew (PM).

In Set I, 24 entries had been completed in the fourth season of PYT evaluation. For the wet season trial, the top three test entries did not significantly outyield the check variety BPI-Mg7 (1.4 t/ha). The highest yielder was VC 4146-B-3 with 1.6 t/ha. Of the 18 entries evaluated in Set II, four entries with yields ranging from 0.7 to 0.8 t/ha outyielded the check BPI-Mg9 with 0.7 t/ha.

Almost all the test entries evaluated were rated moderately to highly resistant to CLS and virus diseases.

Introduction

Homozygous mungbean lines with desirable agronomic characters were evaluated in the PYT to identify those adapted to local agroclimatic conditions with high bean yield potential, early and uniform maturity, resistance to common pests and diseases, tolerance to lodging and acceptable taste and processing qualities. After 2–4 seasons of PYT, selected lines were elevated to the GYT.

Materials and Methods

For crop year 1990–91, two sets of materials were planted during the dry (10 November 1990) and wet (19 July 1991) seasons. Sets I and II were composed of 18 and 24 entries, respectively. In both sets, the entries were sown in four-row, 5-m long subplots distributed in RCBD and replicated three times. The rows were spaced 0.5 m apart.

The cultural management and data collection were based on the standard procedure suggested by the AVRDC International Cooperator's Guide for Mungbean Evaluation Trial.

Results and Discussions

The dry season trial was almost a failure due to unusually heavy rainfall in November and December 1990 (total precipitation was 387 mm with 25 rainy days) and sudden drop of night temperature during the vegetative stage of the crop. These conditions caused stunting of the plants which in turn reduced bean yield.

During the 1991 wet season trial, Set I with 24 entries produced a grand mean yield of 1.3 t/ha. Five test entries outyielded the highest yielding check BPI-Mg7 which produced 1.4 t/ha. Although high significant differences were observed between entries, the top five yielders (1.5 t/ha to 1620 kg/ha) did not significantly outyield check BPI Mg9. The highest yielder VC 4146-B-3 was also rated moderately resistant to CLS. Lines VC 4130-B-2 and VC 4150-B-2 produced the largest seeds (5.9 g/100 seeds) which were comparable to that of the check BPI-Mg9.

In set II, the bean yields of the 18 entries ranged from 0.3 t/ha for VC 3830-2B-1 to 0.8 t/ha for VC 3995-B-2 or a grand mean of 0.6 t/ha. Four test entries outyielded the check BPI Mg9 (0.7 t/ha) although

the mean differences were not statistically significant. The low mean yield was a result of heavy rains and strong winds during the maturity stage of the crop.

Five breeding lines were rated highly resistant to CLS and mungbean virus.

General Yield Trial

Summary

Two sets of entries were evaluated under the general yield trial (GYT) during CY 1990-91. Set I with 12 entries produced an average bean yield of 1.3 t/ha. The yield difference was statistically significant only for line VC 3876-2B-1-2. In Set II, three test entries outyielded the highest yielding check, BPI Mg9 (0.7 t/ha), although their mean differences were not statistically significant. The high yielding lines in both sets showed high level of resistance to CLS and virus diseases.

Introduction

Twenty-seven mungbean entries were evaluated in two sets of trial under the GYT to obtain more data on their adaptability under local agroclimatic conditions and their reactions to common pests and diseases. The results from this trial served as the basis for selecting entries to the RYT.

Materials and Methods

Set I with 12 entries was planted on 10 November 1990 dry season (DS) and 7 June 1991 wet season (WS) while Set II with 15 entries was planted on 19 July 1991 (WS). All the entries were sown in 5-m long, 4-row subplots, distributed in replicated complete block design (RCBD) and replicated four times. Cultural management and data collection were based on the AVRDC International Cooperator's Guide for Mungbean Evaluation Trial.

Results and Discussions

Set I planted during the dry season did not produce valid results due to the unusual heavy rains in November and December 1990 (total rainfall was 387 mm) and the sudden drop of night temperatures during the vegetative stage of the crop. These resulted in stunted plants, adversely affecting bean yield.

The results of the wet season trial for Set I entries are presented in Table 1. In Set I, with 12 entries, the grand mean yield was 1310 kg/ha. Five breeding lines (yield range of 1.3 to 1.6 t/ha) outyielded the check Pag-asa 5 (1.3 t/ha). However, only the difference in yield of VC 3876-2B-1-2 was significant over the check. It was also rated highly resistant to CLS and virus diseases. Line VC 3560-B-B-4-4 produced the largest seed with 6.2 g/100 seeds.

Table 1. The performance of the high yielding mungbean lines in the GYT during the wet season, 1991[a].

Entry	Bean Yield (kg/ha)	100-Seed wt (g)	Days to maturity	Plant ht (cm)	Disease Rating CLS[b]	Disease Rating Virus[c]
Set I						
VC 3876-2B-1-2	1623 a	5.6 e	57.0 ab	81.1 a	1.0 e	1.0 a
VC 2764 Sel (Y)	1537 ab	5.1 f	56.5 b-d	70.6 b	1.3 e	1.8 a
VC 3995-B-1	1535 ab	5.9 d	56.5 bd	79.8 a	2.0 d	1.3 a
VC 3995-B-7	1507 ab	5.6 e	54.5 f	69.5 bc	2.0 d	1.5 a
VC 3530-B-1-1	1320 bc	6.0 bc	53.5 f	53.7 e	3.5 ab	1.3 a
Pag-asa 5(ck)	1296 bc	6.1 ab	55.8 de	62.4 cd	3.0 bc	1.3 a
BPI Mg9 (ck)	1287 bc	6.0 bc	54.5 f	62.3 d	2.8 c	1.5 a
Mean of 12 entries	1310	5.9	55.7	66.7	2.5	1.5
CV (%)	11.5	19.6	0.9	6.5	16.6	34.3

[a]Data means of 5 m² subplots distributed in RCBD with four replications. Means followed by the same letter are not significantly different at 5% level according to DMRT.
[b]Rated on a scale of 1–5, with 1=highly resistant and 5=highly susceptible.
[c]Rated on a scale of 1–3, with 1=resistant and 3 susceptible.

Of the 15 entries evaluated in Set II, three test entries outyielded the check variety BPI Mg9 (0.7 t/ha) although the yield differences were not statistically significant. The low average bean yield of 0.5 t/ha was due to typhoon damage resulting in flower and pod abortion. The highest yield of 0.8 t/ha was produced by VC 3885 A which also had the highest seed weight of 6.1 g/100 seeds. Almost all the test entries were rated highly to moderately resistant to CLS compared to BPI Mg9 (with a rating of 2.5).

International Mungbean Nursery

Summary

Twenty-two elite mungbean entries were evaluated during the crop year 1990-91. Results showed an average bean yield of 1.4 t/ha. Highly significant differences were obtained among the entries, although the bean yields of the high-yielding lines were not statistically significant over the check BPI-Mg9. The largest seed was produced by VC 3902 with 7.0 g/100 seeds. Four test entries were rated highly resistant to CLS.

Introduction

The International Mungbean Nursery (IMN) is a cooperative trial among the NARS and coordinated by AVRDC. Elite mungbean cultivars/accessions collected from different countries of origin were sent to cooperators for evaluation. The study aimed to provide information on the range of adaptation of mungbean crop, specific adaptation of individual cultivars and the characteristics of the plant influencing adaptation. It also served as a means of disseminating superior cultivars to mungbean research workers.

Materials and Methods

Twenty elite cultivars/accessions from AVRDC together with two local checks were planted on 10 November 1990 and 7 June 1991 for the dry and wet season trials, respectively. Each entry was sown in a 4-row subplot distributed in RCBD and replicated three times. Row length was 5 m and distance between rows, 0.5 m.

Cultural management and data collection were based on the standard procedures suggested by the AVRDC International Cooperator's Guide for Mungbean Evaluation Trial.

Results and Discussion

Results from the dry season trial produced very low mean bean yield due to unusually heavy rains in November and December 1990 and the sudden drop of night temperatures during the vegetative stage of the crop. The data were, therefore, not analyzed and the results not included in the report.

For the wet season trial, 22 entries produced an average bean yield of 1.4 t/ha. Significant differences were observed among entries. However, the 11 top yielders with yields ranging from 1.5 to 1.7 t/ha showed no significant differences over the check BPI Mg9 (1.4 t/ha). The largest seeds were produced by VC 3902 with 7.0 g/100 seeds.

Average plant stature was 66 cm and the plants reached maturity 56 days after emergence. Four test entries, VC 4066 A, VC 3902 A, VC 1137 A and VC 1160 B were rated highly resistant to CLS.

Regional Yield Trial

Summary

Nine entries including two checks were evaluated in RYT in six cooperating stations during the dry and wet seasons of 1990-91. Of the three AVRDC mungbean lines in the trial, EGM 3541 with mean bean yield of 1366 kg/ha outyielded BPI-Mg9 (national check) with 1.3 t/ha during the wet season. However, during the dry season EGM 3121 with 1.0 t/ha had a comparable yield to the check BPI-Mg9. The three promising AVRDC lines and the two national checks were rated highly to moderately resistant to CLS and PM.

Introduction

The RYT for mungbean under upland monoculture conditions was undertaken in cooperation with BPI, IPB and other local organizations involved in mungbean varietal improvement. It was conducted in 8-9 sites in the country to evaluate the performance of the promising lines/accessions of mungbean in the different regions of the Philippines. The results obtained from the RYT served as the basis for recommendation/approval by the Philippine Seedboard of new varietal releases for commercial production.

Materials and Methods

For the crop year 1990–91, nine entries, including two checks (1 national and 1 regional) were evaluated during the dry and the wet seasons in six cooperating stations. Each entry was planted in 10-m long, 4-row subplots distributed in RCBD with four replications. The cultural management and data collection were based on the guidelines of the Upland Crop National Cooperative Trial (UCNCT) of the Philippine Seedboard.

Results and Discussion

Among the three BPI/AVRDC entries (Table 2), line EGM 3541 (VC 3541 A) with bean yield of 1.4 t/ha (wet season) produced slightly higher yield than the national check variety BPI-Mg9 (1348 kg/ha). During the dry season, the yield of EGM 3121 (1.0 t/ha) was comparable to that of the check variety BPI-Mg9 (1.2 t/ha). Line EGM 3541 had the largest seeds with 100-seed weight of 6.4 g (wet season) and 6.2 g (dry season) among the nine entries. The three entries together with the two check varieties were rated highly to moderately resistant to CLS and PM across locations.

Table 2. Summary performance of the AVRDC mungbean entries in the RYT across six locations, Crop Year 1990–91[a].

Entry	Bean Yield (t/ha)		100-Seed wt (g)		Disease Rating[b] CLS		PM	
	WS	DS	WS	DS	WS	DS	WS	DS
EGM 3102	1.3 (7)	0.9 (8)	6 0	6.1	1.8	2.1	1.3	1.3
EGM 3121	1 3 (8)	1.0 (5)	5.8	5.8	1.7	2.0	1.4	1.4
EGM 3541	1.4 (3 5)	1.0 (7)	6.4	6.2	1.8	2.1	1.2	1.7
Pagasa 7 (Nat. ck)	1 4 (5)	1 0 (2)	5.9	6.0	2.0	2.0	1.2	1.2
BPI Mg9 (Nat. ck)	1.3 (6)	1.2 (3)	5.6	6.0	1.6	1.6	1.2	1.2
Mean of 9 entries	1.3	1.0	5.8	6.0	1.8	1.9	1.3	1.3

[a]Data mean of 5.0 m² subplots distributed in RCBD and replicated four times.
[b]Rated on a scale of 1–5, with 1=highly resistant and 5=highly susceptible.
Figure in parentheses represents rank of entry in the trial.

Soybean

Preliminary yield trial

Summary

Twenty promising lines/accessions from AVRDC and other sources were evaluated in the preliminary yield trial during the dry and wet seasons of 1990–91.

The study aimed to identify soybean lines with high bean yield potential, less sensitivity to photoperiodism, resistance to common pests and diseases and other desirable characters.

During the dry season, three entries outyielded the highest yielding check UPL-Sy4 (1.5 t/ha) but the differences were not statistically significant.

For the wet season, lines GC 90086, GC 90083 and G 6977 with bean yields of 2.6, 2.4 and 2.3 t/ha, respectively, outyielded the check variety UPL-Sy4 (2.1 t/ha) but the differences were also not significant.

Introduction

Promising AVRDC soybean lines/accessions were evaluated in the PYT to identify those with high bean yield potentials, resistance to common pests and diseases and other desirable characters.

Materials and Methods

Twenty test entries were evaluated against the standard checks, BPI-Sy4 and UPL-Sy4. Plantings were made on 17 December 1990 for the dry season and on 17 June 1991 for the wet season. In both trials, the entries were drilled in four-row 10-m^2 subplots, distributed in RCBD and replicated three times. Complete fertilizer at 30-30-30 kg/ha was applied at planting. AVRDC procedure for growing soybean was followed in conducting the trial.

Results and Discussions

During the dry season, three test entries outyielded the highest yielding check UPL-Sy4 (1.5 t/ha) but the differences were not statistically significant. The average bean yield of the 20 entries ranged from 1.5 to 1.7 t/ha with a grand mean of 1.3 t/ha. The entries matured in 76–82 days and the plant height varied from 39.7 to 68.7 cm. All were rated resistant or moderately resistant to leaf folder and mites.

In the wet season trial, lines GC 90086, GC 90083 and G 6977 with bean yields of 2.6, 2.4 and 2.3 t/ha, respectively, outyielded the check variety UPL-Sy4 (2.1 t/ha) but the differences were not significant. All the entries were rated resistant or moderately susceptible to soybean rust and soybean mosaic virus infections.

General Yield Trial

Summary

The general yield trial was conducted to further verify the yield potentials, resistance to common pests and diseases and to identify the desirable agronomic characters of lines selected from the PYT.

Of the 14 test entries evaluated during the dry season, only G0062 outyielded the check variety UPL-Sy4 with 1.5 t/ha but the difference was not significant. All entries were early-maturing, ranging from 74 to 81 days from planting.

During the wet season trial, five test entries outyielded the highest yielding check variety UPL-Sy4, but only AGS 147 with bean yield of 2.9 t/ha was highly significant over the check.

Introduction

Selected promising lines from the PYT were further tested for their bean yield potentials, reactions to major pests and diseases and to identify their other desirable agronomic characters. The selections from the GYT were finally evaluated in the RYT for the regional evaluation and possible regional and/or national recommendation.

Materials and Methods

Fourteen and 15 test entries were evaluated against the standard checks BPI-Sy4 and UPL-Sy4 during the dry and wet seasons, respectively. The dry season was planted on 17 December 1990 and wet season on 17 June 1991. In each trial, the entries were sown in four-row 10-m^2 subplots, distributed in RCBD and replicated three times. Complete fertilizer 30-30-30 was applied at planting. Cultural management and data collection were based on the standard cultural practices suggested in the AVRDC International Cooperator's Guide for soybean evaluation trial.

Results and Discussions

Of the 14 test entries evaluated during the dry season, only GC 90062 outyielded the check variety UPL-Sy4 (1.5 t/ha) but the difference was not statistically significant (Table 3). Bean yield ranged from

Table 3. Mean bean yield and other agronomic characters of the soybean entries evaluated under the general yield trial during dry and wet seasons 1990–91[a].

Entry	Bean yield (t/ha)		Days to maturity		Plant ht at maturity (cm)		100-Seed wt (g)		Diseases and pest rating[b]				
	DS	WS	DS	WS	DS	WS	DS	WS	Soybean rust WS	SMV WS	Purple stain WS	Leaf-folder DS	Mite DS
GC 50095-7-0-9	1.4 ab	1.5 b-d	74 e	97 cd	54.9 ab	93 1 d-f	9 0 f	11 1 j	3 3	1 2	1.0	2.3	2 1
BPI-Sy4 (ck)	1.0 c-e	1.0 d-f	76 d	96 de	46.7 c-e	84.5 e-g	11 3 e	12.8 i	2 3	3.7	1.0	2.5	2.3
AGS 147	0 5 f	3 0 a	74 e	93 g	38 2 fg	97 7 cd	13 0 cd	15 8 ef	4.0	1 0	1 5	2 4	1.9
UPL-Sy4 (ck)	1.5 a	1.5 b-d	81 a	98 bc	59 3 a	113.6 b	14.1 bc	16.7 c-e	2 7	2.3	1 5	2.3	1.8
POP #11	1 3 a-c	0.7 f	79 bc	97 cd	46 3 c-e	81 2 fg	14.8 ab	13 4 i	2.7	4 0	1.0	2 3	2.2
POP #10	1.2 a-d	1 8 b	78 c	97 cd	48.3 b-e	97.0 c-e	14 8 ab	21.4 a	2.3	2 3	1 6	2.5	2 1
POP #8	1 2 a-d	0.8 ef	79 bc	95 ef	45 9 c-e	82 3 fg	13 0 cd	12 9 i	4 0	4 0	1.0	2.4	2.2
SJ-5	1 3 a-c	1.2 c-f	78 c	99 b	53 6 a-c	97.1 c-e	13 0 cd	14 5 gh	2.7	2 3	1.2	2 6	1.9
G 0062	1.5 a	1 3 b-e	78 c	101 ab	59.5 a	120 6 a	15 2 ab	18.3 b	2 0	3.0	1.5	2.2	1 9
LG Sy5-8	-	1.4 b-d	-	94 fg	-	109 6 a-c	-	16 2 e	2 7	1 0	1.5	-	-
Grand Mean	1.1	1 43	78	97	47.0	94 6	13 5	15 6	3 0	2 2	1 38	2.4	2 0
CV (%)	17.1	21.5	0 96	0 58	8.4	7 4	5 2	3 6	17 3	18.0	12 1		

[a]DS planted 17 December 1990 and WS 17 June 1991 Data are means of 5 m² subplots distributed in RCBD with three replications Means followed by the same letter are not significantly different at 5% level according to DMRT.
[b]Rated on a scale of 1–5, with 1 = highly resistant and 5 = highly susceptible

0.7 to 1.5 t/ha with a grand mean of 1.1 t/ha. All entries were rated resistant to moderately resistant to leaf folder and mites.

During the wet season trial, five test entries outyielded the highest yielding check variety UPL-Sy4, but only AGS 147 with bean yield of 3.0 t/ha was highly significant over the check. The entries matured from 93 to 102 days from planting. All the entries were rated resistant to moderately susceptible to soybean rust, soybean mosaic virus and purple seed stain.

Regional Yield Trial

Summary

Nine and eleven entries including the national and regional checks were evaluated in the regional yield trial (RYT) during the dry and wet seasons, respectively. The study was designed to verify the performance of promising strains/varieties under the different regions of the Philippines in terms of bean yield potential and reactions to major pests and diseases.

The results from BPI-LBNCRDC during the dry season showed that none of the test entries outyielded the highest yielding check UPL-Sy4 with 1.8 t/ha.

During the wet season, EGSy 129 outyielded the highest yielding national check PSB-Sy1 with 2.0 t/ha but the difference was not statistically significant. Three test entries, EGSy 129, EGSy 9-88-8 and IPB Sy 83-49-3, produced yields comparable to that of the highest yielding national check PSB-Sy1.

Introduction

The regional yield trial for soybean was conducted in cooperation with the Institute of Plant Breeding of the University of the Philippines at Los Baños (UPLB) and other institutions involved in the soybean varietal improvement program. Coordinated by the Field Legumes Technical Working Group of the Philippine Seedboard, promising entries from various national breeding programs were assembled and evaluated for four seasons in 8–12 cooperating stations using common standard procedures. The study was designed to identify high yielding varieties with desirable agronomic attributes adapted to the different regions of the country. Recently, to regionalize varietal recommendations, promising soybean entries in the RYT in a given region were further evaluated for two seasons in the technology adaptation (TA) trial before a variety is released in the region.

Materials and Methods

Nine and 11 soybean entries including the national and regional checks were evaluated in six cooperating stations during the dry and wet seasons of 1990–91. In both season trials, each entry was

planted in 4-row, 10-m^2 subplots distributed in RCBD and replicated four times. The standard procedure for evaluating soybean prescribed in the Upland Crop National Cooperative Trial (UCNCT) of the Philippine Seedboard was followed by all cooperating stations in conducting the test.

Results and Discussions

Out of the nine entries evaluated during the dry season, none outyielded the highest yielding check UPL-Sy4 with 1.8 t/ha. Only IPB Sy 83-49-5 gave comparable yield to the check varieties. Significant differences on 100-seed weight and days to maturity among entries were noted. All entries were rated resistant to moderately resistant to leaf folder and mites.

For the wet season trial, only EGSy 129 outyielded the highest yielding national check PSB-Sy1 with 2.02 t/ha but the difference was not statistically significant. Three test entries namely, EGSy 129, EGSy 9-88-8 and IPB Sy 83-49-3, produced yields comparable to the highest yielding national check PSB Sy1. All entries were rated resistant to moderately susceptible to soybean rust, purple seed stain and soybean mosaic virus.

Vegetable Soybean

Preliminary Yield Trial

Summary

Nine AVRDC vegetable soybean accessions were evaluated under the PYT on 17 December 1990 (dry season) and 17 June 1991 (wet season) to determine their yield potentials, eating qualities and reactions to pests and diseases under local climatic conditions.

During the wet season trial, line G 10478 gave the highest fresh bean yield of 7.1 t/ha. The grand mean fresh pod yield for the nine entries was 6.1 t/ha.

Introduction

There is an increasing desire among farmers to produce vegetable soybean for domestic consumption and for export. Because of its high nutritional value and ease in production even as a backyard garden crop, vegetable soybean has been included as one of the priority crops in the nutrition program of the municipal government. To support this program, promising lines of vegetable soybean from AVRDC were evaluated at the station for yield potential, eating quality, and reaction to pests and diseases under local conditions.

Materials and Methods

Nine entries were evaluated during the dry (planted 17 December 1990) and wet (17 June 1991) seasons. Each entry was sown in four-row, 5-m long subplots distributed in RCBD and replicated four times. The rows were spaced 50 cm apart. The AVRDC standard cultural practices for soybean were followed in raising the crop and evaluating the entries.

Results and Discussions

During the dry season trial, only dry bean yields of the entries were recorded. The dry bean yield of lines AGS 191, AGS 190, AGS 186 and G 10478 ranging from 1.4 to 1.6 t/ha, were significant over the other entries. Accession AGS 190 gave the biggest seed size of 25 8–30.1 g/100 seeds. All entries were rated resistant or moderately resistant to mites and leaf folder infestations.

For the wet season trial, line G 10478 gave the highest fresh bean yield of 7.1 t/ha. Bean yields ranged from 5.8 to 7.1 t/ha with a grand mean of 6.1 t/ha. Lines G 10478, AGS 190, AGS 186 and AGS 191 had comparable bean yields. All the entries were rated resistant to moderately susceptible to soybean rust, purple seed stain and soybean mosaic virus infections.

The vegetable soybean accessions AGS 186, AGS 190 and AGS 191 were rated most acceptable in terms of palatability of the green boiled pods and as shelled green bean to substitute for green peas.

Sweet Potato

Preliminary Yield Trial

Summary

Eleven entries of AVRDC sweet potato accessions/lines were evaluated against the BPI-Sp2 (check) to identify those with high root yield potential and other desirable agronomic characters.

During the wet season, no entries significantly outyielded the check variety BPI-Sp2 which produced marketable root yield of 48.5 t/ha. Further, BPI-Sp2 also showed the widest root diameter of 6.3 cm and resistance to scab infection.

Introduction

The AVRDC lines/accessions multiplied at the Philippines Outreach Program (POP) were evaluated in the preliminary yield trial to determine their root yield potential and reaction to scab infection. The promising materials were further tested in the GYT.

Materials and Methods

Eleven entries evaluated against BPI-Sp2 (check) during the wet season were planted on 11 July 1990 in double-row, 6-m^2 subplots distributed in RCBD in three replications. Planting distance was 75 × 25 cm between rows and hills.

The cultural management and data collection employed were according to the AVRDC procedures on sweet potato trial.

Results and Discussions

Of the 11 entries evaluated, six with marketable root yields of 21.2 to 47.8 t/ha were promising. However, no entry significantly outyielded the check variety BPI-Sp2 which produced a marketable root yield of 48.5 t/ha. Variety BPI-Sp2 produced the widest root diameter of 6.3 cm. On root length, entries CN 1421-41 and I 423 significantly showed the longest marketable roots of 15.2 cm and 15.1 cm, respectively, compared to the check.

Five entries, CN 1489-89, CN 941-32, CN 1423-170, CN 1421-41 and BPI-Sp2, showed resistance to scab infection, whereas CN 1424-9, the lowest yielding entry, was susceptible.

General Yield Trial

Summary

No test entry outyielded the check BPI-Sp2 which produced marketable root yield of 39.4 t/ha during the wet season and 25.9 t/ha during the dry season 1990-91. Moreover, BPI-Sp2 produced the widest root diameter (6.3 cm) and was rated resistant to scab infection. Ten other entries showed resistance to scab infection while CN 1346-9 produced the longest root of 15.6 cm (wet season) and 11.7 cm (dry season).

Introduction

Sweet potato lines/accessions selected from the PYT were further evaluated in the GYT for yield, reactions to scab and other desirable agronomic characters.

Materials and Methods

Fifteen AVRDC sweet potato accessions were evaluated during the wet (planted 11 July 1990) and dry (planted 4 December 1990) seasons. In both trials, the entries were planted in double-row 6-m^2 subplots distributed in RCBD in four replications. The cultural management and yield parameters measured were based on the AVRDC recommendation in conducting sweet potato trials.

Results and Discussions

No test entries significantly outyielded the check BPI-Sp2 during both the wet and dry season trials (Table 4). BPI-Sp2 produced marketable root yield of 39.4 and 25.9 t/ha for the wet and dry seasons, respectively.

Table 4. Root yield and some yield components of AVRDC sweet potato lines/accessions under GYT in two cropping seasons, WS 1990 and DS 1990–1991[a].

Entry	Marketable Root Yield (t/ha)		Non-Marketable Root Yield (t/ha)		Root Diameter (cm)		Root Length (cm)		Scab Rating[d]
	WS[b]	DS[c]	WS	DS	WS	DS	WS	DS	WS
CN 1232-9	24.4 b	17.9 ab	2.0 e-g	0.7 b-f	5.3 b-d	5.7 a-c	13.5 b	10 2 b-d	1
CN 1346-9	24.1 bc	13.1 b-d	0.5 h	0.4 f	5.5 bc	5.4 a-f	15.6 a	11.7 a	1
CN 1219-1	22.6 b-d	14.3 b-d	4.8 a	1.1 ab	4.4 f-h	5 6 a-d	13.5 b	10.8 a-c	1
CN 1330-11	20 9 b-e	16 0 bc	4.5 ab	1 0 a-d	4.4 f-h	4 9 c-g	13.2 bc	10.8 a c	1
CN 1306-22	19.4 c-e	6.6 d-f	2.4 ef	0 5 d-f	5.1 c-e	4.8 c-g	12 4 cd	8 5 f	2
CN 1229-14	19.0 d-f	3.9 f	1.1 gh	1 1 a	5.3 b-d	3.91 g	12.3 cd	8 9 d-f	1
CN 1345-8	18 8 d-f	8 8 c-f	3.9 a-c	0 8 a-f	4 8 d-g	4.8 c-g	10.3 f	7.9 f	2
CN 1229-2	18.1 d-f	4.0 ef	1.7 e-g	0.8 a-f	4.9 c-f	4.5 e-g	11 0 ef	8.2 f	1
CN 1309-18	16.3 ef	15.2 bc	1.0 gh	0.6 c-d	5.9 ab	6.0 ab	10.5 f	10.9 a-c	3
CN 1221-1	14 4 fg	6.0 d-f	3 5 b-d	0.5 ef	4.3 g-i	5.5 a-e	13.2 bc	8.6 ef	1
CN 1280-3	11.0 gh	4.8 ef	2 8 c-e	0.6 c-f	4.8 d-g	4 6 d-g	13.1 bc	10 4 a-c	2
CN 1229-16	7.4 hi	11.8 d-f	2.5 b-f	1 0 a-c	4.6 e-h	5.5 a-e	11.8 de	11.5 ab	1
CN 1424-3	6.7 hi	10.8 c-f	3.6 b-d	0.9 a-e	4.5 e-h	4 9 b-g	10.7 f	9.9 c-e	4
CN 1216-10	6.4 i	9.0 c-f	3.8 a-c	0.6 c-f	3 8 i	4.4 fg	12.1 cd	10.5 a-c	1
CN 1425-557	4 6 i	12.3 b-e	4.7 ab	0.9 a-d	4.0 hi	5.2 b-f	10.8 ef	7.7 f	1
BPI-Sp2 (ck)	39.4 a	25.9 a	1 6 f-h	0.7 a-f	6.3 a	6.4 a	13.2 bc	11.6 ab	1
Grand Mean	17.1	11.3	2.8	0.8	4.9	5.1	12.3	9.9	1.6
CV (%)	23.7	60.9	34.8	45.6	10.7	17.3	7.4	12.5	

[a]Data means of 6 m² sub-plots distributed in RCBD and replicated 4 times Means followed by the same letter are not significantly different at the 5% level according to DMRT.
[b]Planted 11 July 1990 and harvested 11 December 1990.
[c]Planted 4 December 1990 and harvested 10 April 1991.
[d]Rated on a scale of 1 to 5, with 1 = highly resistant and 5 = highly susceptible.

The mean root diameter for all entries ranged from 3.8 to 6.3 cm during the wet season and 3.9 to 6.4 cm during the dry season. The check variety BPI-Sp2 produced the widest root diameter during both seasons which contributed to its high yields. Entry CN 1346-9 produced the longest root of 15.6 cm (wet season) and 11.7 cm (dry season).

Ten test entries showed resistance to scab infection, with CN 1424-3 being most susceptible.

Chinese Cabbage

Preliminary Yield Trial

Summary

Only one dry season trial was conducted with nine open-pollinated and hybrid Chinese cabbage lines (including the check) to evaluate their field performance under the lowland tropical conditions.

Hybrid #85-202 produced the highest marketable head yield of 16.1 t/ha, a mean head weight of 499 g, harvest rate of 97% and solidity of 0.56 g/cc. This hybrid was, however, not significantly different compared to the check Reyna Elena.

Introduction

Since the breeding program on Chinese cabbage was scaled down at AVRDC, no new lines were received at POP for 1991. Therefore, only one yield trial using nine entries was conducted during the dry season of 1991.

Materials and Methods

Nine open-pollinated and hybrid Chinese cabbage lines, including the check, were transplanted on 14 February 1991 (dry season) in 1 × 4.8 m raised subplots distributed in RCBD and replicated three times. Two furrows, 50 cm apart were set in each subplot. One seedling was transplanted 40 cm between hills within the furrow. Complete fertilizer at 60-60-60 kg/ha was applied at planting. Two side dressings, each with 30-75-75, were made 10 and 20 days after transplanting. The plants were sprayed with contact and systemic insecticides and were irrigated as needed. Data were collected as prescribed in the AVRDC Procedures for Chinese Cabbage Evaluation Trial.

Results and Discussions

There were significant differences among entries on marketable head yield which ranged from 6.5 t/ha for line 77M (3)-40 to 16.1 t/ha for #85-202 or a grand mean of 10.7 t/ha. All the hybrids including the check Reyna Elena showed highly significant yield differences over the open-pollinated entries.

The highest mean head weight of 499 g was produced by #85-202 which was statistically comparable to the check Reyna Elena (341 g). Significantly higher harvest rates (86-97%) were observed among the hybrids compared to the open-pollinated entries (56–74%).

The highest solidity of 0.6 g/cc was obtained from #85-202. Entries 77M (3)-40, #82-159 and #85-216 were rated moderately resistant to soft rot.

Tomato

Preliminary Yield Trial

Summary

For the dry season (dry season) trial on processing tomatoes, three F_1 hybrids (PT-4148, PT-4058 and PT-4027) significantly outyielded the check Mapula. Of the 14 fresh market determinate tomato lines evaluated during the dry season, variety Alton from the USA with a mean yield of 40 t/ha significantly outperformed all entries. During the wet season, Pope produced the highest yield of 7 t/ha which was comparable to the yields of Marikit, Alton and CL 5915-153 D4-3-3-NSB.

Introduction

The preliminary yield trial on processing tomatoes was conducted during the regular tomato dry season. Its objectives were to screen lines with high marketable yield potentials, acceptable processing quality and resistance to disease. The PYTs on the fresh market tomatoes were conducted in both the dry and wet seasons. However, more emphasis was placed on the wet season trials to develop heat-tolerant table tomato varieties adapted for off-season production in the lowland tropics.

Materials and Methods

Sixteen AVRDC processing tomato F_1 hybrids were compared to Mapula during the DS 1990-91, transplanted on 9 January and harvested six times from 18 March to 19 April 1991. For the fresh market, 8 AVRDC lines, a line from the USA and 3 lines from the People's Republic of China were transplanted on 24 January 1991 and 9 July 1991 for dry and wet season trials, respectively.

The processing tomato hybrids were set in 3.8 m^2 subplots and the fresh market entries in 5.0 m^2 subplots in both seasons. All sets of trials were distributed in RCBD with three replications. The cultural requirements of the plants were provided following the AVRDC recommendation for evaluating tomatoes.

Data on marketable and nonmarketable yield, horticultural characters and ratings on pests, diseases and physiological disorders were recorded and analyzed statistically.

Results and Discussions

Processing tomatoes, dry season trial. Three hybrids, PT-4148, PT-4058 and PT-4037, with marketable yields of 53.3, 43.5 and 39.5 t/ha, respectively, significantly outyielded the check Mapula which produced 33.5 t/ha. The nonmarketable yields with a grand mean of 5.1 t/ha varied among entries but differences were insignificant. Biggest fruit of 112 g/fruit was produced by PT-4062. The entries flowered from 21 to 30 days after transplanting with peak of harvest in 74–87 days.

Fruitworms attacked all entries and was highest (with score of 5.0) on PT-4063 and PT-4062. The TMV and BW were observed on all test lines at varying degrees of severity but the differences were insignificant among the entries. Fruit cracks, sunscald and blossom end rot were also noted but had minimal effect on the yield.

Fresh market, dry season trial. Alton, a USA open-pollinated line gave the highest total yield of 40 t/ha, outyielding significantly the checks Marikit (31.9 t/ha) and Pope (26.1 t/ha). The lines from China produced the biggest fruits (125–158 g) while the smallest (about 37 g) were observed on Marikit, Pope and Alton. Flowering varied significantly among entries with Pope flowering the earliest at 21 days, and CLN 484 BC1 F3-58-5-4 the latest at 27 days. Peak of harvest ranged from 68 to 74 days. Fruit worms and bacterial wilt were noted but with no significant differences among the entries. Blossom end rot was highest on the China line.

Fresh market, wet season trial. Very low yield levels were obtained from the 14 entries evaluated due to bad weather during the vegetative and reproductive stages of the crop. High incidence of TMV, BW and CLS were observed and recorded. Five lines were dropped from the trial because of the high percentage of missing hills due to BW. However, the yields obtained varied significantly among the test lines. Highest total yield of 7 t/ha was produced by the check Pope.

General Yield Trial

Summary

Six AVRDC and four East/West F_1 hybrid outperformed the check variety Mapula. Marketable yields ranged from 31.2 t/ha for Mapula to 53.1 t/ha for Pr-709.

Two sets of trials on determinate fresh market tomatoes showed better yield performance during the dry than during the wet season. In set I with 12 entries, the yields of eight AVRDC lines were comparable to the check Marikit which ranged from 11.4 to 22.4 t/ha during the dry season and from 0.3 to 0.8 t/ha during the wet. In both seasons, Marikit produced the highest yields.

In Set II with 14 entries, marketable yields ranged from 7.4 to 21.0 t/ha during the dry season and 0.4 to 1.2 t/ha during the wet season.

On the indeterminate type, eight lines out of the 14 entries outyielded the checks. The marketable yields ranged from 37.9 to 50 t/ha during the dry season with the highest produced by FMTT-109. During the wet season, marketable yields ranged from 2.2 to 11.2 t/ha and the highest yielder was FMTT-114. Five lines (FMTT-79, -114, -32, -22 and -138) gave yields comparable to Marikit but significantly outyielded Pope.

Introduction

The general yield trial (GYT) further screened tomato lines for adaptability, marketable fruit yield potential, heat tolerance and reactions to pests, diseases and physiological disorders.

The processing type (11 entries) was evaluated once during the dry season while the fresh market determinate type was divided into two sets (Set I with 12 entries and Set II with 14 entries) and the indeterminate type in one set (14 entries). Both the determinate and indeterminate types were evaluated during the dry and wet seasons.

Materials and Methods

Processing tomato. Six AVRDC F_1 hybrids and four East/West Seed Co. hybrids were compared against the check Mapula. The trial was transplanted on 10 January 1991 and harvested six times from 18 March to 19 April 1991.

Fresh market determinate. Set I was composed of 12 entries. The dry season trial was transplanted on 5 December 1990 and harvested five times from 8 February to 6 March 1991. The wet season trial was transplanted on 8 August and harvested once on 12 October 1991.

Set II had 14 entries. The dry season trial was transplanted on 5 December 1990 and harvested 8 February to 15 March 1991. The wet season trial was transplanted on 1 August and harvested twice on 2 and 8 October 1991.

Fresh market indeterminate. The trial was composed of 14 entries. The dry-season trial was transplanted on 10 January and harvested 10 times from 19 March to 26 April 1991, while the wet season trial, with the same entries was transplanted 8 July and harvested six times from 10 to 30 September 1991.

All the entries were transplanted in 3.8-m^2 subplots during the dry season trial and in 5-m subplots during the wet season. In both seasons, the subplots were distributed in RCBD and replicated four times. The plots were mulched with rice straw and the indeterminate type tomatoes were provided with trellises. The suggested cultural management prescribed by AVRDC in raising the crop was followed. The data recorded and analyzed were those of marketable and nonmarketable yields, number of days to 50% flowering and maturity, fruit size and ratings of pests, diseases and physiological disorders.

Results and Discussions

Processing tomato. Six entries significantly outyielded the check Mapula with grand mean of 42.9 t/ha (Table 5). The highest nonmarketable yield of 6.7 t/ha noted on PT-778 was due to fruit worm infestations and to fruit cracks. Fruit size significantly varied among the entries with biggest fruits (100.5 g) from PT-778. The fruit size of the East/West entries was comparable to Mapula. Flowering of the East/West hybrids was earlier than the AVRDC lines. The effect of fruit worms, BW, TMV, BER and cracking varied among the test lines but the differences were insignificant.

Table 5. Processing tomatoes, yield, horticultural characters and ratings on pest and diseases and physiological disorders (GYT, DS 1990-91)[a].

Entry	Fruit yield (t/ha)			Mean wt of fruits (g)	No. of days to		Ratings on pests, diseases Physiological disorders[b]				
	Market-able	Nonmar-ketable	Total		50% Flowering	Peak of harvest	FW	BW	TMV	BER	Cr
PT-1017	43.0 a-c	3.1 d	46.1	49.5 cd	22 cd	81	1.5	1.0	1.0	1.0	1.0
PT-1599	51.8 a	4.3 cd	56.1	49.0 cd	27 a	80	1.5	1.0	1.0	1.0	1.0
PT-1600	42.8 a-c	5.5 a-c	48.3	72.8 b	28 a	83	1.8	1.5	1.0	1.0	1.0
PT-778	31.6bc	6.7 a	38.3	100.5 a	26 ab	81	1.8	1.0	1.0	1.0	1.3
PT-3027	52.6 a	5.7 ac	58.3	62.8 bc	23 b-d	80	1.5	1.0	1.0	1.0	1.0
Tm-103	32.6 bc	5.1 ac	37.6	77.3 b	24 bc	84	1.8	1.5	2.5	1.0	1.3
Mapula (ck)	31.2 c	5.0 ac	36.2	53.0 cd	27 ab	84	1.8	1.5	2.0	1.5	1.3
Pr-702	43.8 ab	6.1 ab	49.8	52.0 cd	22 cd	88	1.5	1.0	1.0	1.0	1.0
Pr-708	43.8 ab	4.1 cd	47.9	37.3 d	21 d	79	1.8	1.0	1.0	1.0	1.0
Pr-709	53.1 a	4.3 b-d	57.9	42.0 d	22 cd	77	1.0	1.0	1.0	1.0	1.0
Pr-805	45.4 a	5.2 a-c	50.5	37.0 d	22 cd	80	1.5	1.0	1.3	1.0	1.0
Grand Mean	42.9	5.0	47.9	57.5	24	81.5	1.6	1.4	1.3	1.0	1.0
CV (%)	17.6	21.6	17.8	5.8	5.6	22.2	47.3	38.0	16.8	24.1	

[a]Transplanted 10 January 1991, harvested 18 March to 14 April 1991 (6 times).
[b]Ratings from 1 to 5 with increasing order of severity (FW=fruit worm; BW=bacterial wilt; TMV=tomato mosaic virus; BER=blossom end rot; Cr=cracking).
Note. Means followed by the same letter are not significantly different from each other at 5% level according to DMRT.

Fresh market determinate. In Set I, the marketable fruit yields ranged from 11.4 to 22.4 t/ha during the dry season. The yield performance of eight entries was comparable to Marikit which produced the

highest yield. Entry CLN 657 BC1-267-0-0 gave the highest nonmarketable yield and biggest fruit size. The entries flowered from 21 to 24 days, while the peak of harvest significantly varied from 62 to 70 days after transplanting. The entries were infested with fruit worms, had fruit cracks and sunscalding, but their effects were not significant. TMV, BW and CLS were also present but were minimal.

During the wet season, the entries produced very low yields of 0.2–0.8 t/ha. High incidence of CLS, TMV and BW were noted in all entries. These were attributed to the heavy rainfall in August (602.8 mm) and September (265.7 mm)with 24 and 18 rainy days, respectively.

In Set II, the marketable yields of the 14 entries ranged from 7.4 to 21.0 t/ha during the dry season. Eight lines were comparable to Marikit but significantly outyielded Pope, the second check. Highest marketable and nonmarketable yields were produced by CL 5915-93 D4-1-0-C-1. Fruit size varied with four lines producing significantly larger fruits, from 53 to 57 g. The differences in flowering (24–31 days) and maturity (71–80 days) from transplanting were insignificant among entries. TMV, BW and CLS were recorded in all lines but their differences were insignificant.

The wet season trial was characterized by low yields which ranged from 0.4 to 1.2 t/ha marketable fruits, small fruit size (14.5–46 g) and high incidence of BW, TMV and CLS.

Fresh market indeterminate. During the dry season, eight lines outyielded Marikit, but the differences were insignificant (Table 6). The highest marketable yield of 50 t/ha was produced by FMTT-

Table 6. Table tomato indeterminate type: horticultural characters and ratings on pests, diseases and physiological disorders (GYT, DS 1991, WS 1991)[a].

Entry	Marketable Yield (t/ha)		Nonmarketable Yield (t/ha)		Fruit size (g)		Days to 50% flowering		Days to Maturity		Rating[b] FW		BW	TMV
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	WS	WS
FMTT-16	38.8 a	3.4 c-d	8.3 a	0.9	56.8 h	47.0 de	30 a	31	81	75	5.0	2.5	2.3 ab	3.0
FMTT-79	43.4 a	8.0 ab	5.5 ab	0 8	68 3 f-h	47.0 de	25 c-e	30	80	74	3.5	2 3	1.5 bc	3 0
FMTT-108	40.7 a	5.8 b-d	4.8 c	0.9	83.0 c-e	56.0 a-d	29 a-c	31	81	75	3.0	3.0	1.3 bc	2.5
FMTT-116	43.0 a	4.3 b-d	7.8 b	1.5	80 0 d-f	50 0 b-d	28 a-c	29	81	75	4 5	3 0	1 0 c	3.3
FMTT-109	50 0 a	2 2 d	7 4 a-c	0 7	97.7 ab	59 0 a-c	27 a-c	29	82	74	3.5	2.5	1.0 c	2.8
FMTT-114	48.3 a	11.2 a	7.7 ab	1 5	59 7 g-h	37 0 ef	21 g	29	75	74	4.0	2 5	1.3 bc	2 8
FMTT-3	47.3 a	3.6 b-d	5.9 a-c	1.2	100 5 ab	60 0 ab	28 a c	29	81	75	4.1	2.5	1.3 bc	2 8
FMTT-110	35 1 a	6 3 b-d	5 0 c	2.0	94.7 a-c	48 0 cd	26 b-d	29	81	75	4.0	2.8	1.0 c	3.5
FMTT-32	47.0 a	7.7 a-c	6.7 a-c	1.5	104 0 a	59 0 a-c	27 b-d	29	81	76	3.5	2.8	2 8 a	3.0
FMTT-22	40 7 a	7.6 a-c	5.4 bc	1 2	72.0 d-f	64.0 a	29 ab	29	81	75	4.0	2.8	1.5 bc	2.3
FMTT-33	37.9 a	3.3 cd	6.5 a-c	0.6	87 0 bd	56 0 a-d	27 b-d	30	84	78	4.5	3 0	1.5 bc	2.5
FMTT-138	47.8 a	11 1 a	6.7 a-c	1 5	74 0 e-g	48 0 d	23 e-g	31	81	74	4.5	2 8	1.0 c	2.5
Marikit	42 8 a	7.4 a-c	5.1 c	1.2	37.7 i	22.0 g	22 fg	28	78	74	4.0	2.5	3.0 a	2.3
Pope	38.9 a	6.4 b-d	5.0 c	1 5	36.5 i	27.7 fg	24 df	28	80	73	4.0	2 8	1.0 c	3 0
Grand Mean	43.8	6.3	6.3	1.2	74.8	48.6	22.	29.5	80	74.7	4.0	2.7	1.5	2.8
CV (%)	14.73	42 6	25 8	47.9	10.8	13.8	7.1	7.7	3.8	4.04	24.9	21.9	47.4	25.6

[a]Dry season trial transplanted 10 January 19[illegible], harvested 19 March to 26 April 1991 (10 times).
Wet season trial transplanted 8 July 1991, harvested 10 to 30 September 1991 (6 times).
[b]Ratings from 1 to 5 with increasing order of severity (FW=fruit worm; BW=bacterial wilt; TMV=tomato mosaic virus; BER=blossom end rot; Cr=cracking).
Note: Means followed by the same letter are not significantly different from each other at 5% level according to DMRT.

109. The production of nonmarketable yield significantly varied among entries with highest (8.3 t/ha) noted in FMTT-16. Fruit size significantly varied from 36.5 to 104 g/fruit, with biggest fruits being produced by FMTT-32. Flowering was from 21 days for FMTT-114 to 30.3 days for FMTT-16. The peak of harvest among entries which ranged from 78 to 84 days was comparable to the two checks. Fruit worm damage was insignificant among entries with highest score recorded on FMTT-16. BW, TMV, sunscald and BER were noted but their incidence was too insignificant to affect yield.

During the wet season, marketable yield ranged from 2.2 to 11.2 t/ha. Five lines gave marketable yields comparable to Marikit but significantly better than Pope. Highest nonmarketable yield was noted in FMTT-110. Fruit size significantly varied with biggest fruits produced by FMTT-22. No significant differences were noted on flowering and maturity among the entries. Fruit worms were noted in all lines with a grand mean score of 2.7. The effects of BW significantly varied among the entries, with Marikit being the most susceptible to infection. The entries were infected with TMV, with insignificant differences among them.

Regional Yield Trial

Summary

The nine fresh market tomato varieties evaluated in the RYT in Los Baños, Laguna, the marketable yield of which during the dry season ranged from 17.7 to 24.8 t/ha, showed no significant differences among entries. However, during the wet season, only CL 5915-206 (G) D4-2 with 11.8 t/ha significantly outyielded all the entries including the check Maigaya (7 t/ha). The high nonmarketable yields obtained during the wet season were due to damage from fruit worms and fruit cracks. Panag-ulan produced the largest fruits in both seasons. Flowering of the entries was earlier during the dry than during the wet season while maturity was earlier during the wet season due to the high incidence of CLS.

Introduction

The AVRDC/POP in Los Baños was one of the 13 cooperating stations that conducted the regional yield trial on fresh market tomato during the dry and wet seasons of 1990–91. The trial evaluated the field performance of promising tomato lines/varieties in the different regions of the country. The results from this study were used by the Philippine Seedboard as the basis for releasing new tomato varieties for regional and/or national distribution.

Materials and Methods

Nine entries (two each from AVRDC/POP and East/West Seed Co. and four from the DA-Claveria Experiment Station) were evaluated in both the dry and wet seasons. The dry season trial was transplanted on 14 December 1990 in 4-row 4-m long subplots and the wet season trial in 3-row 4-m long subplots. In both seasons, the subplots were distributed in RCBD and replicated four times. The rows were set 1 m apart and the hills 30 cm within the row.

The crop was fertilized and raised according to the procedures suggested in the AVRDC guide in evaluating tomatoes.

Data on yield and other horticultural characters were taken from the two inner rows and 10 inner plants per row, for the dry season and from one inner row and 10 inner plants for the wet season.

Results and Discussion

The results of the RYT are presented in Tables 7a and 7b. No significant differences were noted among entries of marketable fruit yields during the dry season which ranged from 17.7 t/ha for CES I-8224 to 24.8 t/ha for Panag-ulan. The grand mean for all the entries was 21.1 t/ha.

Table 7a. Yield and horticultural characters of fresh market tomatoes tested under the regional yield trial during the dry season and wet season in Los Baños Laguna[a].

Entry	Marketable yield (t/ha)		NonMarketable yield (t/ha)		Fruit Size (g)		Number of days to 50% Flowering		Number of days to 1st Harvest	
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS
Panag-ulan	24.8 a	10.7 ab	1.2 f	4.9 ab	58.8 a	44.8 a	17 b	21 ab	68	65
Bonanza	18.3 a	9.4 a-c	2.4 b-d	3.9 ab	48.3 b	37.3 ab	23 a	23 a	70	65
CL 5915-222 (G) D4-0	22.7 a	9.3 a-d	1.3 d-f	3.5 ab	30.3d-g	21.8 cd	17 b	20 bc	68	65
CL 5915-206 (G) D4-2	23 0 a	11.8 a	2.2 b-f	6.4 a	23 0 h	24.3 cd	19 b	16 e	68	65
CES I-8224	17.7 a	3 0 f	1.8 b-f	1.4 d	32.0 d	17.5 cd	20 ab	23 a	68	65
CES I-8225	21.8 a	2.2 f	2.7 bc	2.9 d	31.0 de	17.3 cd	20 ab	23 a	68	65
CES II-823101	19.7 a	4 9 ef	2.4 b-e	3.3 cd	30.5 be	21.0 cd	23 a	22 ab	68	65
CES II-82351	22.0 a	1.9 f	2.9 b	2.3 d	39.8 c	28.0 bc	16 b	23 a	68	65
Maigaya (ck)	19.6 a	7.0 b-e	4.8 a	5.3 bc	17.5 h	13.5 d	16 b	18 d	68	65
Grand Mean	21.1	6.6	2.4	3.8	34.6	25.0	19.0	21	68.0	65
CV (%)	24.7	35.5	0.4	28.8	11.5	27.4	12.4	8.4	-	-

[a]Dry season transplanted 14 December 1990 and harvested 20 February to 15 March 1991; wet season transplanted 26 June 1991 and harvested 29 August to 9 September 1991.

Table 7b. Yield and horticultural characters of fresh market tomatoes tested under the regional yield trial during the DS and WS in Los Baños Laguna.

Entry	Pest, diseases and physiological disorders ratings[a]										
	FW		CLS		TMV		Cr		BW	BER	SS
	DS	WS	DS	WS	DS	WS	DS	WS	DS	DS	DS
Panag-ulan	2.5	5.0	4.5 ab	9.0 a	1.0	6.5	2.0 b	4.6 c	2 0	1.0 b	3.0
Bonanza	2.3	4.3	4.0 b	8.0 a-c	1.0	5.5	2.0 b	5 5 c	2.5	3.0 a	3.5
CL 5915-222 (G) D4-0	3.0	4.3	6.0 a	9.0 a	1.0	6.0	2.5 d	5.5 c	1.0	1.0 b	3.0
CL 5915-206 (G) D4-2	2.5	3.5	5.0 ab	9.0 a	1.0	6.0	3.0 b	5 5 c	1.0	1.0 b	3.0
CES I-8224	3.0	4.0	4.5 ab	8.5 ab	2.0	6.0	2.5 b	5 0 c	3.0	1.0 b	3.5
CES I-8225	2.5	4.3	4.0 b	6.5 bd	1.5	6.0	2.5 b	8.0 ab	2.5	1.0 b	3.0
CES II-823101	2.5	6.0	2.0 c	6.0 cd	1.0	6.5	2.5 b	6.0 bc	3.0	1.0 b	4.0
CES II-82351	2.5	5.3	2.0 c	5.0 d	1.0	6.0	3.0 b	6.0 bc	1.5	1.0 b	4.0
Maigaya (ck)	1.0	4.3	3.5 b	7.0 a-d	1.0	8.0	5.0 a	8.5 a	1.0	1.5 b	3.0
Grand Mean	2.4	4.5	3.94	7.5	1.17	6.3	2.8	6.1	1.9	1.3	3.2
CV (%)	5.6	36.2	24.5	19.07	45.0	23.92	7.1	20.8	65.22	6.0	21.4

[a]Legend of pest, diseases and physiological disorders' rating
1 = Resistant (no infection)
3 = Moderately resistant (less than 10% affected)
5 = Moderately susceptible (40% affected)
7 = Susceptible (41 to 70% affected)
9 = Very susceptible (more than 71% affected)

FW=fruit worm
CLS=cercospora leaf spot
TMV=tomato mosaic virus
Cr=fruit cracking
BW=bacterial wilt
BER=blossom end rot
SS=sunscald

Note: Means followed by the same letter are not significantly different at 5% level according to DMRT.

During the wet season, only the highest yielding entry CL 5915-206 (G) D4-2 with 11.8 t/ha significantly outyielded the check Maigaya (7 t/ha).

Nonmarketable yields produced in both seasons varied significantly among entries. The highest recorded on variety Maigaya during the dry season was due to the high percentages of cracked fruits and BER. During the wet season, fruit worm damage, cracks and BER contributed to the highest culled yield of CL 5915-206 (G) D4-2.

Variety Panag-ulan produced the largest fruit with a mean of 58.8 g during the dry season and 44.8 g during the wet season.

The number of days to 50% flowering also varied significantly among entries in both seasons. Maigaya and CL 5915-206 (G) D4-2 flowered the earliest at 16 days during the dry and wet seasons. The mean number of days to first harvest was 68 days for the dry and 65 days for the wet season.

The incidence of fruitworms was higher during the wet than during the dry season. CES II-823101 was the most susceptible during the wet season.

The entries were attacked by CLS in varying levels of severity. The most susceptible was CL=5915-222 (G) D4-0 in both seasons. The effects of TMV and BW were insignificant among entries. Higher incidence of fruit cracks occurred during the wet season than during the dry season. Panag-ulan was susceptible to BER and CES II-823101 to sunscald.

AVRDC-ROC Cooperative Program

Cooperative Projects with Local Institutes

Summary

Promising breeding lines from AVRDC and selected new vegetable varieties from various sources were evaluated in regional yield trials (RYTs) under different environments in Taiwan in cooperation with ROC institutions. Two new vegetable soybean varieties, K S#2 (KVS 39) and KS#3 (KVS 124), were released by the Kaohsiung District Agricultural Improvement Station (DAIS). Crosses for both selections were made at AVRDC. KS#2 resembles Ryokkoh or 305 and KS#3 resembles Tzurunoko or 205. But both KS#2 and KS#3 are higher yielding than 205 and 305. KS#1 released in 1987 is planted to 82.7% of the total vegetable soybean planted area in spring 1990 with an average yield of about 9–10 t/ha. AVRDC multiplied 4142 kg breeder's seed of eight varieties in six crops for the national programs.

AVRDC participated in 72 RYTs conducted under the coordination of three DAIS. AVRDC entries were included in all the trials. In vegetable soybean, selected locations (and seasons) such as Meilong (autumn) had a graded pod yield of 16 t/ha. In spring, Taichung, Likang and Wandau appeared to be high yielding locations. The economic potential of the above locations required further investigation.

Mungbean lines VC3945A, VC4176A, VC3300A and VC4152A appeared to have higher yield and larger seed size than the local check.

In late summer, processing tomato PT4225 produced the highest yield. AVRDC fresh market tomato had the largest fruit size of up to 172 g, whereas Taichung ASVEG No.4 was 141 g. Season's Red was the highest yielding cherry tomato in autumn.

AVRDC hybrid Chinese cabbage 86187 produced significantly higher yield (53 t/ha) than the check.

AVRDC transferred 1395 sweet potato clonal accessions to Chiayi TARI for conservation and use.

Results of evaluation of crisp-head lettuce, butterhead lettuce and leaf lettuce were encouraging. In crisp-head lettuce, Early S-26 can be grown in all three seasons. In spring and autumn, summer gold was the best. Among the butterhead lettuce, Summer Green, Margarita and Butter Crunch were suitable for the three seasons. In leaf lettuce, Black-seeded Simpson was adapted to all three seasons.

Dandy early broccoli was adapted to all three seasons.

Short stout eggplant varieties were the highest yielders while the long, slender ones were invariably low yielders. Such information is valuable for AVRDC and NARS for future breeding.

A number of onion entries gave up to 109 t/ha bulb yield in 135 days with a bulb size of more than 300 g compared to the local check yield of 53 t/ha in 131 days with a bulb size of 270 g. However, the brix of all the high yielders were quite low compared to the check. XPH 3325 produced 94.5 t/ha in 138 days with a bulb size of 417 g and a brix value of 11.47.

AVRDC gained experience in successfully growing and identifying promising entries of a number of promising nonprincipal and future principal vegetable crops.

Introduction

A number of ROC national institutions conducted Regional Yield Trials (RYTs) of promising AVRDC breeding lines and improved selections of new vegetable varieties. In 1991 advanced yield trials were also conducted for a number of selected new vegetables from AVRDC's "Development Basket" and has been supported by the ROC national program since 1988. These vegetables included crisp-head lettuce, butterhead lettuce, leaf lettuce, broccoli, eggplant and bulb onion. In addition, trials were undertaken to examine the feasibility of mechanical harvesting of snap bean with no tillage and with tillage using different crop management practices. Similarly, mechanical harvesting of vegetable soybean was investigated.

The objectives of the above trials were 1) to identify promising improved cultivars, 2) to facilitate the development of labor-saving and cost-efficient management technology for farmers in Taiwan. These objectives were meant to be achieved through close collaboration between ROC national programs and AVRDC.

RYTs were conducted for the following crops: soybean, vegetable soybean, mungbean, processing tomato, fresh market tomato, cherry tomato, Chinese cabbage, and sweet potato. All RYTs were conducted using a randomized complete block design with four replications.

Spacing between rows, between plants and number of plants per hill used in different seasons for the eight crops were recorded.

Nine advanced yield trials (AYTs) of lettuce (crisp-head, butterhead and leaf type), three of broccoli and one eggplant and one onion AYT were also conducted. All the trials were conducted in a randomized complete block design with four replications.

Two mechanical harvestings of snap bean trials were conducted at the Taichung DAIS. Mechanical harvesting of vegetable soybean was also conducted at the Tainan DAIS and at AVRDC. Mechanical harvesting of processing tomato was conducted at six locations.

Direct seeding and transplanting of processing tomato was evaluated for yield.

Development of Vegetable Soybean Varieties

Kaohsiung DAIS released two new vegetable soybean varieties, Kaohsiung no.2 and Kaohsiung no.3 (KS #2 and KS #3) on 10 May 1991. Kaohsiung no. 2 was a cross between Ryokkoh and Kaohsiung no.8, while the latter was a cross between Hanhung Daelip (from Korea) and Kaohsiung no.8. Both crosses were made at AVRDC in 1983. From 1983 to 1987, generation advance and selections were made at Kaohsiung DAIS. Thereafter, regional and district trials were conducted at various institutions and farmers' fields in Taiwan including AVRDC. KS #2 is similar to Ryokkoh and KS #3 is similar to Tzurunoko; however, the new varieties were higher yielding and slightly later-maturing than the older varieties. The new varieties are taller than Kaohsiung no.1 and are therefore suitable for harvesting by machine.

All six varieties recorded higher mean yield than the check KS #1 (Table 1). However, all of them were slightly later-maturing than KS #1. Color and quality (sugar) of the six entries were either comparable or better than KS #1. In the autumn 1990 trial, the graded pod yield of KVS 243 at Meilong was almost 16 t/ha while KS #1 gave 14 t/ha; at AVRDC and Sikang they only yielded 3 and 6 t/ha respectively (Table 2). The marketable yield from spring 1991 trial suggested that Taichung, Likang and Wandan are high yielding locations in that order (Table 3). The economic potential of these areas for production may be explored.

Performance of newly released AVRDC lines

On 23 April 1987, Kaohsiung DAIS released a vegetable soybean, Kaohsiung Selection 1 (KS #1), a pure line selection from Taishoshiroge, AGS 292 made at AVRDC based on its outstanding performance in PYT. In 1988, the total area planted to KS#1 was 46.6 and 55.6% of the total vegetable soybean area in spring and autumn, respectively. In 1989, the area planted was 72% and 65.1% in the spring and autumn, respectively. In spring 1990, the total area planted to KS#1 was 82.7% (Table 4). The average graded pod yield of KS#1 in autumn 1989 was 8.5–9.0 t/ha whereas in spring 1990, it was 9–10 t/ha (Table 5).

Regional and Advanced Yield Trials

Soybean. Three major factors important in selecting a line are high yield, 90–95 days maturity duration and large seed size (>14 g/100 seeds). The mean yield of all locations suggested that none of the entries was outstanding compared to KS #8 and KS #10.

Vegetable soybean. Results of these trials for vegetable soybean are discussed under the heading "Development of Vegetable Soybean Varieties" and are given in Tables 1, 2 and 3.

Mungbean. The objectives of mungbean breeding in Taiwan are 1) stable high yield, 2) dull seeds, 3) more than 60 g for 1000 seeds, 4) uniform maturity for mechanical harvest, 5) resistance to CLS and PM,

Table 1. Yield and horticultural characters of entries in the Taiwan vegetable soybean regional yield trials in summer 1990.

Entry	Marketable yield (t/ha)	Total plant yield	Pod no./ 500 g	Days to maturity	Color
KVS 2	6.5	20.6	233	87	3.1
KVS 39	7.8	23.9	226	91	3.0
KVS 124	8.5	23.9	213	91	3.1
KVS 169	7.8	27.1	227	94	2.3
GC 83006-7	7.1	19.6	212	78	2.2
GC 83008-16	5.8	23.1	234	93	2.3
KS 1	5.7	16.1	189	75	2.4
205	6.5	20.0	219	87	3.1
Ryokkoh	5.3	17.2	199	75	2.1

Table 2. Yield of entries in the Taiwan vegetable soybean regional yield trials in autumn 1990.

Entry	Marketable pod yield (t/ha)				Total plant yield (t/ha)			
	AVRDC	Meilong	Sikang	Mean	AVRDC	Meilong	Sikang	Mean
KVS 243	3.0	15.7	6.7	8.5	11.1	22.9	13.9	15.9
KVS 245	1.3	13.7	6.4	7.1	6.6	30.4	16.7	17.9
KVS 226	1.7	12.5	6.8	6.9	8.7	22.8	14.8	15.5
KVS 251	1.6	13.0	6.7	7.1	8.7	22.6	13.6	14.9
Shirofumi	0.8	11.5	5.9	6.1	6.2	21.4	10.3	12.6
GC 84136-P-4-1-8	1.7	14.2	5.0	6.9	8.7	32.1	17.4	19.4
GC 83006-25-B-B	1.5	8.3	5.9	5.2	9.0	31.3	17.1	19.1
Blue Side	1.1	12.6	4.9	6.2	6.9	27.7	13.4	16.0
KS #1	2.7	14.0	6.5	7.7	11.1	25.9	13.8	16.9
Ryokkoh	2.0	13.2	5.7	6.9	9.0	27.2	17.4	17.9

Table 3. Marketable pod yield of entries in the Taiwan Vegetable soybean regional yield trial in spring 1991.

Entry	Marketable pod yield (t/ha)							
	AVRDC	Li-kang	Wan-dan	Tai-nan	Tai-chung	Tao-yuan	Hua-lien	Mean
KVS 243	5.3	8.2	8.2	5.1	11.4	4.7	5.8	6.9
KVS 245	5.8	4.9	5.5	3.0	10.6	6.4	3.6	5.7
KVS 226	5.3	7.0	8.3	4.7	8.2	4.0	5.2	6.1
KVS 251	5.5	7.9	7.2	5.6	7.8	4.1	4.7	6.1
Shirofumi	3.6	5.3	6.5	4.9	10.0	4.1	5.0	5.6
GC 84136-P-4-1-8	5.2	6.8	6.8	6.2	11.5	6.9	7.6	7.3
GC 83006-25-B-B	5.4	5.5	5.9	3.6	9.1	6.9	5.0	5.7
Blue Side	1.9	6.4	4.5	3.3	10.9	4.3	3.3	4.9
KS #1	5.6	9.7	7.9	4.7	11.5	7.2	6.1	7.5
Ryokkoh	4.5	6.1	6.5	3.6	11.8	5.3	3.6	5.9

Table 4. Vegetable soybean production area, amount and value in Taiwan.

Year/season	Area (ha)			Amount (t)			Value (US$)		
	Total area	KS #1	%	Total production	KS #1	%	Total value (NT$)	KS #1	%
1988 spring	3,895.5	1,814.6	46.6	26,869.2	15,423.8	57.4	22,570	12,955	57.4
1988 autumn	3,783.0	2,103.9	55.6	24,595.7	16,200.2	65.9	17,710	11,664	65.9
1989 spring	3,238.3	2,330.0	72.0	24,800.6	19,805.3	79.9	20,832	16,636	79.9
1989 autumn	4,024.8	2,619.7	65.1	27,197.3	20,172.0	74.2	23,933	17,751	74.2
1990 spring	5,091.9	4,208.9	82.7	40,632.1	35,775.6	88.0	35,756	31,482	

Remarks: Yield estimation (t/ha); Spring: KS #1—8.5; Spring: others—5.5; Autumn: KS#1—7.7; Autumn: others—5.0
(Source: Asia Frozen Food Company, Mr. Hwang)

Table 5. Yield comparison between vegetable soybean, KS #1 and other varieties (t/ha).

Company name	KS #1		Other varieties[a]	
	1989 autumn	1990 spring	1989 autumn	1990 spring
Asia Co.	8.5–9.0	9.0–10.0	5.5–6.5	6.0–7.0
Nong An Co.	8.5	9.0–10.0	8.0 (Ryokkoh)	7.0 (Ryokkoh)
Shin Mei Co.	9.0	9.0	-	-

[a]Other varieties: 205 and Ryokkoh etc.
Source: Kaohsiung DAIS—13 March 1991.

and 6) early maturity. In summer 1990, although there were no significant differences between varieties at AVRDC, at all other locations varietal differences were significant. VC 3945A was significantly higher yielding than the check Tainan No.5 in Tainan, Tungshan and Putzu. VC 4176A was the highest yielder in Yenshui. At AVRDC the yields were higher in spring 1991 and VC 3300A appeared to be stable across locations; VC 4152A and VC 3300A had a 1000-seed weight of 65 g which was quite acceptable in the Taiwan market.

Processing tomato. High stable yield, heat tolerance to extend the production period and high quality are the requirements for Taiwan. Mechanical harvesting is now attempted due to shortage of labor in Chianan area. During the late summer planting, AVRDC's PT lines 4121 and 4225 gave 76 to 109t/ha in AVRDC; Chiku and Tungshih (where PT 4225 was the highest yielder). In autumn, PT 4225 was equally high yielding at AVRDC and Chiku, whereas PT 4446, PT 4433 and PT 4455 gave more than 80 t/ha in Tung shih and was comparable to Oval red.

Fresh market tomato. All the new breeding lines evaluated had yields similar to Taichung ASVEG No. 4. However, FMTT 277 and FMTT 304 had a fruit size of 172 g and 162 g/fruit compared to Taichung ASVEG No. 4.

Cherry tomato. Season's Red gave significantly higher yield than all the other entries in all four locations in autumn 1990 trials. All AVRDC lines had smaller fruits, higher brix and sugar-acid ratio. Spring trials were damaged by heavy rain and as a result, the crop was harvested only three times. AVRDC lines CHT 104, CHT 261 and CHT 264 appeared to be as good as Season's Red. AVRDC lines were superior to Season's Red for most of the horticultural characteristics.

Chinese cabbage. In autumn 1990, four AVRDC hybrids were evaluated in four locations. Hybrid 86187 was the highest yielder with 53 t/ha in Sichou compared to 36 t/ha for Taoyuan ASVEG No. 2. The head weight was also larger than the check.

Sweet potato. This is the last year for sweet potato regional yield trials in which AVRDC will participate. Most of AVRDC's germplasm (1395 clones) has been transferred to Chiayi, TARI. In summer, AVRDC had three entries in the RYT. Entries C75-122, C75-150 and TY No. 1 were highest yielders across four locations. In Kingshan, Penghu and Taoyuan, they were superior to both checks TN66 and TN57.

Lettuce. Ten crisp-head lettuce varieties were evaluated in summer and autumn 1990 and spring 1991 at AVRDC. Yield during summer was quite low. Early S-26 yielded 12.5 t/ha and the second best were Martha and Kaiser with 7 and 6.5 t/ha. respectively (Table 6). In the autumn (the favorable season) trial, four varieties, Alper, Mikado Great 4304, Summer Gold and Georgia gave a head yield of about 24 t/ha. (Table 7). In spring 1991, Summer Gold gave a record head yield of 29.5t/ha. Top mark, Martha, Three Lakes, Early S-25 and Early S-26 were the next best with 23 to 24t/ha. (Table 8).

Of the seven butterhead type lettuce evaluated in summer, Summer Green was the best with a yield of 20.2 t/ha. Butter Crunch, Okayama Salad and White Boston were the next best entries (Table 9). In autumn, Margarita recorded 26.7t/ha. followed by White Boston, Emilia and Butter Crunch (Table 10). Margarita, Emilia and Butter Crunch were again best with 19–21 t/ha in spring 1991 (Table 11). Therefore, Emilia, Butter Crunch and Summer Green are good varieties to grow in Taiwan.

Among the four leaf lettuce tried, Black-Seeded Simpson produced 17.2 t/ha in summer (Table 12) whereas in autumn and spring no significant differences between varieties were recorded (Table 13, 14). Therefore, Black-Seeded Simpson could be used for all seasons.

Table 6. Yield and horticultural characters of crisp head type lettuce varieties in advanced yield trial in AVRDC, summer 1990.

Acc No	Entry	Days to maturity	Yield (t/ha) Total
15	Sunny lakes	39.5	18.7bcd
34	Martha	46.8	23.8abc
93	Kaiser	49.8	28.4a
Alper	33.0	13.0d	
107	Mikado great 4304	44.8	26.9ab
108	Three lakes Mc	37.8	23 8abc
109	Top mark	39.5	16.9cd
110	Early S-25	42.0	24.2abc
111	Early S-26	56.0	26.5 ab
76	Summer gold	45.0	21.2 abcd
LSD (0.05)		5.7	9.1

Date sown: 10 August 1990, Date planted: 14 September 1990; Date harvested: 1 October–9 Nobember 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 7. Yield and horticultural characters of crisp-head type lettuce entries in advanced yield trial in AVRDC, autumn 1990.

Acc. No.	Entry	Days to maturity	Yield (t/ha) Total	Head
15	Sunny lakes	67	67.3	23.0abc
34	Martha	62	48.0	21.4d
93	Kaiser	60	49.0	21.9cd
94	Alper	62	62.9	23.6a
107	Mikado great 4304	64	62.4	23.7a
108	Three lakes Mc.	64	63.7	23.4ab
109	Top mark	62	57.2	21.8cd
110	Early S-25	64	47.3	21.3d
111	Early S-26	54	49.5	22.0bcd
76	Summer gold	60	59.2	23.9a
86	Georgia	62	65.3	23.4a
LSD (0.05)		n.s.	11.7	1.4

Date sown: 5 October1990; Date planted: 6 November 1990; Date harvested: 4–17 January 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 8. Yield and horticultural characters of crisp-head type lettuce entries in advanced yield trial in AVRDC, spring 1991.

Acc No.	Entry	Days to maturity	Yield (t/ha) Total plant	Head
15	Sunny lakes	53	45.0	12.3d
34	Martha	45	33.3	23.1b
93	Kaisor	45	32.3	21.0bc
94	Alper	53	44.5	12.8d
107	Mikado great 4304	51	49.9	15.6cd
108	Three lakes Mc	47	50.2	22.2b
109	Top mark	51	42.3	24.4ab
110	Early S-25	45	31.8	21.7b
111	Early S-26	49	43.7	22.6b
76	Summer gold	46	49.6	29.5a
LSD (0.05)		4.3	5.6	6.0

Date sown: 11 March 1991; Date planted: 9 April 1991; Date harvested: 22–31 May 1991.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Broccoli. In summer crop sown in August, Toro CT21 and Stolto matured in 50 days and gave a head yield of 8 t/ha while Dandy Early matured in 53 days and yielded 8.8 t/ha. The head weight of Dandy Early was the highest (456 g) (Table 15). Dandy Early was the highest yielder in autumn with 13.4 t/ha and a head weight of 528 g; it matured in 54 days (Table 16). Stolto was equally good with 12.2 t/ha in 53 days with a head weight of 481 g. In spring, BR #5 was the best with 8 .4 t/ha and head weight of 354 g maturing in 60 days (Table 17). Dandy Early with 7.1 t/ha and 314 g head weight is not significantly different from BR #5. Therefore for all three seasons, Dandy Early was the best.

Eggplant. Four varieties, Fontana, Terong unganbulat, F-100 and Nite King gave a yield of 44–47 t/ha compared to Farmer's Long 39 t/ha. Among them, Fontana was the earliest to mature (130 days) while

Table 9. Yield and horticultural characters of butterhead type lettuce entries in advanced yield trial in AVRDC, summer 1990.

Acc No	Entry	Days to maturity	Total plant yield (t/ha)
4	Summer green	33.8	20 2 a
17	Tagus	31.5	13.3 c
78	Butter crunch	34.0	20.0 ab
103	Okayama salad	38 5	18.4 abc
64	Brasil 221	23.0	6.3 d
37	White Boston	41.3	17.6 abc
104	Malgarita	30.8	14 7 bc
LSD (0.05)		6.4	5.3

Date sown: 10 August 1990
Date planted: 14 September 1990
Date harvested: 29 September–22 October 1990
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 10. Yield and horticultural characters of butterhead type lettuce entries in advanced yield trial in AVRDC, autumn 1990.

Acc. No.	Entry	Days to maturity	Total plant yield (t/ha)	Head yield (t/ha)
105	Ueahedu	49	36.2	15.9 c
35	Emilia	51	41.2	21.3 b
78	Butter crunch	49	39.8	20.5 b
103	Okayama salad	56	33 0	16.0 c
64	Brasil 221	48	41.0	11.0 d
37	White Boston	51	50.6	22.0 b
104	Malgarita	56	50.4	26.7 a
LSD (0.05)		5.4	6.0	3.5

Date sown: 5 October 1990; Date planted. 6 November 1990
Date harvested: 13 December 1990–2 January 1991
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 11. Yield and horticultural characters of butterhead type lettuce entries in advanced yield trial in AVRDC, spring 1990.

Acc No	Entry	Days to maturity	Total plant yield (t/ha)	Head yield (t/ha)
105	Ueahedu	39.0	30.4	3.3 c
35	Emilia	38.5	32.2	21.0a
78	Butter crunch	39.0	18.8 a	
103	Okayama salad	39.0	36.3	5.7 c
64	Brasil 221	35.5	31.4	1.5 c
37	White Boston	39.0	35.2	11.3 b
104	Malgarita	39.0	35.2	11.3 b
LSD (0.05)		NS	NS	5.5

Date sown: 11 March 1991.
Date planted: 9 April 1991.
Date harvested: 10–22 May 1991.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 12. Yield and horticultural characters of leaf lettuce entries in advanced yield trial in AVRDC, summer 1990.

Acc No.	Entry	Days to maturity	Total plant wt (t/ha)
2	Grand rapid	30.5	11.5 b
20	Green wave	31.5	12.0 b
21	Black Seeded Simpson	34.0	17.2 a
80	Simpson's curled	34.0	15.4 ab
LSD (0.05)		NS	4.2

Date sown: 10 August 1990 Date planted: 14 September 1990. Date harvested: 1–22 October 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 13. Yield and horticultural characters of leaf lettuce entries in advanced yield trial in AVRDC, autumn 1990.

Acc No	Entry	Days to maturity	Total plant yield (t/ha)
2	Grand rapid	40	26.7
20	Green wave	43	29.6
21	Black Seeded Simpson	46	30.0
22	Grand Rapid H-54	46	31.3
80	Simpson's curled	41	34.7
LSD (0.05)		NS	NS

Date sown: 5 October 1990.,Date planted: 6 November 1990.
Date harvested: 10 December 1990–2 January 1991.

Table 14. Yield and horticultural characters of leaf lettuce entries in advanced yield trial in AVRDC, spring 1991.

Acc No	Entry	Days to maturity	Total plant yield (t/ha)
2	Grand rapid	34 7	25.1
20	Green wave	35.9	29.9
21	Black Seeded Simpson	35.7	35.7
22	Grand rapid H-54	35.6	31.1
80	Simpson's curled	35.2	33.0
LSD (0.05)		NS	NS

Date sown: 11 March 1991. Date planted: 9 April 1991. Date harvested: 10–17 May 1991.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 15. Yield and horticultural characters of broccoli entries in advanced yield trial in AVRDC, summer 1990.

Acc. No.	Entry	Days to maturity	Total plant yield (t/ha)	Head yield (t/ha)	Mean head wt (g)
14	No. 441	53.5	22.6	7.5 bc	418
18	Dandy Early	53.5	26.6	8.8 a	456
21	Toro CT 21	50.0	27.0	8.2 ab	432
28	Stolto	50.0	28.4	8.2 ab	408
32	BR # 13	57.0	29.2	6.6 d	
33	BR # 5	53.5	31 3	7.2 cd	366
40	YS 6163	50.0	27.4	7.8 bc	
42	Ultra Green	55.3	27.1	7.4 bcd	
49	Green King	58.3	32.8	7.9 bc	404
LSD (0.05)		5.55	4.26	0.8	43.6

Date sown: 15 August 1990. Date planted: 27 September 1990. Date harvested: 8–29 November 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 16. Yield and horticultural characters of broccoli entries in advanced yield trial in AVRDC, autumn 1990.

Acc. No.	Entry	Days to maturity	Total plant yield (t/ha)	Head yield (t/ha)	Mean head wt (g)
14	No. 441	54	37.9	12 1 ab	487
18	Dandy Early	54	45.1	13.4 a	528
21	Toro CT 21	53	41.1	11 5 bc	443
28	Stolto	53	41.7	12 2 ab	481
32	BR #13	56	42 2	10.1 c	397
33	BR #5	56	45.5	11.1 bc	443
40	YS 6163	53	41.1	11.7 bc	464
42	Ultra Green	57	48.4	11.2 bc	432
49 Green	King	56	46 2	11 1 bc	449
LSD (0.05)		1.8	NS	1.7	53.5

Date sown: 20 September 1990 Date planted: 12 October 1990. Date harvested: 3-13 December 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 17. Yield and horticultural characters of broccoli entries in advanced yield trial in AVRDC, spring 1991.

Acc No	Entry	Days to maturity	Total plant yield (t/ha)	Head yield (t/ha)	Mean head wt (g)
14	No. 441	63	16.7	6.1 cd	266
18	Dandy Early	62	18.0	7.1 abc	314
21	Toro CT 21	58	19.0	5.7 d	291
28	Stolto	53	22.4	6.4 bcd	306
32	BR #13	60	26.4	7.7 ab	296
33	BR #5	60	30.7	8.4 a	354
40	YS 6163	62	23.1	6.8 bcd	293
11	Sprinter	64	26.4	7 6 ab	312
49	Green King	60	26.9	7.4 abc	325
LSD (0.05)		3.5	5.5	1.3	NS

Date sown: 6 March 1991. Date planted: 3 April 1991. Date harvested: 24 May–4 June 1991.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Farmer's Long matured in 135 days. Long-fruit varieties appeared to be low yielders. The short- and fat-fruit varieties were the highest yielders (Table 18).

Onion. Compared to Tainan #1 and Tainan #3 which gave yields of 53 t/ha in 131 days with a brix of 11–12 and a bulb size of 270 g, several entries gave a yield of 90–109 t/ha. Henry's Special P R 38005/R711 PR gave 90 t/ha in 126 days and the bulb was 335 g but the brix was only 7.3. Only one entry had a brix of 11.5 which matured in 138 days and produced 94.5 t/ha with a bulb size of 417g (Table 19). The potential of some of these varieties for the market needs to be explored.

Seed Production and Distribution for Evaluation of Promising AVRDC Lines

ROC national programs organized trials of newly released AVRDC lines to demonstrate their yield potential under farmers field conditions. AVRDC multiplied and distributed 4142 kg of breeder seed materials for six different crops during 1991 (Table 20).

Table 18. Yield and horticultural characters of eggplant entries in an advanced yield trial in AVRDC, spring 1990.

Acc No.	Entry	Days to maturity	Yield (t/ha)	Fruit size (g)	Fruit length (cm)	Fruit width (cm)
1	Onita	158	11.0 e	88	17.1	4.3
5	Terong Unganbulat	146	47.2 a	114	8.7	8.3
8	Fontana	130	44.7 a	216	13.8	11.0
11	CT cha Praya	153	18.6 de	27	8.1	8.2
12	Florida Market	164	27.0 bcde	156	12.1	9.3
13	Black Beauty	136	43.3 ab	125	12.0	6.4
19	Solara	152	10.0 e	25	5.3	5.4
22	MA 83004	129	22.7 cde	97	16.1	6.6
25	F 100	143	45.3 a	214	14.6	7.8
26	Nite King	141	44.2 a	219	10.4	9.2
28	Easter Egg	114	23.1 cde	57	7.7	7.2
31	Masu Eggplant	135	23.2 cde	60	28.1	3.8
32	Pingtung Long	136	25.5 cde	90	23.4	4.0
33	Birde	141	35 2 abcd	67	18.7	4.3
34	Farmer's Long	135	38.8 abc	62	22.1	3.8
LSD (0.05)		NS	7.[illegible]	53	3.0	2.4

Date sown: 23 April 1990. Date planted: 1 June 1990 Date harvested: 27 July–27 October 1990.
Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 19. Yield and horticultural characters of selected entries in the onion advanced yield trial in AVRDC autumn 1990.

Acc No	Entry	Marketable yield (t/ha)	Total yield (t/ha)	Days to maturity	Mean marketable bulb size (g)	Bulb diam (cm)	Neck size (cm)	Firm-ness	Brix	Postharvest treatment (after 4 months)	
										% Sprout	% Rots
27	XPH 3325	94.5bc	96.7	138	417	8.9	1.0	4.0	11.5	2.6	28.8
41	Granex PRR	94.2bc	96.1	129	374	9.4	0.8	3.6	9.2	12.7	12.9
53	4-LG 7-3	66.8ab	68.5	143	284	9.1	1.4	3.2	11.0	3.6	33.1
59	Gold Rush 38051/A4452	60.3hi	61.2	126	286	8.0	1.0	3.7	11.2	0	38.9
61	Tainan #1	53.01	53.6	131	248	8.6	0.95	3.8	11.8	8.4	18.4
62	Tainan #3	52.51	52.9	131	273	8.5	0.9	3.6	11.10	0	14.6
LSD (0.05)		11.8	11.8	3.3	57.2	1.26	0.2	0.4	2 5	17.2	20.3

Date sown: 11 September 1990
Date transplanted: 30 October 1990
Date harvested: 4–18 March 1991.

Table 20. Amount of seeds of released and prereleased promising AVRDC lines in Taiwan, 1991.

Crops	Entry	Seeds amount (kg)
Soybean	Tainan Sel. No. 1	1591
	Kaohsiung Sel. No. 10	1850
Vegetable soybean	Kaohsiung Sel. No. 1	120
Mungbean Tainan No. 5	560	
Chinese cabbage	Taoyuan ASVEG No.	0.3
Processing tomato	PT 4225	19.4
Fresh market tomato	FMTT 3 (Hualien ASVEG No. 5)	0.5
	FMTT 22 (Taichung ASVEG No. 4)	0.5

AVRDC-Korea Outreach Program

Development of Nondestructive Methods of Screening for Resistance to Major Diseases in Pepper

The utilization of detached leaves for screening for bacterial leaf spot resistance in pepper was reported in 1990. In 1991, the objective was to develop screening methods for resistance to Phytophthora blight and anthracnose without creating significant damage to the tested plants.

For Phytophthora blight, two different methods of screening were tried and compared with the conventional one—drenching the inoculum at seedling stage. For the first method, 10 cm vermiculite and perlite in the ratio of 7:3 was used, and immediately drenched with the inoculum as in the conventional method. For the second method, 10-cm long top shoots were positioned in the cavity of silicon plugs. The holes of a plastic pipeline where tap water flows were plugged so that the lower end of the shoot could be kept in constant contact with fresh water. The shoots were wounded with a razor blade and the wound was covered with cotton moistened with the regular inoculum (about 1.0 ml). The cotton was taped in place.

The results are shown in Table 1. In the conventional method two entries, Dahong and Putgochu were shown to have susceptible reaction and the other four were resistant. In the cutting-on-flowing-water method, two additional genotypes, S-7-7 and Kimjang, were classified as susceptible. Furthermore, PI 201234 showed a susceptible reaction in the cutting-on-medium method so that only CM331 was left in the resistant group. Time from inoculation to full development of disease was shortened from 15 days using the conventional method to 7–11 days when detached top shoots were used. Both new methods could replace conventional drenching as a method of screening without killing the test plants of susceptible genotypes. However, higher selection pressure needed to be applied. It was also noted that the cutting-on-medium method sometimes failed to produce consistent results for the same host genotypes in the repeated trials.

For anthracnose, high-pressure spray of inoculum on the skin of detached fruits with different levels of fruit age and spore density in the inoculum was tried. The pressure used was 0.5 kg/cm^2. The disease severity of various varieties as affected by fruit age and spore concentration is shown in Table 1. The spore density of 10^7/ml seemed to best differentiate the diverse genotypic resistance levels. But the reaction of the same genotype was sometimes quite different from one fruit age to another, as expected from the significant interaction of fruit age with variety (Table 2). This means that resistance to anthracnose identified at one fruit age may have to be confirmed at other ages.

New Resistant Sources for Major Diseases of Pepper

Some 183, 14, 59, and 55 accessions were evaluated in the search for new materials resistant to Phytophthora blight, anthracnose, bacterial leaf spot and viral disease, respectively. For the first three, parasitic organisms were artificially inoculated, while virus reaction was investigated under natural epiphytotic conditions.

In the Phytophthora screening, two virulent isolates, T49 and E95, of *Phytophthora capsici* were drenched at the spore density of 10^5/ml to the six-leaf seedlings growing in the polythene pots. For anthracnose, *Colletotrichum gloeosporioides*, Strain G was used as the inoculum source. Inoculum contained 10^7 spores/ml and was sprayed on the skin of 5-week old fruits with a pressure of 0.5 kg/cm. Races 1 and 3, the only known races present in Korea, were used as inoculum sources for bacterial leaf spot. Inoculum was adjusted

Table 1. Disease score of different varieties high pressure-inoculated with *Colletotrichum gloeosporioides* as affected by spore concentration and fruit age.

Entry	Spore concentration (spores/ml)	Fruit age (weeks) 3	5	7	9
PI 260549	10^5	1.0	1.0	1.0	1.00
	10^6	1.2	1.0	1.0	5.0
	10^7	1.4	1.0	1.0	2.0
Unknown	10^5	1.0	1.0	1.0	2.7
(*C. baccatum*)	10^6	1.0	1.0	1.0	4.71
	10^7	1.8	1.3	1.3	5.3
CO 265	10^5	2.8	2.8	2.1	6.0
	10^6	4.8	6.3	4.0	6.0
	10^7	5.9	7.0	3.2	4.0
Choktoma	10^5	1.4	1.2	2.5	2.09
	10^6	4.3	2.4	3.1	2.5
	10^7	5.0	4.0	4.0	3.0
Taean	10^5	3.8	1.5	2.8	1.9
	10^6	8.3	4.1	4.0	2.3
	10^7	7.6	4.1	5.6	2.3
Long Fruit	10^5	3.4	4.3	4.1	2.0
	10^6	6.3	6.0	6.8	5.0
	10^7	6.2	8.4	6.8	7.0
CO 1654	10^5	3.4	2.4	5.5	2.0
	10^6	6.3	4.6	2.5	4.0
	10^7	6.5	4.1	3.0	7.7

Degree of infection: 1 (none)–9 (severe)

Table 2. Analysis of variance.

Factor	d.f.	SS	MS	F (E)	F (age × conc. × var.)
Total	251	1237.3			
Fruit age	3	18.1	6.0	12.3	1.6 ns
Inoculum conc.	2	166.0	83.0	169.4	21.4
Var.	6	519.1	86.5	176.6	22.3
Age × conc.	6	31.3	5.2	10.6	1.4 ns
Age × Var.	18	224.3	12.5	25.4	3.2
Conc. × Var.	12	56.6	4.7	9.6	1.2 ns
Age × Conc. × Var.	36	139.5	3.9	7.9	
Error	168	82.3	0.5		

at densities of 10^5 and 10^8 CFE/ml and was allowed to infiltrate fully expanded leaves previoulsly detached, and then placed on the pipeline in which fresh tap water was flowing. For each disease, the standard check sets including different levels of resistance were included together.

Fifteen and two accessions were newly found to be resistant to Phytophthora blight and anthracnose, respectively (Table 3). No new accessions showed resistant reaction to bacterial leaf spot. Five accessions were rated as mildly resistant to virus disease under field conditions. Two phytophthora-resistant accessions showed relatively high levels of tolerance also to both virus and bacterial leaf spot.

Table 3. Disease reaction of accessions newly identified as resistant to any of four major diseases.

Entry	Accession	Reaction[a] to			
		Phytophthora	BLS	Anthracnose	Viral complex
0002	KC 6	R	MS	M	MS
6503	Szechuan	R	MS	S	MS
6513	Chain Fair	R	MS	M	S
6516	Magic Scarlet	R	MS	MS	S
6521	LV. 1583	R	MR	MR	MS
3504	Keystone × Malaysian	R	MR	S	MR
3515	Mulato Rct Purple	R	MS	M	MS
3518	Chile	R	MS	MS	MS
3523	Criollo	R	MS	M	S
3531	S-7-7	R	MS	MS	MR
3532	S20-1	R	MR	S	MR
5001	Halapeno	R	S	S	S
5002	Piquin	R	S	S	MS
6529	Var. P. Sakaraho	S	MR	R	MS
3521	Unknown	S	MS	R	MS
3527	Unknown	S	MS	M	MR
3534	C00595	S	MR	MR	MR

[a]Reaction was rated from artificial inoculation, except for that to viral complex where disease was scored under natural epiphytotic conditions.

INTHOPE Trial in Suwon[a]

Thirty INTHOPE pepper entries with three local checks were sown on a hot bed on 20 February 1990 and the seedlings were planted to polyethylene film pots (12 cm in diameter) placed on a hot bed. On 15 May, seedlings were transplanted in the field and mulched with black high-density polyethylene film of 0.02 mm thickness. Plants were staked and supported with strings connecting the stakes. Distance between beds was 150 cm from center to center and each bed had two rows. Distance between plants on rows was 40 cm. Field layout followed randomized complete block design with three replicates and 12 plants per plot.

Korean entries such as Hot Long were the earliest in fruit setting among all the entries included in the trial. Keriting and Huaruar showed the highest yield level. Punjab, LV2323 and LV2319 were preselected for their concentrated maturity and will be further evaluated on their usefulness in breeding for nonstaking cultivation and once-over harvest. Pungency, color and other quality/preference characters will be later analyzed with the samples already prepared.

Trials with AVRDC Cherry Tomatoes

Sixteen hybrids and inbreds were evaluated together with six local and 16 foreign commercial varieties to search for cherry tomato seeds that could replace the imported seeds. Seeds were sown on 5 March 1991 and planted to polyethylene pots (12 cm diameter) placed on a hot bed. Seedlings were transplanted to the open field and rain-sheltered fields on 10 May. Spacing was 0.9 m between plants within rows. Plots, each consisting of 12 and 5 plants in the open and rain-sheltered fields, respectively, were laid out in an RCBD with two replicates. Plants were staked with bamboo sticks and additionally supported by strings connecting the sticks. Fertilization followed the Horticultural Experiment Station (HES) standard for regular table tomato, but with two-thirds of the standard amount. Harvesting began on 10 July and the last harvest was on 11 September and 8 October in the open field and rain-sheltered trial, respectively.

[a]Detailed trial data are available from AVRDC.

Twenty-four entries had optimum fruit size ranging from 14 to 20 g. Yield from the two trials were highly correlated with each other. Some AVRDC hybrids with optimal fruit size, such as CHT 266, showed high yield in both trials (Table 4). Two AVRDC hybrids, CHT 224 and CHT 266, and an inbred line, CHT14-17C16-1-0, were comparable to the most popular imported hybrids in the scores obtained from the panel tests (Table 5).

Table 4. Horticultural characteristics of selected entries of cherry tomato.

Entry no.	Variety (combi)	Unit fruit wt (g)	Days to flowering	No fruit set /cluster	Days for coloration /cluster	PH	Soluble solids (°Brix)	Yield (MT/ha) Open field	Yield (MT/ha) Rain shelter
501	CHT224(F_1)	17 a-d	38	19 d-i	28 a-d	6.3 a-f	8.1 a-h	37.3 a-g	37.1 a-c
502	CHT266(F_1)	19 a-d	51	19 d-i	24 a-e	5.7 c-j	7.3 c-h	50.2 ab	50.9 a
503	CHT268(F_1)	14 a-d	80	18 d-i	28 a-e	5.8 c-j	8.7 a-g	46.3 a-c	42.7 a-c
517	Ruby	7 c-d	32	11 f-i	25 a-e	6.2 b-i	5 1 h	39.3 a-f	13.2 bc
520	Popo	24 a-c	75	4 d-i	26 a-c	5 2 f-k	9 1 a-f	44.6 a-e	47 0 ab
528	Mini Carol	9 b-d	70	72 b	30 a-d	7.6 a	8.9 a-f	51 2 ab	32.5 a-c
546	Pepe	9 a-d	115	45 a	35 a-b	6.9 a-c	6.9 c-f	42 0 a-e	26.0 a-c

Numbers having the same letter designations are not significantly different at 5% by DMRT

Table 5. Panel test results* for some selected cherry tomato entries.

Entry	Color	Size	Skin texture	Taste	Shape	Overall
CHT 224 (F_1)	2.7	3.9	3.2	2 9	4.1	3.4
CHT 266 (F_1)	3.2	3.7	3.7	2.1	3 6	3.3
CHT14-17C16-1-0	3.7	3.6	3 2	2.3	4.1	3.4
Ruby	2.3	3.9	2.7	2.3	3.7	3 1
Popo	3.6	2.6	3 4	2.1	3 3	3.0
Mini Carol	3.6	3.9	3.2	2.7	4.2	3.5
Sugar Pearl	3.0	3.4	4.8	2.2	3.6	3.4
Pepe	2.8	2.6	3.0	3.6	4.0	3 2
Chelseamini	3.2	2.4	3.0	2.4	3.8	3.0
Sugar Lump	2.2	3.3	3.6	1.9	2.8	2.7
Yellow Pico	3.6	3.9	3.1	1.4	3.7	3.1

*1 (poor)–5 (excellent)

The same set of materials was tested in two other locations, Choonchon (lowland) and Hoengsong (elevation 550 m), through the kindness of Mr. K.K. Lee, Chief of Economic Crops Division, Kangwon Provincial Rural Development Administration. As shown in Tables 6 and 7, CHT 266 and a few other AVRDC entries were comparable to popular imported cultivars such as Minim Carol and Pepe in yield in both trial sites.

Population Breeding of Chinese Cabbage for TuMV Resistance

In 1990, 156 adult plants without virus symptoms were selected from an F_2 generation of seven combinations between virus-resistant parent O-2, and some HES breeding lines. Of these, 102 plants survived winter and were self-pollinated in spring 1991. Since it is known that the genetic resistance to TuMV strains C_4 and C_5 is controlled by two recessive genes, attempts were made to fix those genes by culturing anthers from the F_1 plants of the combinations. Forty-five families produced a large amount of seeds, enough to meet the needs of family evaluation. They were planted in the fall and inoculated with virus mixture collected from different places in the country by the carborundum method. Eleven families with very low virus infection or without virus infection were selected and 67 plants were finally chosen from those families for their superior horticultural characteristics in addition to absence of virus disease symptoms.

Table 6. Performance of some selected cherry tomato entries grown in Choonchon.

Entry	No. fruits harvested/plant	Yield (t/ha)			Overall score
		Total (A)	Commercial (B)	B/A (%)	
CHT 266	143	65.7	31.7	60.5	5
CHT 268	145	64.4	41.1	63.6	6
CHT 289	138	65.3	42.7	65.4	6
CHT 310	112	52.9	36.2	68.3	6
CHT 311	96	40.0	25.8	65.1	5
CHT312	86	33.9	20.5	60.4	6
CHT14-171C-3-18-3-0	92	36.7	18.7	51.1	5
Sugar Red	95	53.0	36.9	69.6	5
VHT 105	102	76.9	55.0	71.3	5
Mini Carol	204	64.1	36.0	56.2	6
Kumbangwul	91	41.5	17.1	41.9	2
Yellow Pico	45	19.2	13.3	69.2	3

Table 7. Performance of some selected cherry tomato entries grown in Hoengsong.

Entry	No. fruits harvested/plant	Yield (t/ha)			Overall score
		Total (A)	Commercial (B)	B/A (%)	
CHT 224	58	26.1	18.0	68.8	4
CHT 266	70	33 2	23.2	69.8	6
CHT 268	73	29.9	21.6	72.1	6
CHT 389	68	3.1	21.9	71.3	6
CHT 306	71	28.6	18.5	64.7	5
CHT 310	71	36.2	23.0	63.5	5
Sugar Red	73	38.1	24.0	62.9	6
CHT 104	63	48.9	35.0	71.6	5
CHT 105	45	34.5	25.3	73.3	4
Yellow Pico	30	14.9	13.0	87.2	4

Out of 44 anther-derived lines, only one showed resistance—much lower than the expected ratio of 1 out of every 16 lines. The bias could be caused by certain selection pressure involved with anther culture, or the presence of virus strains other than C4 and C5 in the inoculum, or both factors.

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AVRDC-Bangladesh Agricultural Research Project

Introduction

Bangladesh belongs to the humid tropical region. It has three distinct seasons. During the cool season, from November to February when the temperature varies from 11.5 to 27°C, the environmental conditions are favorable for producing temperate vegetables with irrigation. In summer, from March to May, the temperature ranges from 20 to 35°C while rainfall is minimal. June to October is the monsoon season and is characterized by floods, cyclones, high temperature and humidity. Vegetable production and marketing during the three seasons are beset with problems. The annual rainfall varies from 1194 mm to 3455 mm. Vegetable production in Bangladesh is far below requirements. To meet the daily requirement, national production must be increased at least threefold.

Collaborative research with AVRDC was first suggested by Dr. Robert Chandler, the former Director-General of AVRDC, during his visit to Bangladesh in 1974. AVRDC has maintained a technical assistance and professional cooperative relationship with the Bangladesh Agricultural Research Institute through a Memorandum of Agreement signed in 1976 with the AVRDC-Philippine Outreach Program (POP). Initially, the cooperation mainly involved technology and information flow from AVRDC to Bangladesh for use by the national agricultural research system.

The contract between BARC/Bangladesh Agricultural Research Center and AVRDC, signed in 1989, aimed to strengthen vegetable research to improve vegetable production, explore vegetable seed production potential and promote homestead gardening directed at improving the nutritional level of the Bangladesh population. This contract is supported by USAID. The AVRDC contract activities started in Bangladesh with the arrival of a Senior Horticulturist/Agronomist from AVRDC Headquarters on 18 April 1991.

There are considerable environmental similarities between Bangladesh and Taiwan. The research work done and materials developed at AVRDC can easily be adapted under Bangladesh conditions. The sweet potato variety Kamalasundari and the tomato variety Marik are two varieties which had been developed at AVRDC and which had been released by the National Seed Board in 1985.

A brief review of the work done in the last seven months of 1991 follows.

Plant Introductions

More than 260 lines/varieties of different vegetable crops from various sources (e.g. AVRDC, Thailand and India) were introduced into the country.

The new introductions carry many desirable characters including earliness, high yield, good quality, heat tolerance and resistance to diseases and insect pests. All these new lines/varieties have been given to BARI Horticulture Research Center for testing.

Tomato. A summer tomato crop was successfully grown during June-August at BARI. Two single-row preliminary observational trials at BARI, the first trial on summer tomatoes on raised beds, were completed in August. This trial was sown on 2 May 1991 and transplanted on 23 June 1991. Four lines/varieties, TM00111, TM00367 (AVRDC), TM0054 (Brazil) and Ratan (local), were used in this study. All the lines established and grew very well except Ratan which was affected by wilt. It flowered profusely but no fruit set without the hormone spray. The hormone tomatotone (para-chlorophenoxy acetic acid) was sprayed at 0.2% on the plants at the flowering stage. After 3–4 days of spray fruit setting started. The fruits were ready for harvesting just after 25 days of spraying; the first harvesting was done on 7 August and four pickings were done. The average yield per plant ranged from 760 to 940 g and the fruit weight was 50–60 g. In Bangladesh, the price of tomato during August is about Tk. 100–150 per kg (US$1.00 = Tk.36.3987). This experiment gave an average yield of about 20 t/ha. This technique can be further successfully used to raise summer tomato crops (Table 1).

Table 1. Effect of tomatotone on yield components and seed formation.

Line/Variety	Average yield/ plant (g)	Estimated yield (t/ha)	Average no. fruits/ plant	Average fruit wt. (g)
TM 00111	760	17	12	60
TM 00367	940	21	18	50
TM 0054	780	17	13	60

The second screening trial of AVRDC tomato lines for summer production was sown on 30 June and transplanted on 25 July 1991 on raised beds. Out of the 31 lines only four lines, CHT 261, CC 5915, CHT 104 (F_1), CHT 105 produced fruit. The fruit number per plant ranged from 4 to 7. Fruit setting started only in September. All the four lines were free from bacterial infection but more moderately infected with virus.

Chinese cabbage. Ten lines of Chinese cabbage were sown for observation on 26 May 1991 and transplanted on 20 June 1991. The vegetative growth of five lines was satisfactory but there was no sign of head formation. A second observational trial on nine AVRDC heat-tolerant lines and one local line was sown on 15 July 1991 and transplanted on raised beds on 15 August 1991. Three lines, 85-216, 83-20 and 62 (ASVEG) produced partial heads and very good vegetative growth. The line 77M-3/2 46 gave excellent vegetative growth. The plants became ready for harvesting just 50-55 days after transplanting in summer.

Vegetable soybean. To determine whether vegetable soybean can be grown in summer, a line introduced from AVRDC, AGS 292, was sown on 5 May 1991. In spite of heavy rains and high temperature this line grew very well. Pod formation started within 40 days of sowing; pods were ready for use as a vegetable after 65 days of sowing. The average pod number per plant recorded was 50. Seeing the success of one line, another preliminary trial on six AVRDC lines, AGS 292, G 9053, G 10134, GC 84128-9-2-1, GC 84126-13-4-4 and AGS 5292 (T), were sown on 4 July 1991. The pod formation started in 36 days. The first harvesting was done 65 days after sowing. Out of the six lines, GC 84128-9-2-1, GC 84126-13-4-4 and AGS 292 gave the best performance with an average pod number ranging from 45 to 60. It seems possible to grow two crops of vegetable soybean during summer.

Pepper. To determine performance of hot pepper in summer, 29 AVRDC lines were tested in a trial sown on 1 July and transplanted on 28 August 1991. Continuous rains delayed flowering and fruit setting and the plants started flowering only in the first week of October.

Kangkong. A varietal comparison trial on three varieties, namely, pointed leaves, broad leaves and Gima kalmi (local), was planted on 17 June 1991. Of these, Broad Leaves from Taiwan performed best in terms of yield, quality, earliness, growth duration and number of cuttings. The average yield recorded in variety Broad Leaves was 46 t/ha compared to 35.8 t for the local variety. The seed production potential is being tested.

Okra. Out of the nine okra lines sown on 17 June 1991, line OK 0285 gave the highest fruit number (18) and yield (370 g/plant). No virus symptoms were observed in this line.

Other vegetables which showed promise for summer cultivation were yard-long bean, kakrol, long melon and round melon.

Home Gardening

In Bangladesh the homestead area occupies about 5% of the total cultivated land. There are 13 million homesteads. About 80% of households have no technical knowledge about year-round vegetable gardening. This problem is aggravated by the lack of seeds of improved varieties, lack of irrigation water, and low price of seasonal vegetables.

At present, five vegetable cropping patterns with 14 vegetable crop combinations in a 6 × 6-m plot have been recommended. They are:

Radish/tomato - red amaranthus - red amaranthus - Indian spinach.
Red amaranthus - eggplant - red amaranthus - okra.
Spinach - garlic - red amaranthus - stem amaranthus - red amaranthus.
Batishak - onion - kangkong - red amaranthus

Cabbage - red amaranthus - bitter gourd - red amaranthus.

A new modified plan of the above pattern has been prepared for on-station testing to raise crop intensity to almost double and meet the total needs of the family for vitamin A, vitamin C and iron. In the new plan, home gardeners could raise their own seedlings, produce and preserve their own seeds and also plant quick-growing fruit plants like papaya, lemon, guava and banana (Fig. 1).

Research Planning

The Project participated in internal research review and annual central review meetings of the Horticulture and On-Farm Division of BARI and helped in modifying the projects. It also suggested some new programs in discussions with the scientists. Seventeen experiments on germplasm collection and evaluation were proposed, 2 on nursery technology development, 9 on varietal improvement and cultural management of solanaceous vegetables, 4 on crucifers, 8 on vegetable legumes, 18 on cucurbits, 3 on the improvement of leafy vegetables and okra, 4 on home garden development, 7 on vegetable seed production and technology and 17 on breeder's seed production and maintenance. On spices, 23 experiments have been proposed (in rabi and kharif season). Of these research programs, 29 new experiments including one on vegetable soybean and summer tomatoes have been planned this year.

Seven scientific papers were also reviewed and prepared by researchers for publication in the journals.

Different national institutes, regional research stations, homestead sites, farmer's fields and farming systems research sites were visited.

Training and Personnel Development

A five-day vegetable breeding training program on *Solanaceous* and cole crops was organized at BARI from 29 September to 3 October, 1991 for 40 participants from BARI, DAE, BAU, BINA, BADC, NGOs and Bangladesh agricultural colleges. Resource persons from AVRDC and guest scientists from BARC and USAID also attended.

The trained participants are currently part of the national pool of people who are taking lead roles in vegetable production, teaching, research and extension activities in the various national research and development programs.

Other Activities

BARC team to Chittagong region to assess cyclone damage. On 29 April 1991 a devastating cyclone accompanied by tidal bore hit the south and southeast part of Bangladesh. A large area was affected by this cyclone causing the death of many people and animals, crop infrastructures as well as research systems. From 16 to 19 May, the team visited agricultural institutions to get a firsthand account of the damage brought about by the cyclone and recommended immediate and sustained rehabilitation steps. Technologies and other inputs to the concerned sector were made available through BARC, e.g. quick-growing vegetables such as red amaranths, kangkong, Indian spinach, okra, brinjal, yard-long bean; rice seeds, particularly of the short-duration varieties; feed concentrate; fodder, such as cowpea, maize, pulses and planting materials of quick-growing fruits such as papaya, guava, lemon and banana etc.

Kangkong seed for cyclone-hit area. Some 10 kg of kangkong seeds were ordered released by the AVRDC Director General to replace some of the standing crops destroyed by the cyclone that hit Bangladesh this year. Kangkong, a sturdy, nutritious vegetable can extend a life line in distressed areas because it is quick-growing and is suitable to grow under the prevailing conditions after the cyclone. The BARI Horticulture Research Center divided the seeds into 900 packets and distributed them with information on proper cultivation to 600 farmers in Chittagong and 300 farmers in the subdistricts of Cox's Bazaar. They planted, grew and used them for their families. Areas planted to the crop had expanded and were planted with kangkong cuttings.

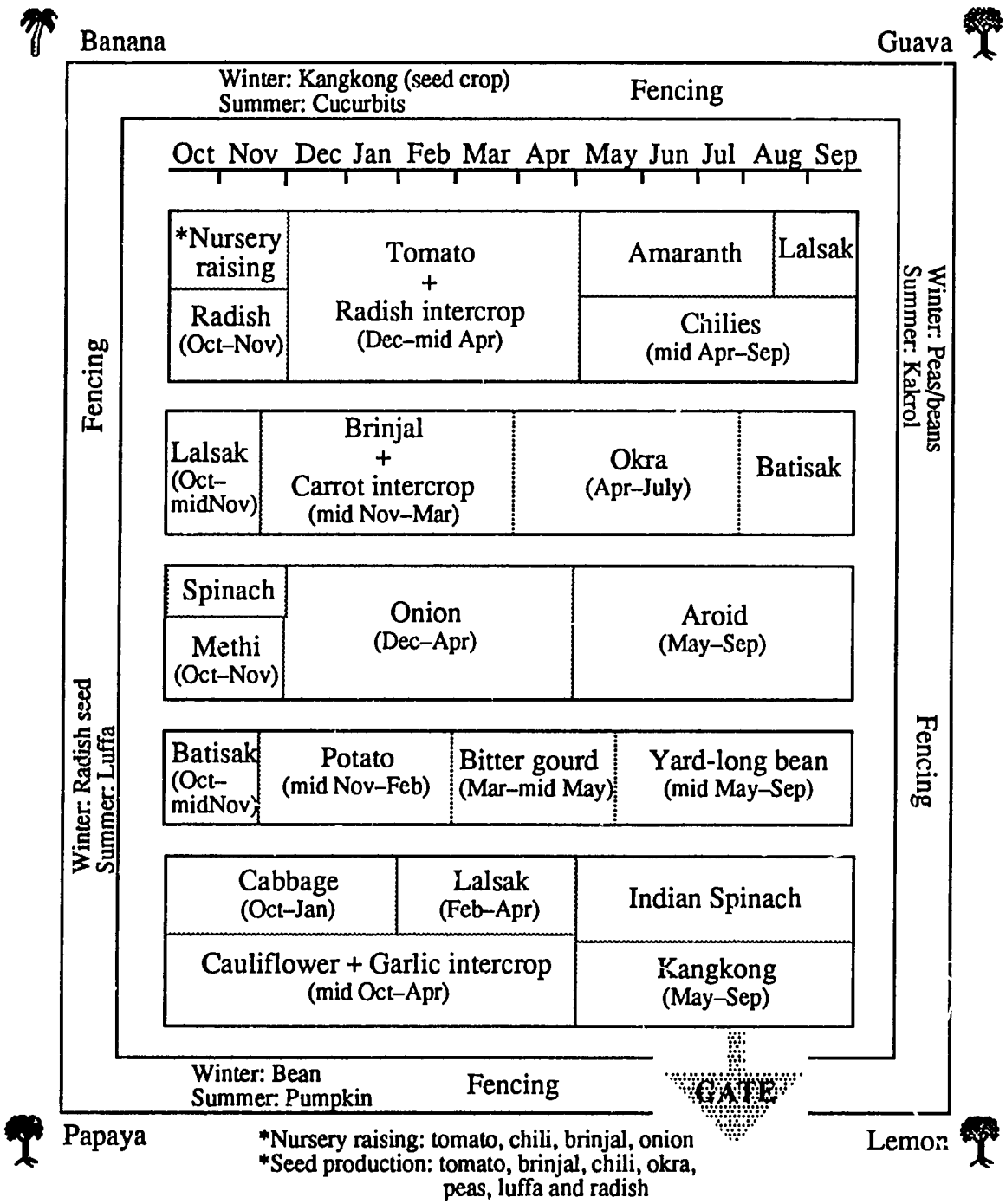

Fig. 1. Modified vegetable cropping pattern for increased crop intensity.

Regional Program

AVRDC-Thailand Outreach and Regional Training Program

Introduction

Strong research and extension capabilities are needed to backstop national vegetable production programs in every developing country. These needs prompted AVRDC to assist the NARS in the region by providing agricultural researchers and extension workers training on vegetable production, and research and development. To make this assistance readily available to all countries that did not have ready access to Taiwan where the AVRDC headquarters is located, the Asian Development Bank in cooperation with the Government of Switzerland financed the Regional Training Program in Vegetable Production. This was implemented by the AVRDC regional office in Thailand (AVRDC-TOP). The program is hosted by Kasetsart University on behalf of the Royal Thai Government. Considering the achievements from the first two phases of this regional program and the demand for more technical training from countries such as China, Vietnam, Laos, Myanmar and Cambodia among others, Technical Assistance for Phase III was again granted by the Bank in May 1991. This new assistance enabled the regional office to offer more and direct services not only to the countries in Southeast Asia and China, but also to countries in South Asia. Several international cooperative links have been forged between the countries in the region and AVRDC through AVRDC-TOP. Research is focused not only on AVRDC's mandate crops but also on crops of economic importance to Thailand such as baby corn, asparagus and cucumber. On-farm trials with direct involvement by farmers has brought the program to the mainstream of the Thai vegetable industry.

Objectives

The program's general objective is to develop a core of trained vegetable research and extension workers in developing countries in the region. Specifically the regional program aims to:

- Expand the scope of the ongoing training and outreach program (TOP) of AVRDC to include in-country training for trainers and refresher courses to strengthen the national capabilities in various developing countries around the region to conduct their own training program;
- Strengthen the existing research programs on diseases and pests which have been identified to be of significant economic importance;
- Provide supplemental equipment to optimize the utility of research/training infrastructure provided by the previous technical assistance; and
- Strengthen and expand international cooperation with developing countries in the region.

Program Activities

In addition to the regular training program, special courses, study tours, workshops and refresher courses for former AVRDC-TOP trainees as well as other national research and extension workers were conducted by the program staff in 1991. The special courses and study tours have been designed to provide national program researchers and participating farmers with the latest techniques in vegetable research and enable them to observe developments in vegetable production in Thailand which they could adapt.

The technical assistance also enabled the regional program to concentrate on the need to develop/improve its own vegetable training program while providing support to increase the number of research training scholars from the South Asian Developing Market Countries (DMC) (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) for which a vegetable research network was formed under the ADB-assisted South Asian Vegetable Research Network.

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Linkage with countries like Myanmar and Cambodia was started towards the end of 1990 and was reaffirmed in the early part of 1991. This was made possible through the assistance of international research and humanitarian agencies. Formalization of an AVRDC-Vietnam agreement has been worked out during this period. Extension of IDRC support to AVRDC/TOP-China program has now been confirmed.

A total of 44 studies on principal AVRDC crops and important crops of the region were carried out at AVRDC-TOP research and training site in Kamphaeng Saen Campus of Kasetsart University (KU). Studies under AVNET, an AVRDC program in coordination with KU's Tropical Vegetable Research Center with the regional program's input, were also conducted. Thus, some of the studies listed here are those of AVNET. As in previous years, on-farm trials were conducted in different locations either on farmers' fields in cooperation with the local agencies or in various cooperating research stations. Testing of AVRDC crops in other countries has also been carried out by various cooperating agencies in the region. Results of these trials are either sent to AVRDC-TOP or directly to the Center.

The research program under the previous technical assistance had identified certain vegetable diseases and pests such as soybean rust and legume viruses that are of significant economic importance. The present technical assistance further intensifies research on diseases and pests including the on-farm trials and testing of various kinds of vegetables. Research on vegetable soybean was intensified in 1991. To support farmers' request for more seeds of vegetable soybean, the area for seed production in TOP fields was increased. Since the extension work on asparagus was already extensively carried out by the farmers in the vicinity of Kamphaeng Saen, the on-farm research on asparagus has been dropped.

Exchanges of scientific information and germplasm have continued, covering a wide array of countries such as Laos, Cambodia, China, Vietnam, Myanmar, Bhutan, Pakistan, Nepal, Bangladesh, Sri Lanka and the Southeast Asian countries.

Accomplishments

Field improvement/facilities. The expansion of the training and research program prompted AVRDC-TOP to request a larger experimental area and to make this newly added area more suitable for research. In the early half of 1991, a new farm road connecting the main experimental area was constructed. New cement irrigation canals were also built.

To accommodate large volumes of vegetable soybean seeds and other AVRDC principal crops, a new cold room was built. This is in addition to the cold room which was previously donated by IDRC.

Training. During the bridging period between Phase II and Phase III, the 9th training course was conducted which graduated 26 researchers equipped with modern techniques in vegetable production and research. Four of these training scholars were directly sponsored by ADB, while the rest were funded by other international agencies like United National Development Programme (UNDP) Special Programs, United Nations Children Education Fund (UNICEF), and nongovernmental religious organizations like COERR and Bread for the World (BfDW).

The first 6 months of phase III were spent on preparations for the 10th Regional Training Program: scholarship solicitation and contacting of concerned government agencies. This training course had 22 participants from 9 countries: Bhutan, China, Laos, Myanmar, Nepal, Pakistan, the Philippines, Thailand and Vietnam. Sponsors include: Swiss Development Cooperation, Mennonite Central Committee, German Foundation for International Development (DSE) and International Development Research Centre (IDRC). Some of the scholars were also sponsored by funds provided by ADB. The course officially started on 15 October 1991.

A one-month special training-cum-study tour was conducted for Sri Lankan agricultural officials and cooperating farmers in August 1991. This group under the sponsorship of USAID underwent a week of general vegetable production training in AVRDC-TOP Kamphaeng Saen site (KPS), then toured main vegetable and fruit production areas in Central, Northern and Southern Thailand. This was the second in a series of such special courses conducted for MARD of Sri Lanka—a USAID-funded project dealing with irrigation and crop diversification. Special study tours were also coordinated for agricultural officials of countries such as Vietnam, China, the Philippines and Cambodia.

Research

In 1991 a total of 44 studies were conducted at AVRDC-TOP. Most of these were either routine field trial work or preliminary evaluation trials. General data from the on farm trials were collected but not analyzed. The results were presented. As mentioned, the AVNET experiments for 1991 were also conducted in the same field. Results of these trials are reported together with other cooperating countries elsewhere in this Report. Results of 26 studies conducted by the 9th Regional Training Program (RTP) group have been published. Thus, results of research reported here are those conducted by AVRDC-TOP staff that had significant findings and had not been included in those two reports. Research conducted was mainly on: a) yield trials for AVRDC principal crops such as Chinese cabbage, tomato, sweet potato, pepper, grain and vegetable soybean and mungbean; b) yield trials for crops of importance to Thailand such as baby corn, asparagus and cucumber; c) cultural management and crop protection studies; d) seed multiplication and quality evaluation trial; e) home garden programs, f) demonstration plots for AVRDC-improved crops that were released in Thailand; and g) AVNET trials.

Tomato

Determinate tomato varietal trial. Twenty-two determinate-type tomato cultivars from Indonesia, Malaysia, the Philippines, USA, Thailand and AVRDC were tested during the rainy season from May to September 1991 at AVRDC-TOP's experimental field in Kamphaeng Saen district, central lowland Thailand. A randomized complete block design with four replications was used. Plot size was 4.8 m^2 with 12 plants per row. Spacing was 1 m between rows and 0.4 m between plants. Seeds were sown on 8 May 1991 and seedlings were transplanted into experimental fields on 31 May 1991. Average day and night temperatures during flowering and fruit setting periods were 23.6 and 24.9°C.

As shown in Table 1, heat-tolerant check cultivar CL 5915-93 D4 - 1 - O - 3 gave the highest marketable yield of 22 t/ha, while heat-sensitive check TK-70 yielded only 6.1 t/ha. The lowest yield of 1.0 t/ha was obtained from VC 204 and Walter. Seedathips I and II, commercial cultivars released by AVRDC-TOP, produced the smallest fruits of 21 g/fruit and had a pink-orange color. The fruit of the rest of the tomato lines were red when ripened. These two Seedathips showed a high degree of heat tolerance with an average yield of 21 t/ha. Other test cultivars exhibited some specific outstanding characters such as: thick pericarp, nearly 8 mm (Mapula of the Philippines), big and firm fruit of CLN 657 BC_1F_2 - 267 - O - 3 - 12 -7 as well as large fruits and high yield (MT II of Malaysia and Ratna of Indonesia).

Varietal trial of F_1 hybrid fresh market table tomato. Thirteen F_1 hybrid fresh-market tomatoes from AVRDC were tested from June to September 1991 at AVRDC-TOP KPS field. Seedathip II commercial cultivar released by AVRDC-TOP, which carries some degree of heat tolerance, was added as check. This cultivar had small pink, ovate fruits weighing about 17 g/fruit. The experimental design was randomized complete block with three replications. Twenty-day old seedlings were transplanted in 2-row plots with 10 plants/row spaced 100 cm between rows and 50 cm between plants. Data were collected from only eight plants inside each row.

Days to flowering varied from 19 to 28 days after transplanting, and most of the FMTT lines flowered later than Seedathip II. The newly improved FMTT varieties from AVRDC had combined good characteristics of large fruits and heat tolerance. These characters were shown by FMTT 251, 260, 264 and 269 with an average fruit weight of over 80 g. Seedathip II produced fruits weighing an average of 17 g only. Marketable yields of all lines tested were rather low, due to unfavorable conditions for fruit setting and severe damage inflicted by fruit worm. FMTT 251 and 269 gave better performance than others. They had a yield of more than 3 t/ha, with large fruits weighing over 80 g/fruit and thick pericarp (Table 2).

Indeterminate tomato varietal trial. Fourteen cultivars of indeterminate tomatoes were evaluated from May to September 1991 at AVRDC-TOP experimental site at Kamphaeng Saen Campus.

Most of these improved lines from AVRDC carried some degree of heat tolerance and were able to set fruit under unsuitable conditions with an average daytime temperature of 33.4°C and 25.0°C during nighttime at flowering. The experimental design was a randomized complete block with four replications. Twelve plants of each cultivar were planted in one-row plots. Spacing was 40 cm between plants and 1 m between rows.

Table 1. Yield and performances of 22 determinate type tomato cultivars grown during May to September 1991 at TVRC/KPS field.

Entry or variety name		Source	Days to flower DAT	fruit set score	Disease rating (yellow leaf curl	foliage cover	Fruit traits: shape	size g	color	crack	pericarp thickness cm	firmness kg/cm²	brix	Yield (t/ha): mktble	nonmarketable: small fruit	crack	insect damage
CL 5915-93D4-1-0-3 (HT check)		AVRDC	14	4	1	poor	deep globe	38.7	red orange	mild	0.6	2.2	4 5	22 0	6 0	3 0	4.1
BL 653	Seedathip II	Thailand	14	4	1	poor	ovate	21.6	pink	mild	0 5	2.5	3 3	21.0	4.9	5 6	2.5
BL 652	Seedathip I	Thailand	13	4	1	good	ovate	21.3	pink-orange	-	0.5	1.2	4.4	20.8	5.9	3.2	2.7
BL 695	HT II	Malaysia	15	4	1	poor	deep globe	61 3	orange-red	medium	0.6	2.2	4.5	15.9	5.0	6.0	2.4
BL 694	HT I	Malaysia	19	4	1	poor	globe	37.8	orange-red	mild	0 6	2.5	4.9	14.4	5.4	3.4	1.8
BL 697	Ratna	Indonesia	14	4	1	good	deep globe	58.4	red	-	0.5	1.2	5 0	14.3	4 6	2 3	3.1
CLN 659BCIF2-358-4-13		AVRDC	20	3	4	poor	deep globe	51 7	red	-	0 5	2.0	3 9	12.7	5 2	0.8	4.8
CLN 657BCIF2-247-0-3-12-7		AVRDC	25	3	4	poor	deep globe	72.8	red	mild	0.6	3.0	3.6	10.0	1.5	2.6	4.3
BL 699	Berlian	Indonesia	13	3	1	good	deep globe	47.8	red	-	0.5	1.2	5.0	9.5	3.7	1.7	2.2
BL 708	Mapula	Philippines	18	3	4	poor	oblong	48.9	red	mild	0 8	3.2	4.2	9.2	6 2	1.2	2.7
BL 701	Harilut	Philippines	15	2	1	good	deep globe	68.2	red	medium	0 5	2.0	5.7	7.2	0.9	1.9	1.6
TK 70 (HS chck)		AVRDC	17	2	3	good	globe	69.9	red	medium	0.6	1.7	4.3	6 1	3.1	4.1	0.8
CLN 475BCIF2-265-4-19		AVRDC	22	3	4	poor	deep oblate	50.3	red	heavy	0.5	3.4	4.0	5.2	1.4	2.4	1.8
BL 704	Apollo	Philippines	18	3	4	poor	ovate	34.3	red	-	0 5	2.0	4.0	4.5	2.4	0.3	0.4
BL 705	UFC 1	Philippines	13	3	1	good	oblong	34.3	red	-	0 6	2.5	3.7	4.0	5.0	0.1	0.8
BL 703	Maigaya	Philippines	14	4	2	poor	ovate	21.7	red	mild	0.5	2.0	5.2	3 9	1.3	1.2	0.7
BL 654	P 502	USA	15	3	2	good	globe	51.6	red	mild	0.7	3.7	3 6	3 3	0.8	1.3	0.7
CLN 475BCIF2-265-12-9-1		AVRDC	25	3	4	poor	deep globe	39 6	red	medium	0 5	2.2	4.4	3.0	1.8	0.9	1.1
BL 702	Improved Pope	Philippines	14	1	1	good	oblong	32 2	red-orange	medium	0.5	1.2	5.5	1.4	0.5	0.5	0.1
BL 655	VF 134-1-2	USA	22	2	2	good	globe	55 3	red	heavy	0 5	2 5	4.5	1.2	0.0	0.4	0.2
BL 708	Walter	Philippines	25	1	4	poor	oblate	47.3	red	mild	0.4	2.9	4.0	1.0	0.4	0.4	0.3
BL 707	UC 204	Philippines	20	2	3	good	cylindrical	56 8	red	heavy	0.5	1.5	3.0	1.0	0.5	1.8	0.4

Table 2. Yield and characteristics of F_1 hybrid fresh market table tomato grown from June to September 1991 at KPS.

Variety	Days to flower DAT	Fruit characters: size (cm)	wall thickness	firmness kg/cm²	Yield (t/ha): marketable	nonmarketable: insect damage	crack	small
FMTT 22	24	79	0 4	2 0	1 9	1 4	0.2	0 5
FMTT 105	19	64	0 4	2 3	2.1	1.3	0 1	1.2
FMTT 114	23	51	0 4	2 0	2 0	1.1	0 3	1.7
FMTT 115	21	36	0 5	2 1	3 7	1.2	0 0	1 7
FMTT 138	20	51	0 5	2 5	2 6	0 7	0 2	1 2
FMTT 251	25	80	0 6	2 8	4 3	1.6	0 2	1.0
FMTT 260	28	81	0 6	3 2	1 9	1.3	0 1	0.5
FMTT 264	27	82	0 6	2 8	2.6	1.3	0 1	0.6
FMTT 265	24	67	0.6	2 8	1 6	1 2	0 1	0.7
FMTT 267	24	76	0.5	2 4	2.5	1 4	0 1	1.1
FMTT 269	24	94	0 5	2 8	3 2	1 6	0.3	1.1
FMTT 2n	21	69	0 4	2 0	1.6	1.7	0.2	0.9
FMTT 304	27	63	0 5	2 7	1 1	0.7	0.1	0.5
Seedathip 11	20	17	0 4	2 0	3.9	0.6	0 0	0.7

The marketable yields varied from 1.6 to 18.8 t/ha, depending on the degree of heat tolerance of the cultivars. FMTT 138 F hybrid HT check gave the highest yield of 18.8 t/ha, while L 4783 HS check produced only 2 t/ha. Seeda and GOP, commercial cultivars from Thailand and the Philippines, respectively, did not carry a heat-tolerant gene so that growing these cultivars during off-season would result in very low yield (Table 3). Three new breeding lines, selected from CLN 657 BC.F_2.274, showed good performance. They had big fruits (over 80 g), with high firmness value which was better than the FMTT 138 F_1 hybrid cultivar. The yield of these three new breeding lines ranged from 10.9 to 14.6 t/ha.

Table 3. Yield of 14 indeterminate tomato cultivars grown from May to September 1991 at AVRDC-TOP field.

Entry and variety name	Yield (t/ha): marketable	nonmarketable: small fruit	crack	insect damage
FMTT 138 (HT-check)	18 8	5.8	2 0	3.8
CL 6046BCIF2-51-0-20-5-15-14-1	17 6	IB.3	0.5	2.1
CLN 657BCIF2-274-0-15-4	14 6	2.9	1.5	4.2
CL 5915-206D4-2-2-0	12.7	3 3	2 4	2.7
CLN 657BCIF2-285-0-20-0-24	11.0	2 4	I.B	1.8
CLN 657BCIF2-274-0-15-7	10.9	2.0	3.0	4 5
CLN 657BCIF2-274-0-15-0	10.9	1.8	2 3	4.7
CL 6046BCIF2-51-1-1-20-5-10-13	10.0	5.5	1.4	1.0
CL 5915-206D4-2-2-0-4	9.5	3.8	3.7	3.3
CL 5915-206D4-2-5-0	8.6	4.0	2.6	2.5
CLN 657BCIF2-285-0-20-0	7.6	1.8	1.0	1.4
BL 651 (Seeda Thailand)	2.6	0.6	0.0	0.3
L 4783 (HS check)	2.0	1.0	0.9	1.0
BL 700 (GOP from Philippines)	1.6	0.5	1.3	0.3

Vegetable Soybean

Vegetable soybean varietal trial in summer. Eight cultivars of vegetable soybean were grown from April to June 1991 at KPS experimental field. A randomized complete block design with four replications was used for this trial. Each cultivar occupied 4 beds, 5 m long with 2 rows per bed. Spacing

between rows was 50 cm and between plants, 20 cm. After emergence, extra seedlings were removed, maintaining 16-20 plants/m² at harvest. Yield and other agronomic data were gathered from six middle rows of 4 m length inside each row. Days to harvest of each variety varied from 63 to 67 days after sowing, depending on pod maturity.

As shown in Table 4, the plant heights of Tzurunoko, AGS 292 and Wakakusa ranged from 34 to 47 cm. They were taller than the rest and their canopies completely covered the space between rows. Solunako, White Lion and Karitea had small plant size so that the number of plants/m² should be increased up to more than 20 to minimize damage from sunlight.

Table 4. Characteristics of eight vegetable soybean cultivars grown from April to June 1991 at KPS field.

Variety	No. of plants/ m²	100 seed wt. g	Plant height cm	Flower period DAP	Days to harvest DAP	Ave. whole plant wt g/plant	Mean pod wt. (g) 3 seed	2 seed	1 seed	Size of 2-seeded pod width cm	length cm	thickness cm
AGS 292	17	38.4	37	26-30	67	172	3.5	2.4	1.3	1.4	5.6	0.9
Tsurunoko	16	26.2	47	27-33	67	144	2.4	1.7	0.8	1.2	4.7	0.8
Uakakusa	21	35.3	34	24-29	63	123	3.2	2.2	1.2	1.4	5.1	1.1
Kegon	15	28.1	28	26-30	63	114	3.0	2.2	1.3	1.5	5.0	1.0
Solunako	17	30.6	21	24-28	65	97	2.9	2.0	1.2	1.3	4.5	0.9
Karitea	16	36.1	27	25-28	66	154	3.6	2.3	1.4	1.3	4.8	1.1
White lion	18	37.7	26	24-28	65	154	3.0	2.2	1.2	1.3	4.7	1.0
Fukuiji	16	34.3	30	24-28	66	138	3.6	2.5	1.3	1.2	4.7	1.0
L.S.O. 05			8.5			ns						

AGS 292 had the highest pod weight per plant of 86.2 g, number of pods per plant at 43 pods and marketable pod yield of 9.6 t/ha (Tables 5 and 6). The percent number of marketable pods (2 and 3 seeds) per plant and weight of marketable pod number per plant of the top yielding cultivars AGS 292, Tsurunoko and Wakakusa were more than 50% of total pod number per plant and more than 65% of total pod weight per plant, respectively. Fukuji and White Lion had rather low percentages of both marketable pod number per plant and marketable pod weight per plant at only 20 and 35%, respectively. The marketable pod size obtained from all cultivars seemed to be smaller than the standard size which requires 175 or less pods per 500 g package. Under high temperature conditions, flowering was gradual taking more than 2 weeks to complete, and maturity of pods varied, making it difficult to pin down the suitable harvesting time.

Growing of vegetable soybean during summer requires more intensive grading of pods. Harvesting time should not be delayed, otherwise pods might overmature.

Vegetable soybean varietal trial in rainy season. Nine vegetable soybean cultivars were evaluated from July to September 1991 at KPS field. One unknown variety from a private export company was added to the eight cultivars tested in summer. Design, plot size, methods and data collection were similar to the previous summer trial. Plant population of each cultivar was maintained at 19–20 plants/m² but Karitea, White Lion and the unknown variety had fewer numbers of plant/m² due to poor seed germination. Harvesting was done when 70–80% of pods matured or at 61 to 64 days after planting.

Vegetative growth and pod development of each cultivar were inferior to the summer-grown plants. The mean weight of 3-seeded, 2-seeded and 1-seeded pods was lower, affecting the number of graded pods in the 500-g package (Table 7). Only the unknown variety had pod size large enough to reach the export requirement of 175 pods/500 g package. As shown in Table 8, the total pod number per plant was only 16 to 22 pods and about 50–65% were marketable. The average whole plant weight and the total pod weight/ plant were also much lower, compared to those grown during summer. There was not much variation in total marketable pod yield among varieties (Table 9). The highest yield of 6.7 t/ha was obtained from Wakakusa and the lowest yield was from Solunako at 4.2 t/ha.

Table 5. Number and weight of fresh pods/plant of eight vegetable soybean cultivars grown from April to June 1991 at KPS field.

Variety	No. of plants/ m²	No. of fresh pods/plant								Weight of fresh pod/plant (g)							
		3 seed	2 seed	1 seed	some seed aborted	insect damage	abnormal pod	unfilled pod	total	3 seed	2 seed	1 seed	some seed aborted	insect damage	abnormal pod	unfilled pod	total
AGS 292	16.9	4.8	17.3	4.4	5.4	1.1	1.3	8.5	43	16.8	40.8	5.6	10.2	2.0	2.5	8.3	86.2
Tzurunoko	16.4	3.4	17.8	3.0	3.6	0.6	0.4	12.2	41	8.1	30.7	2.5	4.7	0.9	0.7	9.9	57.5
Wakakusa	20.6	4.8	9.6	2.9	7.4	0.7	1.3	6.7	33	15.4	21.2	3.5	12.4	1.2	3.2	6.8	63.7
Kegon	15.2	3.8	6.6	2.5	4.4	0.6	2.5	7.6	28	11.3	14.6	3.3	9.6	1.3	4.1	7.1	51.3
Solunako	17.4	3.5	6.1	2.2	7.8	0.4	0.4	11.4	32	10.0	12.3	2.7	13.8	0.5	0.6	7.8	47.7
Karitea	15.9	1.6	8.1	2.2	10.0	0.7	0.4	16.7	40	5.7	18.8	3.1	21.6	0.8	0.8	14.5	65.3
White lion	17.8	2.3	6.2	2.2	12.1	0.3	0.3	13.2	37	7.0	13.4	2.5	17.5	0.4	0.5	14.0	55.3
Fukuiji	16.1	1.3	5.7	2.0	10.5	0.5	0.4	18.0	38	4.5	14.2	2.5	17.5	0.6	0.9	14.8	55.0
L.S.D. 0.05		1.16	2.27	0.73	3.24	ns	0.81	3.55		3.46	5.30	0.82	3.09	1.00	2.26	4.75	

Table 6. Fresh pod yield (t/ha) of eight vegetable soybean cultivars grown from April to June 1991 at KPS.

Variety	No. of plant/ m²	Fresh pod yield (t/ha)							No. of marketable pod/500 g	Total grade pod yield (t/ha)
		3 seed	2 seed	1 seed	some seed aborted	insect damage	abnormal pod	unfilled pod		
AGS 292	16.9	2.8	6.8	0.9	1.7	0.4	0.4	1.4	191	9.6 a
Tzurunoko	16.4	1.6	6.2	0.5	1.0	0.2	0.2	2.0	271	7.9 b
Wakakusa	20.6	2.7	3.7	0.6	2.2	0.2	0.6	1.2	196	6.4 c
Kegon	15.2	2.3	3.0	0.7	2.0	0.3	0.9	1.5	200	5.3 c
Solunako	17.4	1.8	2.2	0.5	2.5	0.1	0.1	1.4	215	4.0 d
Karitea	15.9	0.9	3.0	0.5	3.4	0.1	0.1	2.3	198	3.9 d
White lion	17.8	1.2	2.3	0.4	3.0	0.1	0.1	2.3	208	3.4 d
Fukuiji	16.1	0.8	2.6	0.5	3.2	0.1	0.2	2.7	187	3.4 d
L.S.D. 0.05		0.61	0.70	0.15	0.59	0.19	0.49	0.80		1.19

Means in each column followed by the same letter are not statistically different at the 5% level (DMRT).

Table 7. Characteristics of nine vegetable soybean cultivars grown from July to September 1991 at KPS field.

Variety	No. of plants/ m²	100 seed weight g	Plant height cm	Days to flower DAP[a]	Days to harvest DAP	Ave whole plant wt. g	No. of node	No. of branch	Mean pod weight (g) 3 seed	2 seed	1 seed	Pod traits length cm	width cm	thick cm
AGS 292	19.0	29.6	35.8	27	63	71.2	9	4	3.2	2.2	1.2	5.4	1.4	1.0
Solunako	18.8	30.5	23.1	27	62	61.8	8	2	2.6	1.9	1.1	4.6	1.3	0.9
Kegon	19.7	28.4	25.2	28	82	70.9	8	3	3.1	2.2	1.1	5.0	1.4	1.0
Tzurunoko	19.5	34.2	45.0	27	64	81.6	11	4	2.4	1.7	1.0	4.5	1.2	0.8
White Lion	17.2	37.1	26.6	28	61	81.0	9	4	3.0	1.8	1.2	4.9	1.3	1.0
Karitea	16.9	37.1	26.0	26	62	79.5	8	4	3.2	2.2	1.2	4.9	1.3	1.0
Wakakuga	20.0	34.7	32.5	27	61	78.5	9	4	3.3	2.2	1.2	5.1	1.3	1.0
Fukuiji	19.8	32.6	29.7	27	63	70.3	8	3	3.3	2.2	1.2	4.8	1.3	1.0
Unknown	15.3	49.8	36.4	28	64	98.5	9	4	4.5	2.8	1.6	5.4	1.5	1.0

[a]Days after planting.

Table 8. Number and weight of pods per plant of nine vegetable soybean cultivars grown from July to September 1991 at KPS field.

Variety	No. of plants/ m²	No. of fresh pods/plant 3 seed	2 seed	1 seed	some seed aborted	insect damage	abnormal pod	unfilled pod	total	Weight of fresh pods/plant (g) 3 seed	2 seed	1 seed	some seed aborted	insect damage	abnormal pod	unfilled pod	total
AGS 292	19.0	1.4	10.1	1.4	2.0	0.2	0.7	0.3	16	4.3	22.5	1.7	3.3	0.3	9.5	0.4	42.0
Solunako	18.8	2.7	8.4	1.6	3.2	0.1	1.0	0.4	17	7.1	15.5	1.8	4.5	0.2	6.0	0.5	35.6
Kegon	19.7	2.2	9.2	2.5	2.8	0.1	0.6	0.5	18	6.9	20.0	2.9	4.9	0.2	4.8	0.7	40.4
Tzurunoko	19.5	1.7	12.0	1.3	1.5	0.3	0.7	0.2	18	4.0	21.1	1.3	2.0	0.3	10.2	0.2	39.1
White Lion	17.2	2.7	11.5	1.9	4.2	0.1	1.1	1.1	22	6.6	20.7	2.3	6.6	0.2	6.3	1.4	44.1
Karitea	16.9	1.5	10.6	1.8	4.0	0.1	1.2	1.2	20	4.9	23.5	2.2	6.7	0.3	7.4	1.4	46.4
Wakakusa	20.0	2.2	11.8	2.7	2.7	0.2	0.8	0.8	21	7.3	26.2	3.3	4.1	0.3	3.0	1.1	45.3
Fukuiji	19.8	1.2	9.3	1.4	3.7	0.3	0.7	0.6	17	4.0	20.1	1.6	6.5	0.4	5.9	0.7	39.2
Unknown	15.3	0.9	9.7	3.6	1.2	0.4	0.6	1.7	18	4.0	27.5	5.8	2.7	0.9	5.7	4.4	51.0

Table 9. Fresh pod yield of nine vegetable soybean cultivars grown from July to September 1991 at KPS field.

Variety	No. of plants/m²	Fresh pod yield (t/ha) 3 seed	2 seed	1 seed	some seed aborted	insect damage	unfilled pod	abnormal pod	No. of mktble pod/500 g	Total grade pod yield t/ha
AGS 292	19	0.8	4.2	0.3	0.6	0 1	1.8	0.1	215	5.0
Solunako	19	1.3	2.8	0.3	0.9	0	1.0	0.1	246	4.2
Kegon	20	1.4	4.0	0.6	1.0	0	1.0	0.1	212	5 3
Tzurunoko	20	0.8	4 1	0.3	0.4	0.1	2.0	0	275	4.9
White Lion	17	1.1	3.5	4	1.1	0	1.1	.2	255	4.7
Karitea	17	0.8	4.0	0.4	1.1	0.1	1.2	0.2	213	4.8
Wakakusa	20	1.5	5.2	0.7	0.8	0.1	0.6	0 2	209	6.7
Fukuiji	20	0.8	4.0	0 3	1.3	0.1	1.2	0.1	218	4.8
Unknown	15	0.6	4 2	0.9	0.4	0.1	0.8	0.7	171	4.8

Chinese Cabbage and Pepper

Studies on Chinese cabbage and pepper were conducted by the 9th RTP training scholars and were reported in the 9th RTP training report. As pepper evaluation is part of AVNET the results of the evaluation conducted at AVRDC-TOP field by TVRC and AVRDC-TOP are included in the AVNET report.

Mungbean

Mungbean cultivars recommended by Thailand were sown at AVRDC-TOP around the 27th of each month, starting from August 1987 to March 1990. Yield and yield components data were recorded from three sets of cultivars. The first set comprised the recommended Kamphaeng Saen 1 and Kamphaeng Saen 2 from 37 planting dates. The second set included U-thong 1 with the aforementioned cultivars in 33 planting dates. The 3rd set composed of the above three cultivars plus Chainat 60 and PSU 1 in 11 planting dates.

Analysis of variance was performed for each set, using the data of seed yield, number of pods per plant, number of seeds per pod and 1000-seed weight. Variation due to interaction between genotype and environment (G × E) was generally greater than that which was due to genotypes in almost all characters in all sets of experiments, with the exception of the number of pods per plant and 1000-seed weight of the third set. The G× E interaction revealed that the order of performance of these mungbean cultivars changed according to planting dates. The planting dates were then grouped based on their effects on the cultivars using GEBEI computer package constructed by the University of Queensland, Australia as reported by Puddhanon and Nakatat in 1988. Finally, the dates of the first set were clustered based on grain yield, number of pods per plant, number of seeds per pod and 1000-seed weight into five, six, six and six groups. In the second set of cultivars, the dates were classified into five, six, seven and six groups. In the third set, the dates were assigned into five, three, five and three groups, respectively. Although this study was conducted over a period of more than 3 years, the G × E interaction could not suggest which mungbean cultivars should be planted in Kamphaeng Saen Campus and what months they should be planted to ensure yield or yield components. Even the irrigation factor that Imrie and Shanmugasundaram had reported as the most important environmental factor affecting grain yield did not play a significant role in this study.

Development of downy mildew resistant soybean isoline Nakhon Sawan 1 through backcrossing[1]. Soybean (*Glycine max* (L.) Merr.) var Nakhon Sawan 1 (NS1) was developed for resistance to downy mildew disease incited by *Peronospora manchurica* (Naum.) Syd. The backcross

[1] Master of Science thesis of Mr. Anuwat Jene-kritiya, AVRDC-TOP training staff, conducted at AVRDC-TOP field under the supervision of Dr. Peerasak Srinives.

method was used to transfer resistant gene(s) from var AGS 129 to NS 1. Six backcross generations, recurrent parent (NS 1), and donor parent (AGS 129) were evaluated for 12 agronomic characteristics. They were days to flowering, days to harvest, plant height at flowering, plant height at harvest, leaflet shape, number of pods per plant, number of seeds per pod; seed width, seed length, seed thickness, 100-seed weight and seed yield per plot. Fifteen lines with NS 1 phenotype expressed homogeneity in downy mildew resistance and were visually selected from BC_5F_2 generation. The selected isolines were evaluated in a replicated trial, of which four characters, i.e. plant height, number of pods per plant, 100-seed weight and seed yield were recorded.

The population mean of BC_1 and later backcross generations were found to be similar to the recurrent parents in all traits, except for the plant height at harvest and the days to harvest, which were stable since the BC_2 and the BC_6 generations, respectively. Seed yield was positively correlated with days to flower, days to harvest, plant height at harvest, leaflet shape, number of pods per plant and number of seeds per pod. Leaflet shape was positively correlated with the number of pods per plant, the number of seeds per pod and the seed yield but negatively correlated with the seed width and the 100-seed weight.

All 15 isolines selected from BC_5F_2 were not different from NS 1 in 4 traits studied. It was concluded that backcross method employed to improve resistance to downy mildew on NS 1 was successful in five backcrossings.

MYMV demonstration trial. Several demonstration plots were set up at AVRDC-TOP, KPS field in June–August 1991 to determine the presence of mungbean yellow mosaic virus (MYMV) under natural conditions in Central Thailand. These demonstration trials showed absence of MYMV on all 135 mungbean lines, including many from AVRDC, Pakistan and India, planted in KPS field during the time of the trial.

Seed multiplication of AVRDC elite mungbean lines. Ten AVRDC elite mungbean lines were multiplied at AVRDC-TOP, KPS field. Seeds were sown in a 4-row plot, measuring 2 x 6 m², on 19 February 1991. Distance between rows was 50 cm and distance between plants was 12.5 cm. Two plants were maintained per hill. Data were collected from 10 plants in the two middle rows. Harvesting was done twice on 26 April and 5 May.

Results of the trial are presented in Table 10. The highest yielder was VC 3944 A with 1.5 t/ha and the lowest was VC 3741 A with 0.6 t/ha.

Table 10. Yield and agronomic characters of 10 AVRDC elite mungbean lines, AVRDC-TOP, KPS, dry season 1991 .

ACC. No.	Days 50% F[a]	Days 50% M[b]	Disease score CLS	Disease score PM	Disease score Lod	Plant stand/ m²	Plant height (cm)	1000 SW (g)	Yield (t/ha)
VC 1160 B	34	56	NA	NA	1	13.8	80.5	60.6	1.2
VC 1163 D	32	54	NA	NA	1	14.2	66.3	57.8	0.9
VC 3689 A	35	57	NA	NA	2	16.3	78.0	49.9	0.9
VC 3741 A	30	52	NA	NA	1	16.0	61.3	56.4	0.6
VC 3751 A	33	54	NA	NA	1	16.5	67.0	67.8	0.7
VC 3944 A	34	56	NA	NA	2	22.7	94.1	55.2	1.5
VC 3945 A	33	56	NA	NA	2	17.3	81.1	51.6	1.4
VC 4066 A	35	56	NA	NA	1	20.0	83.0	58.2	1.3
VC 4152 A	34	54	NA	NA	1	17.2	78.7	68.1	1.4
VC 4176 A	34	56	NA	NA	1	20.8	84.6	58.2	1.2

[a]Flowering
[b]Maturity

Soybean and Sweet Potato

Results of the experiments conducted at the AVRDC-TOP field in 1991 are presented in the 9th AVRDC-TOP Regional Training Program Report.

Home Gardening

The home garden program of AVRDC-TOP is a continuous testing ground for the development of cropping patterns involving vegetable crops indigenous to Thailand and other countries in the region. The

program also involved adaptation trials for all newly developed or released varieties of vegetables coming from research institutions, farmers or commercial seed producers.

Two training scholars of the 9th Regional Training Program conducted studies on nutrition concerning four kinds of popular crops and on seed production of four important vegetable crops in Malaysia (see 9th RTP Training Report 1991)

A total of 0.8 t of vegetables was produced from the AVRDC-TOP home garden consisting of three sets measuring 5 × 5 m^2/set. The seed production area produced substantial amounts of popular and indigenous vegetable seeds for distribution to farmers in the area.

Germplasm Exchange

Germplasm from AVRDC have been continuously distributed to various countries in the region especially to those countries that cannot obtain materials directly from Taiwan. Extensive planting of AVRDC mungbean and soybean is being undertaken in Cambodia. Through the training scholars, new materials have been collected from China, Bhutan, Nepal, Vietnam and Pakistan. These materials are being tested in the Regional Program. In 1991, 32.2 kg of seeds were distributed to more than 40 institutions in the region.

Publication and Information Exchange

Publications released within this period include the 9th Regional Training Program Report (ISBN 974-552-984-2) and Soybean Rust caused by *Phakopsora pachyrhizi* (ISBN 974-7315-39-4). Other AVRDC-TOP publications scheduled for release are the revised directory of training alumni, AVRDC-TOP Bulletins and reprints of Home Gardening Technoguide.

The Regional Program still acts as a repository and exchange and distribution center of all AVRDC publications, including those coming from China. Through AVRDC-TOP, all AVRDC publications are being received by the Chinese, Vietnamese and Laotian researchers and extension workers.

Regional and International Cooperation

Under the regional program, collaborative work has been undertaken with several countries in Asia. These cooperative programs are: AVRDC/TOP-China, AVRDC/TOP-Bangladesh and AVRDC/TOP-Sri Lanka. A memorandum of understanding binds the respective national agricultural research systems (NARS) and AVRDC-TOP. Intensive testing of AVRDC-generated technologies and materials are being carried out in Vietnam. The Director of AVRDC-TOP has been invited for several short-term consultancies in Vietnam during the past 4 years. The AVRDC-TOP's success in both China and Vietnam can be well measured in terms of the number of AVRDC materials released in these countries. Recently, the Vietnamese Deputy Minister and Deputy Director of International Cooperation exchanged visits and met with the TOP Director and AVRDC Deputy Director General to discuss the formation of an official linkage between the Vietnam government and AVRDC. The TOP Director and the AVRDC Deputy Director General then visited Vietnam to inspect various research agencies in both Hanoi and Ho Chi Minh cities and to further discuss with representatives of the Vietnamese agencies the formalization of cooperation.

AVRDC/TOP-China

The AVRDC TOP-China program is in its third phase. It puts emphasis on strengthening existing research and cooperation between AVRDC and the Chinese Academy of Agricultural Science/Ministry of Agriculture, evaluating the performance and impact of released AVRDC-improved varieties under field conditions in China and conducting in-country workshops on vegetable production and research in China. The specific objectives of the cooperative project with China are:

1. to carry out in China the trials on original crop yield and on-farm trials of AVRDC-developed heat-tolerant and disease-resistant materials of Chinese cabbage and tomatoes, improved varieties of soybean, mungbean and sweet potato and other vegetable crops, if any;

2. to extend the selected AVRDC materials (as parents of hybridization) after successful regional trials, into farmers' and production fields for direct use, or inclusion in the respective national crop-breeding programs;
3. to exchange germplasm and technical information on the abovementioned crops;
4. to expand collaborative work between AVRDC and Chinese scientists;
5. to provide programmed training for Chinese researchers and scientists on vegetable production and research at AVRDC's Regional Training Program site in Thailand;
6. to initiate and carry out important surveys on: a) soybean rust disease caused by *Phakopsora pachyrhizi*, and b) tomato virus diseases caused by TMV and CMV; and,
7. to foster scientific exchange through reciprocal scientific visits between AVRDC and Chinese agricultural institutions.

Activities

Varietal trial/testing of AVRDC materials. This phase of AVRDC/TOP-China project marked the all-out expansion of performance testing in China of AVRDC-improved lines, varietal releases, intensive seed production, distribution of released lines and multiplication of promising cultivars for testing in more provinces. Crossing or hybridization of AVRDC materials is being done by all the cooperating institutions. Several promising crosses with AVRDC parental lines have also undergone the selection and evaluation trials in China.

Results of 3-year yield trials under Phase II showed that considerable success has been achieved with AVRDC-improved mungbean, Chinese cabbage, tomato and sweet potato. Promising preliminary results were obtained from the newly started pepper research, particularly in the positive identification of disease-resistant materials from AVRDC lines to an epidemic *Phytophthora* blight caused by *Phytophthora capsici* in Xinjiang Autonomous Region.

AVRDC soybean materials so far tested by the Chinese soybean breeders were found unsuitable for direct production because of the requirement of a variety possessing both extremely short maturity and very high grain yield in Central and Southern China. However, these AVRDC materials have been crossed with local soybean varieties to make use of their several good breeding characters. In Wuhan, a total of 411 crosses were made using AGS soybean lines from AVRDC.

Most of the introduced AVRDC fresh table tomato selections were made from the progenies of AVRDC tomato line CL 591-206-D_4-2-2 which possesses good gene characteristics for resistance to TMV and other diseases, high plant growth vigor, high fruit setting, high number of fruits per plant and other superior characteristics. However, many of these materials have lower soluble solids and lycopene content, not suitable to be used as a dual-purpose processing tomato. Four hybrid tomatoes developed out of AVRDC processing tomato lines which yielded more than 60 t/ha have been promoted for production in Northern China. These are: Hongzha #10, Hongzha #12, Hongzha #16 and Hongzha #20. Both Hongzha #16 and Hongzha #20 are currently being extensively used as the major processing tomato cultivars in Xinjiang Autonomous Region. Another AVRDC line selected for direct or extension use in Southern China was TM 103 F_1. During summer it outyielded the local variety Xia Xing by 108% in Guangdong Province.

Though not superior to the national variety Xushu #18, AVRDC sweet potato lines have higher protein and carotene contents. Considering yield level and other objectives of the sweet potato program of China, the AVRDC lines cannot be directly released to farmers. However, many valuable genetic characteristics present in AVRDC lines can be utilized such as multiple resistance to diseases and insects from CI 412-2, high carotene content from CI 415, CI 35-2, CI 591-51 and noncompact plant type of CN R80-3.

The AVRDC-developed Chinese cabbage appealed to Chinese farmers because of its heat tolerance, early maturity, disease resistance, excellent eating quality and attractive head shape. To promote nationwide planting of this Chinese cabbage variety, seeds of Hybrid #62, Hybrid #58 and Hybrid #59 were produced and disseminated throughout China. During 1986–87, a total of 272 kg hybrid seeds have been produced with profits of US$2.01 million. In 1990, 2 t of hybrid seed of #62, the heat-tolerant AVRDC Chinese cabbage, were produced in Nanjing by the cooperating institute—Jiangsu Academy of Agricultural Sciences alone. The total planting area of AVRDC summer Chinese cabbage now reached more than 1,333 ha in China, giving a reported total profit of US$2.5 million. In addition to the success of direct utilization, the Chinese researchers had also done tremendous work on the use of Chinese cabbage lines in their

crossing activity. Varieties from AVRDC lines of Chinese cabbage, tomato and mungbean released in China are listed in Tables 11 and 12. As reported by a former Chinese training scholar at AVRDC-TOP, 3500 kg of Hybrid #62 seeds have been distributed to farmers to date. The target for 1992 seed production for this variety is 7500 kg. The introduction of AVRDC mungbean materials in China was successful and had considerable impact on Chinese agriculture.

Table 11. AVRDC Chinese cabbage varieties released in China.

AVRDC Line	Local Name	Releasing Agency
Hybrid #58	FU Bao	Jiangsu AAS
	Nai Re #1	Guangdong AAS
	Xia Bai 58	Sichuan AAS
Hybrid #62	Xia Teng	Jiangsu AAS
	Nai Re #2	Guangdong AAS
	Xia Bai 62	Sichuan AAS
Hybrid #59	Nai Re #3	Guangdong AAS
	Xia Bai 59	Sichuan AAS
77M (2/3)-41-0-2-0-0	Nai Re #4	Guangdong AAS

Table 12. AVRDC tomato and mungbean varieties released in China.

Crop	Location	AVRDC Lines	Local Name
Tomato	Beijing[a]		Hongzha #12
			Hongzha #20
			Hongzha #10
			Hongzha #16
	Chengdu	PT 4098	PT 4098
		PT 4172	PT 4172
		PT 4071	PT 4071
	Guangdong[a]		Co 39-3 F_7
			Co 39-4 F_1
		TM 103 F_1	TM 103
Mungbean	Xuzhou	VC 1973 A	Xuyin #1
	Beijing	VC 1973 A	Zhong Lu #1
	Hubei	VC 2778 A	Er Lu #2
		VC 1381	V 1381
	Jiangsu	VC 2768 A	Su Lu #1
		VC 2917 A	VC 2917 A
	Guangdong	VC 2768 A	Yue Yin #1
			Yue Yin #2

[a]One of the AVRDC lines used as one of the parents in crossing work.

Considered as a minor crop in China, mungbean is now fast gaining wide acceptance. It was dubbed as the crop for prosperity. In addition to the outstanding VC 1973 A which was released in different parts of China under different local names such as Xuyin #1 and Zhong Lu #1, VC 2768 A, VC 2719 A, and VC 8061 A were already in line for promotion by the Chinese agricultural institutions. VC 2778 A has recently been released in Hubei as Er Lu #2. Feedback from counties where extensive plantings were conducted both in Hubei and neighboring provinces showed Er Lu #2 to have wide adaptability, high yield, superior eating and commodity qualities, high resistance to Cercospora leaf spot and other diseases. The average reported yield for this variety is 1.7 t/ha, 64.2 % higher than that of the high yielding local variety, for a total cumulative yield increase of 32,070 t in the provinces promoted, giving an added economic value of US$14,108,280. In Jiangsu Province, VC 2768 A was officially released as Su Lu #1 in 1990 and, VC 2917 A was recommended to be released soon as a superior mungbean variety especially suited for mechanization. In other areas of China, most of the outstanding AVRDC mungbean lines gave an average yield of more than 1.5 t/ha, with the highest at 4.0 t. A considerable amount of mungbean germplasm is being sent to China each year, making China a potential mungbean exporter.

Training/personnel development. A total of 25 researchers and extension workers have undergone the 5-month regional training course in vegetable production and research at AVRDC-TOP during phase II of this project. This brings the total number of Chinese researchers/extension agents to 56 since the project's inception in 1983. These training scholars came from Beijing, Tianjin and in the province of Heilongjiang, Jiangsu, Shandong, Sichuan, Guangdong, Yunnan and Xinjiang. Most of these trained scholars are now responsible members of vegetable and legume research teams in their respective institutions. At AVRDC-TOP, they worked on various crops and disciplines, learning the rudiments involved in vegetable production techniques which they could apply in their country. Besides IDRC, GTZ of Germany also provided support to some scholars. With the addition of two more cooperating provincial Agricultural Academies and pepper as a newly added crop of AVRDC for trials, a number of researchers still need to be trained to bring the personnel profile of vegetable research in China to an adequate level. In this report, nine researchers from different parts of China are now undergoing the 10th Regional Training Course which started on 15 October 1991.

Workshops, symposia and meetings. Several leading Chinese researchers participated in a number of important international workshops outside China through this project. Their participation fostered exchange of scientific knowledge and information among prominent researchers from AVRDC headquaters and other countries. Symposia and meetings within China were also held.

Germplasm exchange. The exchange of genetic materials between Chinese agricultural institutions and AVRDC through AVRDC-TOP is carried out continuously. A considerable amount of vegetable germplasm from China has been given by the Chinese Academy of Agricultural Sciences (CAAS) to AVRDC scientists during their visits to China. In addition, large amounts of materials have been brought to AVRDC-TOP through the training scholars who may include these materials in their research activities at AVRDC-TOP.

Likewise, China received AVRDC's elite lines for breeding and testing purposes. Some 200 sets of accessions and 150 sets of breeding materials for all AVRDC's mandated crops have been sent to date. Those that could not be directly utilized were used in crossing and hybridization under the breeding program. Several outstanding lines from AVRDC breeding materials have already been developed by the Chinese researchers.

Technical/scientific information exchange. Scientific information exchange is a continuing activity between AVRDC-TOP and the Chinese agricultural institutions. AVRDC-TOP has been receiving scientific publications either in Chinese or in English from the cooperating institutions in China. In return, AVRDC and AVRDC-TOP, through the latter, regularly send to the cooperating agencies AVRDC's scientific reports, publications, bulletins and newsletters which provide Chinese researchers with new information concerning vegetable research and production.

Surveys of major diseases. Surveys on soybean, tomato, and pepper diseases in the experimental plots and in the farmers' fields in Beijing, Xuzhou, Nanjing, Wuhan, Chengdu, Guangzhou and Xinjiang were conducted in 1989. From these preliminary surveys, priorities of intensive disease surveys and strategic control measures were identified. Through a series of meetings and discussions between the AVRDC-TOP scientist and the local scientists, preliminary surveys on soybean rust caused by *Phakopsora pachyrizi* and on virus diseases of tomato were later conducted in several Central and Southern provinces of China. The soybean rust survey was organized and led by the Oilseed Crops Research Institute of the Chinese Academy of Agricultural Sciences (CAAS) in Wuhan, while the Vegetable and Flower Research Institute of the CAAS in Beijing and the Vegetable Research Institute of the Jiangsu Academy of Agricultural Sciences (JAAS) in Nanjing led and coordinated the national survey on virus diseases of tomato, primarily concerned with TMV and CMV.

An initial workshop on recognition of the importance of soybean rust in China, co-sponsored by this project, was held in Wuhan, China on 22–27 March 1991. Scientists from AVRDC-TOP, the Oilseed Crop Research Institute, and cooperating institutions from the provinces of Hubei, Hunan, Yijian, Guangdong, Guangxi, Yunnan, Guizhou, Jilin and Shanxi participated during the workshop. National research strategic measures and survey standards as well as networking in China for soybean rust studies was discussed and organized during the workshop. Although the priority of conducting such a survey was recognized by the Chinese government, the implementation of these activities still needs further support and cooperation from all agencies concerned.

AVRDC/TOP-Vietnam

A strong program on testing of AVRDC-generated technologies and materials is being carried out in Vietnam. Twenty-six researchers from Vietnam have undergone the 5-month training course in vegetable production in AVRDC-TOP and four more have been training under the 10th RTP. These researchers carried out testing of AVRDC materials in Vietnam. Most of these trainees have come out with vegetable cultivars developed out of AVRDC lines suitable for local conditions. This sentiment was expressed by the Vietnamese Deputy Minister of Agriculture and its Deputy Director of International Cooperation during meetings with AVRDC officials.

Through the training scholars, visiting Vietnamese agricultural officials and the unofficial scientific exchange channels, germplasm exchange has been carried out between different agricultural institutions in Vietnam and AVRDC-TOP. Since 1987 several AVRDC mungbean, soybean, tomato and Chinese cabbage lines have been released for national production by the different cooperating institutions. As reported last year, a new tomato variety, #12, developed from AVRDC's CL 5915-223 D4-2-1-0, was released in 1989 by the Ho Chi Minh City Seed Multiplication Center for farmers' use in South Vietnam. This variety was also found promising in the North. The 1990-91 winter-spring trials found the following lines with high yield and resistance to leaf curl virus to be promising: CL 143-0-10-3-1-10, CL 5915-93 D4-1-0-3, CL 591593 D4-1-0-12 and CL 604 BC 3F2-51-0-20-5-15-14-1. The promising lines for spring-summer plantings with high and stable yield of 2555 t/ha and high leaf curl virus resistance were: CL 1131-0-0-13-06, CLN 657 BC1F2-267-0-3-1-4, CLN 657 BC1F2-285-0-20-0-24 and CL 5915-206 D4-2-2-0.

Trials conducted by Dr. Yo-Tong Yuan on 13 AVRDC sweet potato lines revealed that all of these CN lines were highly susceptible to sweetpotato weevil. However, they were very high yielders compared to the local varieties. Sweet potato is extensively used in South Vietnam in rotation with other cash crops. Its production poses no great problem but its marketability does.

Legume production in Vietnam has gone a long way. Several research institutes/agencies, both in the South and in the North, have been doing extensive work in legume production, especially soybean and mungbean leaders of legume research in Vietnam are the Legume Research and Development Center of the Institute of Agricultural Science, the Horticulture Technology Center in the north and Cantho University in the South. Several AVRDC soybean and mungbean varieties have been released both in the North and the South (Table 13). As reported by Cantho University officials, 50–60% of 9000 ha-mungbean planting area in the Mekong Delta is planted to AVRDC varieties which the farmers call Taiwanese or Japanese varieties. The newly released variety DX 135 or VC 3528 A, yields from 1.5 to 2.5 t/ha and is very tolerant to drought. This variety is now very popular in Ang Giang province. Although not officially released yet, VC 3178 A or V 87-13 is very promising for wide scale planting in Central Vietnam, with yields around 2 t/ha. In North Vietnam the two AVRDC mungbean varieties put into wide scale multiplication were VC 3664 A and VC 3738 A. They both showed high and stable yields with good tolerance to drought. Two more lines [VC 2768 A (044) and VC 2768 B (045)] have also been found resistant to diseases and extensively multiplied.

Table 13. AVRDC lines released in Vietnam.

Crop	Location	AVRDC line	Local Name
Tomato	South Vietnam	CL 5915-023 D_4-2-1-0	#12
Mungbean	Hau Giang/ Mekong Delta	VC 2768 A	DX-102 a
	"	VC 2763 A	DX-113
	"	VC 1560 D	DX-91
	Ang Giang*	VC 3528 A	DX-135
		VC 3178 A	V 87-13
		VC 3061 A	V 87-41
Soybean	North Vietnam	G 2261	AKO 3
		G 2261 (another selection)	AKO 5

*The newly released mungbean line by Cantho University found to be tolerant to drought and with yields ranging from 1.5 to 2.5 t/ha.

Soybean has been used as an intercrop with maize or planted after the rice crop. Due to many production constraints, the planting area dwindles every year. In 1991 only 20,000 ha were planted to soybean in the South compared to 70,000 ha in 1990. In the North it is much less. However, several AVRDC soybean lines have been released in the North for farmers to use. In the South, the promising AVRDC lines were AGS 147, AGS 129, G 87-1 and G 87-5. Several other lines are being tried under the ASET.

Hardworking researchers face many constraints in vegetable production in Vietnam, and the development of official cooperation between AVRDC and the Government of Vietnam would mean stronger research linkage between AVRDC and the different Vietnamese research institutes. As a result, greater assistance in terms of technology, information and personnel development could be provided by AVRDC. There is an excellent opportunity for further expansion and strengthening AVRDC's linkage with Vietnam. However, bilateral special project funding is required.

AVRDC/TOP-Bangladesh

AVRDC/TOP-Bangladesh cooperative program with USAID funding and led by Dr. M.L. Chadha as senior horticulturist/agronomist has been extended for another phase. Activities under this project are reported in a separate section of the AVRDC 1991 Annual Progress Report.

AVRDC/TOP-Cambodia

Cooperation between Cambodia and AVRDC-TOP is being considered. The Director was invited by UNICEF to visit Cambodia as consultant to the UNICEF Food Production Program. The strategies which he developed together with UNICEF officials and Cambodian agricultural researchers for home gardening and vegetable production activities being promoted are:

Home gardening program. Some 10–15 technicians will undergo an intensive training program at AVRDC-TOP, KPS to learn the: a) importance of home gardening, b) nutritional aspects of home gardening, c) setting up of a home garden, d) cultural practices for both introduced and indigenous vegetables and e) economic aspects of home gardening. To enable them to see actual home gardens they will also be given an opportunity to visit several home gardens in Thailand.

These trainees will in turn conduct the in-country training program in Cambodia. This in-country training will be a 3-week to 1-month intensive training of technicians and participating farmers. One or two resource persons from Thailand will be sent to Cambodia to alternately conduct the training for a period of 7-12 days each. These activities will be sponsored by UNICEF with AVRDC-TOP as the coordinating and training agency.

Vegetable production strategies. The Director/Resident Scientist of AVRDC-TOP met with the Deputy Minister of Agriculture and the Agriculture Directorates of the Ministry to discuss possible bilateral programs on the improvement of vegetable production in Cambodia. Some of the suggestions were: conduct of intensive research and yield trials for the development of vegetable varieties from AVRDC-improved materials suited to Cambodian conditions; establishment of a network with national, regional, and international agencies, i.e. AVRDC directly or through AVRDC-TOP, should be established to facilitate progress in all phases of vegetable production. Through this network the transfer of vegetable germplasm, and the introduction of new varieties possessing characteristics desirable to small farmers, growers and consumers could be promoted.

Personnel development. AVRDC-TOP had already trained three Cambodians in its 9th Training Course. They are back in Cambodia and involved in legume research and production. The other Cambodian who came from the Refugee Camp in Thailand is now busy teaching his fellow refugees the rudiments of vegetable production in preparation for repatriation to their country.

To sustain the project the Cambodian Government aimed to encourage a) attendance of technicians and researchers to the regular AVRDC-TOP Regional Vegetable Production and Research training programs; b) support of study tours to main vegetable producing countries in the region; c) conduct of seminars/workshops on important topics on vegetable/legume production, home gardening and nutrition, and, d) establishment of a technical information gathering program for vegetable research and production.

In Cambodia, the Resident Scientist identified the Gemini virus-incited mungbean yellow mosaic disease on a local mungbean variety in the mungbean field of Phnom Penh. His identification was later confirmed in the laboratory tests from the sampled specimens by Dr. Pisawan, a Thai virologist of Kasetsart University. This is the first reported incidence of the devastating mungbean yellow mosaic virus (MYMV) disease occurring in this region. The urgent and important research activities in Cambodia that need to be undertaken are: 1) development of disease-resistant and high yielding varieties, 2) integrated pest management, and 3) establishment and promotion of quality seed production.

AVRDC/TOP- Sri Lanka

The regional program has been offering special courses and study tours for Sri Lankan researchers and farmer cooperators for the last 2 years. Germplasm and scientific information exchange has been taking place. Sri Lankan scholars are routinely included in the regular AVRDC-TOP training program.

Other Activities

In 1991, AVRDC-TOP also was involved in several workshops and symposia in Thailand. These workshops were: 1) Thrips Workshop held in Rama Gardens, 13–14 March 1991; 2) International Workshop on Household Garden Projects, Rama Gardens, 13–15 May 1991; and 3) MYMV Working Group Meeting, Rama Gardens, 14–15 July 1991. AVRDC-TOP had also been involved in the workshop conducted by the Food and Fertilizer Technology Center (FFTC) in Chiang Mai, an activity related to the cooperative project between FFTC and Chiang Mai University on irrigation and mulching for vegetable production. In relation to that workshop, a tour of the AVRDC-TOP/KPS site was organized for the 34 participants.

In 1991, several visitors and study tour groups have visited the program. They were either briefed on the program activities of AVRDC-TOP, Bangkok or toured around the AVRDC-TOP Kamphaeng Saen site.

Appendices

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Ann Hwa, Manager, Food and Dormitory Services
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Teng-sheng Tu, B.S., Farm Superintendent

---

† Left during 1991
◊Leave without pay

Financial Statements

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The Board of Directors
The Asian Vegetable Research and
Development Center

We have examined the statements of assets, liabilities and fund balances of The Asian Vegetable Research and Development Center as of December 31, 1991 and 1990, and the related statements of changes in core fund balances, operating expenditures of core fund, and changes in special project fund balances for the years then ended Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

As mentioned in Note 2 to the financial statements:

1. The Center maintains its accounts on a cash basis, except for the inclusion of reserves and the corresponding provisions for unused compensated annual leave and repatriation expenses

2. Capital expenditures are charged off as deductions from funds and, accordingly, are not included among the assets in the accompanying statements of assets, liabilities and fund balances

3. The Center records its transactions in the currencies in which these are denominated The accompanying statements reflect the actual U.S. dollar amounts of transactions in U S dollars, and the U.S dollar equivalents of transactions in other currencies translated, for convenience, at the year-end bank buying exchange rates, except contributions and grants which are translated at the exchange rates in effect when these were received.

In our opinion, the financial statements referred to in the first paragraph present fairly the assets, liabilities and fund balances of The Asian Vegetable Research and Development Center as of December 31, 1991 and 1990, and the changes in its funds for the years then ended, on a consistent basis of accounting as described in the second paragraph.

In connection with our examinations, we noted no indication that the Center was not in compliance with any of the terms, conditions, or provisions of the grant agreements. It should be noted, however, that our examinations were not directed primarily toward obtaining knowledge of such non-compliance.

T. N. Soong & Co

March 2, 1992

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF ASSETS, LIABILITIES AND FUND BALANCES
December 31, 1991 and 1990
(Prepared on a Modified Cash Basis and
Expressed in U.S. Dollars - Note 2)

A S S E T S	1991	1990
CASH	$4,302,634	$3,289,702
ADVANCES AND REFUNDABLE DEPOSITS	32,553	61,429
PREPAYMENTS TO INSTITUTE OF INTERNATIONAL EDUCATION (Note 3)	51,574	43,390
TOTAL ASSETS	$4,386,761	$3,394,521
LIABILITIES AND FUND BALANCES		
RECEIPTS FOR CUSTODY (Note 4)	$ 288,834	$ 235,566
RESERVE FOR EMPLOYEE BENEFITS (Notes 2 and 3)		
Unused compensated annual leave	761,128	700,549
Repatriation expenses	360,876	347,764
	1,122,004	1,048,313
FUND BALANCES		
Core fund	1,283,676	1,247,286
Working capital fund (Note 2)	400,000	-
Restricted core fund (Note 5)	417,501	52,466
Special project funds (Note 6)	874,746	810,890
	2,975,923	2,110,642
TOTAL LIABILITIES AND FUND BALANCES	$4,386,761	$3,394,521

The accompanying notes are an integral part of the financial statements.

(With T. N. Soong & Co. report dated March 2, 1992)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN CORE FUND BALANCES
For the Years Ended December 31, 1991 and 1990
(Prepared on a Modified Cash Basis and Expressed in
U S. Dollars - Note 2)

	1991		1990	
ADDITIONS				
Contributions:				
Republic of China (ROC)	$4,241,098		$4,129,104	
United States of America (Note 7)	1,000,000		1,209,758	
Federal Republic of Germany - Expenditures incurred in restricted core fund	290,206		268,476	
Japan	433,000		470,000	
World Bank	350,000		350,000	
Thailand	212,096		205,987	
Republic of Korea	139,280		-	
Philippines	-		100,000	
France	86,431		90,171	
Australia	87,571	$6,839,682	90,080	$6,913,576
Grants:				
Project support from Japan International Cooperation Agency (Note 2)	55,300		79,300	
Taiwan Kagome Co., Ltd.	1,167	56,467	-	79,300
Translation adjustment (Note 2)		202,758		(69,247)
Other income (Note 8)		709,500		706,410
Total Additions		7,808,407		7,630,039
DEDUCTIONS				
Capital expenditures (Note 2)				
Equipment and furniture		182,862		312,029
Vehicle equipment		-		131,078
Building and improvement		54,538		-
Books and journals		33,135		29,181
		270,535		472,288
Operating expenditures		7,128,717		6,927,625
Transfer to working capital fund (Note 2)		400,000		-
Total Deductions		7,799,252		7,399,913
INCREASE IN FUND BALANCE		9,155		230,126
BALANCE, BEGINNING OF YEAR				
As previously reported		1,247,286		1,032,177
Translation adjustment (Note 2)		27,235		(15,017)
As Restated		1,274,521		1,017,160
BALANCE, END OF YEAR		$1,283,676		$1,247,286

The accompanying notes are an integral part of the financial statements.

(With T. N. Soong & Co. report dated March 2, 1992)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF OPERATING EXPENDITURES OF CORE FUND
For the Years Ended December 31, 1991 and 1990
(Prepared on a Modified Cash Basis and Expressed in
U.S. Dollars - Note 2)

	1991	1990
Salaries	$3,154,367	$2,905,742
Regular wages	1,187,363	1,127,362
Benefits for staff	1,125,820	1,346,230
Supplies	547,854	621,289
Utilities	212,762	188,095
Travel	394,782	275,351
Training scholarships	138,767	119,709
Postage, telephone and cable	84,132	60,087
Repairs and maintenance - vehicles	43,679	25,824
Provision for unused compensated annual leave (Notes 2 and 3)	29,290	17,342
Moving expenses	17,146	64,096
Gasoline	32,162	31,783
IIE administrative expenses	25,442	18,137
Entertainment and recreation	25,556	7,156
Insurance - vehicles	14,758	15,831
International conference	75,683	85,540
Freight and landing service	14,060	13,772
Miscellaneous	5,094	4,279
Total	$7,128,717	$6,927,625

The accompanying notes are an integral part of the financial statements.

(With T. N. Soong & Co. report dated March 2, 1992)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN SPECIAL PROJECT FUND BALANCES
For the Years Ended December 31, 1991 and 1990
(Prepared on a Modified Cash Basis and Expressed in
U.S. Dollars - Note 2)

	1991	1990
ADDITIONS (Note 6)		
Council of Agriculture (COA)/ROC	$1,110,408	$ 724,576
Japan Shipbuilding Industry Foundation	-	590,000
German Agency for Technical Cooperation	-	103,500
Asian Development Bank (ADB)	556,762	100,000
US AID	91,984	21,494
International Development Research Center (IDRC)	74,138	26,089
National Science Committee (NSC)	72,300	-
Training scholarships	50,500	96,015
International Board for Plant Genetic Resources (IBPGR)	140	6,475
Others	147,080	122,862
Total Additions	2,103,312	1,791,011
DEDUCTIONS		
Operating expenses	1,504,392	1,357,907
Capital expenditures (Note 2)	545,200	307,675
Total Deductions	2,049,592	1,665,582
INCREASE IN FUNDS	53,720	125,429
FUND BALANCES, BEGINNING OF YEAR		
As previously reported	810,890	696,023
Translation adjustment (Note 2)	10,136	(10,562)
As Restated	821,026	685,461
FUND BALANCES, END OF YEAR	$ 874,746	$ 810,890

The accompanying notes are an integral part of the financial statements.

(With T. N. Soong & Co. report dated March 2, 1992)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS
December 31, 1991 and 1990
(Amounts Expressed in U.S. Dollars Unless Otherwise Stated)

1. ORGANIZATION AND OPERATIONS

The Center was established in the Republic of China as an autonomous, philanthropic, and non-profit research and development organization for promoting production, marketing and utilization of vegetables in Asia. The members of the Center consist of the countries or organizations approved for membership by the Center's Board of Directors.

The financial requirements of the Center are funded by contributions and grants or donations from member and non-member countries or organizations.

The Center may terminate its operations by a resolution adopted unanimously by all members of the Board of Directors. In case the Center terminates its operations, all buildings, equipment and other assets belonging to the Center (and/or the affiliated sub-centers) will be transferred, upon the concurrence and approval of the Board of Directors and host country, to organizations in the host country which were formed and are operated exclusively for scientific or educational purposes, and which meet certain conditions prescribed in the Center's Charter.

2. SIGNIFICANT ACCOUNTING POLICIES

Accounting basis of financial statements

The Center maintains its accounts on a cash basis, except for the inclusion of reserves and the corresponding provisions for unused compensated annual leave and repatriation expenses.

Capital expenditures

Capital expenditures are charged off as deductions from funds and, accordingly, are not included among the assets in the accompanying statements of assets, liabilities and fund balances.

Translations

The Center records its transactions in the currencies in which these are denominated. The accompanying statements reflect the actual U.S. dollar amounts of transactions in U.S. dollars, and the U.S. dollar equivalents of transactions in other currencies translated, for convenience, at the year-end bank buying exchange rates, except contributions and grants which are translated at the exchange rates in effect when these are received. Translation adjustments are reflected as additions to or deductions from the funds.

Employee benefits

Contributions to employees' benefits, consisting of retirement benefits, unused compensated annual leave are charged off as deductions from the funds when paid or accrued.

Working capital fund

In 1991, the Center, following a common practice among international agriculture research centers, established an initial working capital fund of US$400,000. The Center plans to gradually increase the working capital fund over the years from excess of revenues over operating expenditures of the core fund.

3. EMPLOYEE BENEFITS

Retirement plan

The Center has made arrangements for its senior staff members to be hired by the Institute of International Education (IIE) so that they may participate in suitable retirement and group insurance plans. The Center pays the entire cost of participation in the retirement and group insurance plans. As requested by IIE, certain payments for non-American senior Staff have been made to IIE quarterly not later than 15 days prior to the commencement date of each quarter. The staff member can receive the benefits under the plan only after he reaches retirement age, even though he may leave the Center earlier

The Center has a retirement savings plan covering all of its local employees. Under the retirement benefit the Center deposits 1/12 to 2/12 of the employee's monthly salaries, based on the service period of the employee to a savings account. Withdrawal of funds by the employee from the plan is permitted under certain conditions. The changes in the fund balance follow:

	1991	1990
Beginning of Year	$1,147,072	$ 884,824
Translation adjustment	60,701	(30,737)
Contribution	394,904	353,249
Interest income	175,563	12,162
Payment	(39,267)	(72,426)
End of Year	$1,738,973	$1,147,072

Reserve for unused compensated annual leave

Under Section 8 of the Information and Conditions of Service for Regular Staff, the Center shall calculate, at the end of each fiscal year, the annual leave to the credit of its employees up to a maximum of 44 days for local employees and 48 days for international staff depending on their available unused annual leave. The Center shall compensate an employee for unused annual leave to his credit upon his resignation or termination.

Reserve for repatriation expenses

In accordance with the professional personnel policy of the Center, when the employment of an international staff is terminated, the Center is liable for the transportation and relocation costs of his immediate family. The Center sets up a reserve of up to about $361,000 for such repatriation expenses.

4. RECEIPTS FOR CUSTODY	1991	1990
Self-sustaining operation fund	$132,529	$122,696
Other	156,305	112,870
	$288,834	$235,566

5. RESTRICTED CORE FUND	1991	1990
Balance, Beginning of Year		
As previously reported	$ 52,466	$ 52,772
Translation adjustment	(24)	5,944
Restated Balance	52,442	58,716
Addition	655,265	262,226
Expenditures	(290,206)	(268,476)
Balance, End of Year	$417,501	$ 52,466

This contribution is made through the German Agency for Technical Cooperation. This fund is placed under certain restriction as to its use. Expenditures of this fund are reflected as part of contributions and deductions to Core Fund.

6. SPECIAL PROJECT FUNDS

These include funds provided by various project sponsors of specific projects including AVRDC vegetable variety and cultivation improvement project (by Council of Agriculture/ROC); vegetable production training program (by JSIF); tropical vegetable information service and vegetable project (by IDRC); regional training program and collaborative vegetables research program (by ADB); collaborative vegetables research network in Southern Africa (by GTZ); and studies of heat to tolerance mechanisms of fruit set and quality of fruits (by NSC) etc.

Contributions to restricted core fund and special project funds require the fulfillment of certain conditions and terms as set forth in the signed agreements regarding the restrictions in exclusive use of stipulated budget items, etc.

7. CONTRIBUTION BY UNITED STATES OF AMERICA

The annual contribution of the United States of America is made through a grant from the US Agency for International Development (US AID). Funds provided by this grant are to be used exclusively in support of the Center's Core budget, subject to certain terms and conditions specified in the grant agreement. For 1989, the balance of $209,758 for the USAID approved grant was received in January 1990, and was treated as 1990 contribution.

8. CORE FUND - OTHER INCOME

	1991	1990
Income from various services rendered	$258,920	$290,284
Income on training overhead and fund balance	58,341	56,800
Refunds of various expenditures incurred in previous years	16,066	36,766
Interest earned from funds other than US AID grants	233,067	224,839
Income on sales of field products	27,527	35,163
Food and dormitory services	46,497	37,396
Miscellaneous income	69,082	25,162
	$709,500	$706,410

The income from food and dormitory services excludes employees' salaries and benefits of $201,676 for 1991 and $198,911 for 1990.

9. CONTINGENCY

In 1989, the US AID supported AVRDC Vitamin A Gardening Project in Niger was charged in court by some Nigerien merchants for recovery of merchandise ordered from the merchants by the embassy employee using the Project's stationery. Much of the merchandise has been recovered by the merchants, but the lawsuit is still pending. The Center has retained the services of local counsel to handle this case. The response of the local counsel on the possible outcome of the litigation and its implication to the Center has not been received. Management believes no significant loss will be incurred by the Center.

Meteorological Information for 1991

1991 Monthly meteorological data collected at AVRDC weather station.

	Month	January	February	March	April	May	June	July	August	September	October	November	December
Humidity	Mean	98	98	98	98	98	7	98	98	98	99	99	100
%	Mean	66	68	71	2	71	72	75	77	76	76	73	65
Air temp.	Mean	22 8	22.9	26.8	28.2	30 8	32.4	32 3	32.0	31.1	28.5	25 9	23.8
%	Mean	13.4	13.6	17.7	19.5	22 3	24.5	25 0	25 2	23 9	20.3	17.1	14.2
Soil temp.	Mean	23.9	23.3	26.6	28.8	32.5	33.5	32 1	32 3	31.0	29.1	25.6	23.0
%	Mean	20.8	20.1	23.5	25.5	28.7	30 0	29.7	30 3	29.7	27.3	23.9	21.4
Soil temp.	Mean	23 9	23.3	25.8	28.1	31.3	33 3	32.8	33.4	32.7	30 6	27.7	25.5
%	Mean	23 4	22.6	25.3	27.5	30.8	32 6	32.3	33.0	32.2	30 2	27 3	25.1
Wind km	Daily mean	103	99	101	79	84	109	85	58	76	68	-[a]	78
Solar rad Watt-h/m²	Daily mean	3482	4014	4503	5142	6108	5321	5331	5648	4315	4059	3608	3389
Prec. mm	Total	22	28	4	24	22	684	617	92.3	67	14	17	34
Evapo. mm	Daily mean	3.4	3.9	5.0	5.5	6.9	7.9	6.2	5.8	4.8	4.2	3.5	3.2

[a]No data