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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
ADF — acid detergent fiber
ADRC — Agricultural Development Research Center (Northeast Thailand)
a.i. — active ingredient
AMV — alfalfa mosaic virus
ANOVA — analysis of variance
ARTT — advanced soybean rust tolerance trials
ASEAN — Association of Southeast Asian Nations
ASET — AVRDC Soybean Evaluation Trials
ATER — area time equivalency ratio
ATI — Agricultural Training Institute (Philippines)
AUDPC — Area under disease progress curve
ARC — AVRDC Asian Regional Center
AVNET — Collaborative Vegetable Research Program for Southeast Asia
AVRDC — Asian Vegetable Research and Development Center
AVSET — AVRDC Vegetable Soybean Evaluation Trials
Avg. — average
AYT — advanced yield trial
BADC — Bangladesh Agricultural Development Corporation
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)
BSHS — Bangladesh Society for Horticultural Science
BSU — Benguet State University (Philippines)
Bt — *Bacillus thuringiensis*
BW — bacterial wilt
CAAS — Chinese Academy of Agricultural Sciences
CAMV — cowpea aphid-borne mosaic
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
CHC — cabbage head caterpillar
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 Mejoramiento de Maíz y Trigo
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
CR — common region
CRIH — Central Research Institute for Horticulture (Indonesia)
CSIRO — Commonwealth Scientific Industrial Research Organization (Australia)
CTA — Technical Centre for Agricultural and Rural Co-operation (EC)
CTL — control theshold level
cv. — cultivar
c.v. — coefficient of variation
CVMV — chili veinal mottle virus
DAC — double antigen coating
DAE — days after emergence
DAI — days after inoculation
DAIS — District Agricultural Improvement Station (Taiwan)
DAS — days after sowing
DAT — days after transplanting

DBM — diamondback moth
diam — diameter
DM — downy mildew
DMRT — Duncan's multiple range test
DNA — deoxyribonucleic acid
DOAE — Department of Agricultural Extension (Thailand)
DSR — disease severity ratings
DWB — dry weight basis
EC — electric conductivity
EEC — European Economic Community
EDTA — ethylenediaminetetraacetic acid
DAS ELISA — double antibody sandwich
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
FLSD — Fisher's least significant difference
FMTT — fresh market tropical tomato
FMV — feathery mottle virus
GCLV — garlic common latent virus
GIS — Geographic Information System
GRSU — Genetic Resources and Seed Unit
GTZ — German Agency for Technical Cooperation (Germany)
GYT — general yield trial
HPLC — high performance liquid chromatography
HS — heat-sensitive
HSI — head shape index
HSP — heat shock protein
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)
IBWDN — International Bacterial Wilt Disease Nursery
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
ID — internal diameter
IDIAP — Instituto de Investigación Agropecuaria de Panamá
IDRC — International Development Research Centre (Canada)
IEM — immuno-electron microscopy
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 Centre for Africa (CGIAR)
ILRAD — International Laboratory for Research on Animal Diseases (CGIAR)
IMN — International Mungbean Nursery (AVRDC)
IMPMN — International Mungbean Powdery Mildew Nursery (AVRDC)
IMYMVN — International Mungbean Yellow Mosaic Virus 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)
ISEM — immunosorbent electron microscopy
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)
LI — light interception
LYSV — leek yellow stripe virus
MAb — monoclonal antibody
MAFF — Ministry of Agriculture, Forestry and Fisheries (Japan)
MARDI — Malaysian Agricultural Research and Development Institute
MARIF — Malang Research Institute for Food Crops (Indonesia)
m asl — meters above sea level
MYMV — mungbean yellow mosaic virus
NAR — net assimilation rate
NARC — Nepal Agriculture Research Council
NARS — national agricultural research systems

NBPGR — National Board for Plant Genetic Resources (India)
NC — nitrocellulose
NIAB — Nuclear Institute of Agriculture and Biology
NIRS — near-infrared reflectance spectroscopy
NGO — Nongovernment organization
NPGRL — National Plant Genetic Resources Laboratory (Philippines)
OP — open-pollinated
OPC — Office of Publications and Communications
OYDV — onion yellow dwarf virus
OYT — observational yield trial
PBNV — peanut bud recrosis virus
PCARRD — Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PCR — polymerase chain reaction
PDA — potato dextrose agar
PDAF — Provincial Department of Agriculture and Forestry (Taiwan)
PE — polyethylene
PeMV — pepper mottle virus
PMMV — pepper mild mottle virus
POME — palm oil mill effluent
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
RAPD — random amplified polymorphic DNA
RDA — Rural Development Administration (Rep. of Korea)
RFLP — restriction fragment length polymorphism
RGR — relative growth rate
RH — relativo humidity
ROC — Republic of China
ROI — return on investment
RTI — rust tolerance index
RYT — regional yield trial
SABRAO — Society for the Advancement of Breeding Researches in Asia and Oceania
SAI — stem area index
SAVERNET — South Asian Vegetable Research Network
SD — standard deviation
SDC — Swiss Development Council
SDI — selective dissemination of information
SEC — standard error of calibration
SED — standard error of deviation
SEP — standard error of prediction
SLV — shallot latent virus
SPFMV — sweet potato feathery mottle virus
SPLCV — sweet potato leaf curl virus
SPLV — sweet potato latent virus
SPV II — sweet potato virus II
SPYDV — sweet potato yellow dwarf virus
SRI — soybean rust infection
SSD — single seed descent
STI — stress tolerance index
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
TLCV Tai — Taiwan tomato leaf curl virus
TMGMV — tobacco mild green mosaic virus
TMV — tobacco mosaic virus
TOA — tomato oatmeal agar
ToMV — tomato mosaic virus
TSIPS — Taiwan Seed Improvement and Propagation Station
TTC — triphenyl tetrazolium chloride
TTLCV — Taiwan tomato leafcurl virus
TSWV — tomato spotted wilt virus
TuMV — turnip mosaic virus
TVDF — Tropical Vegetable Data File (AVRDC)
TYLCV — tomato yellow leaf curl virus
TVMV — tobacco vein mosaic virus
UCNCT — upland crop national cooperation trial
UNDP — United Nations Development Programme
UNICEF — United Nations International Children's Educational Fund
UPLB — University of the Philippines at Los Baños
UPM — Universiti Pertanian Malaysia
USAID — United States Agency for International Development

Crop Improvement Program

Allium Breeding

Strategies for Allium Improvement

Summary

Based on the literature, status papers presented at the International Symposium on Alliums for the Tropics. and the survey report on onions in the tropical regions (1990) conducted by the Natural Resources Institute, U.K., problem areas identified which deserve high priority in the allium improvement project are resistance to: (1) purple blotch and Stemphylium blight in onion, garlic, and shallot crops; (2) viruses (onion yellow dwarf virus [OYDV], leek yellow stripe virus [LYSV], shallot latent virus [SLV], and garlic latent virus [GLV]) for both garlic and shallots, and (3) thrips in onion, garlic, and shallot. Tolerance to abiotic stresses, viz., (1) high temperature (onion, garlic) and (2) high and low moisture stress (onion, garlic, and shallot) also need attention. Long storage life of bulbs is essential to reduce storage losses in the tropics. Early maturity in onion is required to make the crop more easily adaptable to various farming systems. Heterosis needs to be explored for improving productivity. Development of male sterile lines using sterility genes derived from tropical germplasm also needs to be initiated.

Seed production problems in onion, particularly in the tropics, are many and need attention. Work on flowering and seed set in garlic and developing shallot varieties which can be propagated by true seeds will also be initiated. To achieve all these objectives, special attention will be given to the enhancement of genetic resources in these crops. Provision of breeding lines both at early and advanced stages will receive highest priority at AVRDC to help national programs tackle area-specific problems. Cooperation from national programs and collaboration with international organizations are vital to the success of the programs at AVRDC.

Introduction

Onion, garlic, and shallot crops are widely grown in the tropics. Onion is the second most important crop among vegetables after tomato. Tropical countries invariably suffer from low productivity in all these crops. Several biotic and abiotic factors adversely affect the productivity in the tropics.

Recognizing the importance of alliums in the tropics, AVRDC has included them in its list of priority crops to work for their overall improvement.

During the first year, the most urgent and essential task of the allium improvement project was to establish a sound breeding goal, setting practical objectives based on the crop situation and problems faced by these crops in major target areas, besides defining priorities based on the available resources and prevailing environmental factors. The information collected from various sources has lead to the development of a sound improvement project for these crops.

Sources of Information

Information was collected from several sources such as:

(1) Presentations and discussions regarding status papers of participants from several countries during the International Symposium on Alliums for the Tropics held at Bangkok, Thailand, on 15-19 February 1993 (table 1);
(2) Literature survey, including monographs and review papers on related subjects;
(3) Survey report on "Onions in the Tropical Regions" (1990) by Lesley Currah and Felicity Proctor

The survey report on "Onions in the Tropical Regions" (1990) includes responses from 46 countries and was quite useful in identifying constraints in onion production in tropical countries.

The International Symposium on Alliums for the Tropics coorganized by AVRDC and serveral international and national organizations helped identify problem areas in onion, garlic, and shallot crops mainly in the tropics. Status reports from 21 countries, which cover majority of the target areas for AVRDC's activities, were presented during the symposium (table 1).

Table 1. Status papers presented on production constraints during the International Symposium on Alliums for the Tropics, February 1993

No.	Country	Title	Authors
1	Argentina	Onion breeding in Argentina	C. Galmarini
2	Bangladesh	Status of *Allium* production in Bangladesh	A.K.M. Amzad Hossain and Md. Zamiul Islam
3	China	*Allium* production and research in China	Xu Peiwen et al.
4	India	Status of *Allium* production and research in India	M.L. Pandita
5	Indonesia	*Allium* production and research status in Indonesia	A.H. Permadi
6	Iran	Evaluation of onion production in Iran and its problems	Ahmad Saffarian
7	Malaysia	Status of alliums in Malaysia	P. Vimala et al.
8	Myanmar	Production of alliums in Myanmar	Aye Thein
9	Nepal	Constraints of onion production and improvement/ Measures adopted by farmers in Nepal	K. Budathoki and S.P. Bhattarai
10	Pakistan	Production of alliums in Pakistan	M. Banaras Raja
11	Papua New Guinea	Onion production in Papua New Guinea	G.C. Wiles
12	Philippines	The status of alliums in the Philippines	Ester L. Lopez and E.A. Anit
13	Reunion Island	Allium production in Reunion Island	J.C.Girard et al.
14	Sahelian countries of Africa	Onion production and constraints in Sahelian countries of Africa	W.O. Baudoin et al.
15	Senegal	Onion varieties in vegetable cropping systems in Senegal	J. Pages
16	South Africa	Onion breeding in South Africa	C. Bester and J.J.B. Vanzijl
17	Sri Lanka	Production of alliums in Sri Lanka — prospects and constraints	U.R. Sangakkara
18	Taiwan	The progress and problems of *Allium* crops in Taiwan	Chao-Hsiung Lin
19	Tanzania	Status of *Allium* production in Tanzania	T.A. Mtaita and D. Msuya
20	Thailand	The status of alliums in Thailand	S. Sukhontasing and C. Parnutat
21	Zimbabwe	Onion production and constraints in Zimbabwe	J.M. Made

Literature covering the general situation of the crop and some important specific aspects were taken into consideration. The major sources of information in this category are listed in table 2. The information from these sources were quantified as indicators of the relative importance of problem areas for these crops.

Although onion, shallot, and garlic crops are horticulturally very distrinct from each other, these crops share diseases, insect pests, sensitivity to daylength, temperature, and other problems.

Table 2. Literature used to help identify priority problem areas and breeding objectives for allium

1. Bose, T.K. and Som, A.G. (eds.).1986.Vegetable Crops in India. Calcutta: Naya Prokash.
2. Currah, L. and Proctor, F.J. 1990. Onions in Tropical Regions. Bulletin No. 35. NRI Publication.
3. Eucarpia - proceedings of 4th Allium symposium. 1988. 6-9 September 1988, held at IHR, Warwick, U.K.
4. IBPGR .1982. Genetic resources of Allium species – a global report. AGPG/IBPGR/81/77/ IBPGR/FAO; Rome. 38 p.
5. Jones, H.A. and Mann, L.K. 1963. Onions and their allies. Leonard Hill: London.
6. Pathak, C.S. and R.V. Gowda. 1992. Onion improvement in India. Advances in Horticulture. Vol.V (eds.) Chadha, K.L. and Kalloo, G. Malhotra Publications: New Delhi, India.
7. Purseglove, J.W. 1985. Tropical crops; monocotyledons. New York: Longman.
8. Rabinowitch, H.D. and Brewster, J.L. (eds). 1990. Onions and allied crops. Volume I: Botany, physiology and genetics, 273 p. Volume II: Agronomy, biotic interactions, pathology and crop protection, 320 p. Volume III: Biochemistry, food science and minor crops, 265 p. Boca Raton, Florida: CRC Press.
9. Tindall, H.D. 1983. Vegetables in the tropics. London: Macmillan.
10. Yamaguchi, M. 1983. World Vegetables: Principals, Production and Nutritive Values. Westport, CT: AVI Publishing Co.

General Situation and Goals

Tropical countries produce about 30% (8.4 million t) of the world's onions grown on about 45% (0.9 million ha) of the world's arable land. Yields of tropical onions average about 9.5 t/ha, which is low compared to the 18 t/ha average in temperate zones. For garlic, tropical countries with about 39% (0.18 million ha) of the production area produce only 28% (0.8 million t) of the world's total production. Garlic yields are generally low (7.3 t/ha) but in tropical environments are particularly low (4.5 t/ha).

Another important crop in the allium group is shallot which performs well under tropical climatic conditions and often stores better than bulb onions. Yield levels of shallot are generally low (8.3 t/ha), but its market value is high compared to onions.

The need for improving the productivity of alliums in tropical environments is well documented.

The goal of the AVRDC allium improvement project, therefore, is to tackle production constraints through improved genotype, increased yield, stability, resistance to major diseases and pests, tolerance to high temperatures and water stresses, long storage life of bulbs suitable for growing in the tropics with major emphasis on the high humid tropics.

Major Production Constraints

Diseases are considered the most serious production constraints of onion, garlic, and shallot crops. Purple blotch (*Alternaria porri*), Stemphylium blight (*Stemphylium vesicarium*), and Anthracnose (*Colletotrichum gloeosporioides*) are considered serious problems (table 3). Virus diseases are considered the most important problems in garlic and shallots (table 6). Among the storage diseases of onion, black mold (*Aspergillus niger*) and bacterial pathogens are major problems. Thrips (*Thrips tabaci*) is believed to cause more damage than all other pests to alliaceous crops (table 4). Among the abiotic factors considered important for allium production in the tropics are high temperature and moisture stresses (both high and low) (table 5).

In onion, improved varieties (table 5) suitable for growing under tropical conditions are constrained by high temperature and short daylength. It is estimated that about half of the farmers in tropical developing countries use local seeds. These varieties, although acclimatized to the tropics, lack uniformity and produce many unmarketable bulbs like doubles, premature blotters, and thick necks. Seed production in onions is considered one of the most important problems in tropical countries. Storage capacity of bulbs is another major constraint in the tropics.

The choice of varieties is an important parameter which generally varies from one location to another. This also needs to be taken into consideration. In a breeding program such as AVRDC's which serves a wide region, it is important to identify not only the characteristics of most concern but also those most widely preferred.

Table 3. Importance of various onion diseases from different information sources

Diseases	Status papers presented at the *Allium* symposium[a]		Literature[b]
	Tropical Asia	Other regions	
Purple blotch	EH[d] (90)[c]	VH (54)	VH
Stemphylium blight	VH (40)	L (9)	VH
Black mold	VH (40)	M (18)	VH
Bacterial soft rot	H (30)	L (9)	VH
Anthracnose	H (30)	L (9)	H
Basal rot	H (20)	H (36)	H
Nematodes	L (10)	H (27)	H
Downy mildew	L (10)	H (27)	M
Pink root	(0)	H (45)	H

[a] International Symposium on Alliums for the Tropics, Thailand, 15-19 February 1993.
[b] Summarized from literature listed in table 2.
[c] Scores are based on the frequency and importance of the disease (100 = all participants [listed in table 1] rated the disease as the most important; 0 = no participant listed the particular disease).
[d] EH = extremely high; VH = very high; H = high; M = medium; L = low.

Table 4. Importance of major insect pests of onions from different information sources

Insect pests	Status papers presented at the *Allium* symposium[a]		Literature[b]
	Tropical Asia	Other regions	
Thrips	EH[d](90)[c]	VH (63)	VH
Beet army worm	H (30)	L (9)	H
Mites	M (20)	L (9)	M
Leaf miner	M (20)	L (0)	L
Head borer	L (10)	L (0)	L
Onion fly	L (10)	M (18)	M

[a]International Symposium on Alliums for the Tropics, Thailand, 15-19 February 1993.
[b]Summarized from literature listed in table 2.
[c]Scores are based on the frequency and importance of the disease (100 = all participants [listed in table 1] rated the disease as the most important; 0 = no participant listed the particular disease).
[d]EH = extremely high; VH = very high; H = high; M = medium; L = low.

Table 5. Importance of various production constraints in onion based on the data collected from different information sources

Constraints	Status papers presented at the Allium symposium[a]		Literature[b]
	Tropical Asia	Other regions	
Problems in seed production	VH[d](70)[c]	M (27)	H
Storage losses	VH (60)	VH (63)	VH
High temperature	VH (50)	M (18)	VH
Moisture stress	VH (40)	H (27)	H
Nonavailability of planting material	VH (40)	L (9)	H
Double bulbs	H (30)	H (27)	H
Nonavailability of early varieties	M (20)	M (18)	H
Premature bolting	L (10)	H (45)	M
Low dry matter	L (10)	M (18)	H

[a]International Symposium on Alliums for the Tropics, Thailand, 15-19 February 1993.
[b]Summarized from literature listed in table 2.
[c]Scores are based on the frequency and importance of the disease (100 = all participants [listed in table 1] rated the disease as the most important; 0 = no participant listed the particular disease).
[d]EH = extremely high; VH = very high; H = high; M = medium; L = low.

Table 6. Importance of various production constraints in garlic and shallot crops in tropical Asian countries based on information collected from different sources

Constraints	Status papers presented at the *Allium* symposium[a]		Literature[b]	
	Garlic	Shallot	Garlic	Shallot
Diseases				
Viruses	EH[d](70)[c]	VH (50)	EH	VH
Purple blotch	H (30)	M (20)	VH	H
Stemphylium blight	M (20)	L (10)	M	L
Anthracnose	(0)	L (10)	L	H
Pink root	(0)	L (10)	L	M
Nematodes	M (20)	L(0)	VH	M
Insect pests				
Thrips	VH (30)	VH (40)	VH	VH
Beet army worm	M (20)	M (20)	H	H
Mites	L (10)	(0)	H	L
Other				
Storage losses	M (20)	VH (40)	H	VH
High temperature	VH (30)	L (0)	VH	L
Moisture stress (High)	M (20)	M (20)	H	H

[a]International Symposium on Alliums for the Tropics, Thailand, 15-19 February 1993.
[b]Summarized from literature listed in table 2.
[c]Scores are based on the frequency and importance of the disease (100 = all participants [listed in table 1] rated the disease as the most important; 0 = no participant listed the particular disease).
[d]EH = extremely high; VH = very high; H = high; M = medium; L = low.

In onion, bulb color, pungency, size uniformity, dry matter, and storage life are all equally important in the Asian tropics. Some countries prefer only red bulbs with high dry matter and more pungency, whereas others prefer yellow-skinned bulbs with sweet flavor. Long storage life is preferred by all; however, at present, lack of this trait in tropical onions leads to huge storage losses. Aside from having white colored bulbs, onions intended for dehydration should have high dry matter (>16%) and high pungency. Most of the white onion varieties grown in the tropics have low dry matter.

Early bulb maturity is another area where not much was done in the past. Most of the onion varieties at present take a minimum of 140 days for bulb maturity. An early variety maturing in less than 120 days with acceptable yield is desirable.

Available Genetic Variability

Onion (*Allium cepa*) and shallot (*A. cepa* var. *ascalonicum*) belong to the same group. Shallots, although sometimes distinguished botanically from bulb onions, appear to be a type which have been selected for their ability to remain vegetative, having accumulated a large number of genes for the splitting characteristic. They tend to flower less readily but are fully crossable with bulb onions.

Garlic (*Allium sativum*) is another vegetatively propagated crop. Very few lines show flowering capacity, but without any seed setting. Some success has been achieved recently in

seed setting in this crop in Japan and the USA, mainly from the clones collected from the former USSR.

There are about five more species, viz., *A. fistulosum* (Welsh onion), *A. ampeloprasum* (leek), *A. schoenoprasum* (chives), *A. tuberosum* (Chinese chives), and *A. chinense* (Rakkyo), which are grown widely but in limited areas.

Although *A. cepa* holds a great deal of genetic variation, many useful genes such as disease resistance and stress tolerance have been located in other species, e.g., *A. fistulosum* and *A. roylei*. Little success has so far been achieved from interspecific crossing programs using these species.

In garlic and shallot, large amounts of variability for several traits exist in lines collected from different places. This variability can be of great use in the improvement project. Enhancement of genetic resources has been given major emphasis in all the target crops, i.e., onion, garlic, and shallots. AVRDC will collaborate with the International Board for Plant Genetic Resources (IBPGR), regional gene banks, and national agricultural research systems (NARS) partners in the various activities related to germplasm enhancement of allium crops.

Improvement Strategy

Resistance to diseases will be given the highest priority in variety improvement. Purple blotch and Stemphylium blight need to be studied in all three crops with more attention to onion and garlic. Sources of resistance to these diseases need to be identified. The success in this area, so far, has been very limited worldwide. Similarly, resistance to thrips needs to be given due attention. Possibilities of locating resistance to thrips need to be explored, in addition to developing integrated pest management (IPM) methods to control this pest.

Virus diseases are a serious problem in garlic and shallot production. Viruses, viz., onion yellow dwarf virus, leek yellow stripe virus, shallot latent virus, and garlic latent virus are considered to be serious in both crops. Work on virus elimination and indexing has been given priority. Success in virus elimination is expected to lead to the development of technology for the mass production of virus-free garlic and shallot using tissue culture techniques. This technology will be used by NARS partners for large-scale production of virus-free planting material. This will also help in the easy exchange of germplasm material. The possibility of developing resistance to virus diseases will also be explored.

Studies on tolerance to high temperature and to high and low moisture stress are expected to lead to the identification of lines having wider adaptability within the tropics. Breeding lines will be tested during the hot-wet season at AVRDC; including growth-chamber studies will also be conducted. Flooding experiments will be conducted under controlled conditions to identify lines tolerant to high temperature and moisture stress. Similarly, growth chamber and field experiments will be conducted for low moisture stress. The genotypes thus identified will be used in the breeding project. Onion and garlic crops will be the main targets for studies on these abiotic factors.

Due attention will be given to developing lines with long bulb storage life mainly in onion and garlic. Problems related to seed production in onion also require attention.

Hybrid varieties generally exhibit yield and adaptability advantages over open-pollinated varieties. At present, very few hybrid onion varieties are available especially for the tropics, and they are grown in a limited area in tropical countries. Stable male sterile lines, preferably using male sterility derived from tropical germplasm, will be developed to exploit heterosis in onion.

The other challenging areas which AVRDC will explore include flowering and seed set in garlic. Garlic production through true seeds will reduce losses due to virus diseases, besides

reducing the cost of planting material. The use of sexually fertile garlic producing true seeds will also help in genetic maneuvering in this crop.

Similarly, the initial cost of planting material and viral diseases are two important factors which limit the production of shallots. There is growing emphasis on developing true seed varieties of shallots for commercial cultivation. At present, vegetative planting material is used commercially. Work will be initiated to develop shallot varieties which can be propagated by true seeds.

International Collaboration

To achieve the various goals set for the improvement of bulb alliums at AVRDC, international collaboration will be vital, particularly in the areas of (1) enhancement of genetic resources, (2) establishment of allium nurseries in tropical countries, (3) bilateral cooperation with centers actively engaged in related problems such as disease resistance, temperature and moisture stress, etc., and (4) collaboration with advanced centers to work on specific problem areas such as virus diseases, stress physiology, and biotechnology.

Germplasm Enhancement

Germplasm enhancement is one of the important activities in the improvement of onion, garlic, and shallot crops.

Seeds of 402 germplasm accessions of alliums were collected during the year from all over the world, which brings the total collection to 525. Of these, 350 accessions are onion (*Allium cepa*) varieties the majority of which belong to the short-day type.

Seeds of 27 species of alliums were also collected which include some of the important species such as *A. fistulosum*, *A. altaicum*, and *A. vavilovii*. These may be useful in breeding for disease and stress resistance in onion.

A total of 95 accessions of garlic were collected mainly from the tropical Asian countries, the majority of which were from Taiwan, Indonesia, Philippines, India, and Thailand. These collections exhibited a large amount of variability which will be utilized in the improvement project.

Thirty-five shallot accessions were collected mainly from Taiwan, Indonesia, Philippines, and Thailand. Flowering shallot lines were also collected from Taiwan and Indonesia. These lines will be used to develop true-seed shallot varieties.

Germplasm Evaluation Trials in Onion

Summary

To identify suitable genetic material for the onion improvement project, a total of 206 entries were evaluated through one observational and six preliminary evaluation trials. These trials were conducted at different planting dates between December 1992 to April 1993, covering the spring and summer seasons, to identify useful genotypes having better adaptability, high bulb yield, early maturity, disease resistance, long storage life, and high dry matter. The trials conducted after the March planting generally had lower bulb yields, which may be due to increased atmospheric

temperature during that period. Promising genotypes were identified for high yield, early maturity, long storage life, high dry matter, and resistance to Stemphylium blight.

Introduction

Tropical onions, in general, suffer from low bulb yields, poor storage life, low dry matter, susceptibility to diseases and insect pests, besides high temperature and moisture stress. Identification of useful genotypes for these traits is one of the important aspects of the onion improvement project.

Evaluation trials were conducted on the entries collected from all over the world to: (1) observe and evaluate the collected germplasm at different planting dates; (2) select promising lines for further testing, and (3) search for genetic material to be used in the onion improvement project. Both observational and replicated yield trials were conducted to identify useful genotypes.

Materials and Methods

A total of 206 entries were included in seven germplasm evaluation trials (GET) conducted at seven different planting dates between December 1992 to April 1993 (table 7). A popular commercial variety, Granex 429, was used as a check in all these trials. Seedlings were grown in plastic trays, filled with a sterilized mixture of soil, compost, sand, and rice hull. The field plot consisted of a 1.5-m-long and 0.6-m-wide beds. Spacing between two rows in a bed was 15 cm and 10 cm between plants in a row. A randomized complete block design with three replications was used. Beds were mulched with dry rice straw. Regular management practices related to irrigation, weed, and pest control were carried out. Bulb maturity was based on >75% fall of tops. Disease screening for Stemphylium blight was carried out in the trial GET 3 when the disease infection, intensity, and spread were very severe.

Table 7. Germplasm evaluation trials (GET) in onion conducted during 1992-93

Trial no.	No. of entries	Sown	Dates planted	Harvest
GET 1	24	19 Oct. 1992	10 Dec. 1992	10 Apr. 1993
GET 2	55	16 Nov. 1992	04 Jan. 1993	28 Apr. 1993
GET 3	68	26 Nov. 1992	19 Jan. 1993	13 May 1993
GET 4	9	16 Dec. 1992	02 Feb. 1993	28 May 1993
GET 5	5	14 Jan. 1993	04 Mar. 1993	12 June 1993
GET 6	35	28 Jan. 1993	23 Mar. 1993	29 June 1993
GET 7	10	05 Feb. 1993	02 Apr. 1993	02 July 1993

Results and Discussion

The first four trials (GET 1 to GET 4) conducted at different planting dates up to February 1993 produced higher bulb yields, whereas later trials (GET 5 to GET 7) planted during March and April had lower bulb yields. Bulb size was also affected severely at later planting dates with the majority of the bulbs either medium or small, compared to early planting dates which produced large-sized bulbs.

Promising lines were selected from each trial for high bulb yield and quality traits. These are presented in tables 8-11.

Table 8. Yield and other traits of some selected entries from a prelimilary evaluation trial of onion varieties (GET 2)

AVRDC no./ Variety	Source	Plant ht (cm)	Leaf no. (/plant)	Fresh leaf wt (g)	Bulb diameter (cm) Polar	Equatorial	Neck	Bulb yield	Premature bolting (t/ha)	Dry matter (%)	Pungency[a] (%)	Bulb color
AC 4	India	70.0a	13.8b	22.7bc	4.2d	3.6cd	2.4a	31.3	6.4de	8.4	-	Red
AC 8	India	73.8a	9.8f	22.7bc	4.2d	3.6d	2.2ab	27.8	24.3b	9.4	-	Red
AC 9	India	70.6a	10.0ef	30.0a-c	5.0c	3.9cd	2.2ab	26.6	19.2bc	9.7	-	Red
AC 18	India	66.5a	15.3a	30.0a-c	4.9cd	3.9cd	2.5a	32.8	1.3e	9.7	-	Yellow
AC 26	India	52.0b	11.0d-f	22.6bc	7.0b	3.8cd	1.6cd	29.7	37.1a	11.7	6.7	Red
AC 42	India	50.6b	10.6d-f	28.6a-c	7.1b	4.6bc	1.6cd	27.3	3.8h	13.1	6.6	Red
AC 43	India	47.9b	12.0cd	20.6c	7.4b	4.8bc	1.3de	29.6	8.9c-e	10.9	6.8	Red
AC 48	India	51.5a	12.9bc	37.3a	7.6b	5.1b	2.0bc	35.1	18.8bc	11.9	6.6	Dark red
AC 49	India	52.4a	10.6d-f	34.6ab	7.4b	5.2b	1.9bc	38.1	9.0c-e	11.3	7.2	Yellow
AC 51	India	53.6b	11.6de	37.0a	7.3b	5.3b	1.8c	36.4	15.6b-d	10.7	6.7	Yellow
Granex 429 (ck)	USA	37.6c	10.1ef	6.7d	9.2a	6.6a	1.3e	74.1	0.0e	6.1	4.1	Yellow
c.v. (%)		8.2	7.3	26.5	7.0	13.2	10.4		47.2			

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).
[a]Unit of pungency is micromole pyruvic acid/g fresh weight.

Table 9. Performance of promising onion lines grown in spring 1993 (GET 3)

AVRDC no.	Variety	Source	Yield (t/ha) Market-able	Total	Bulb diameter (cm) Polar	Equatorial	Rot (%)	Double (%)	Bulb diameter (%) Large	Medium	Small	Color	D.M.[a]
TA 5	IEE/305	Egypt	34.1cd	52.9b	5.3b	6.8a	1.28b	34.6cd	25.6ab	32.1a-d	6.4bc	Red	114
TA 6	IEE/316	Egypt	43.2a-d	59.5ab	5.5b	7.0a	0.00b	23.3d	28.6ab	46.8ab	1.3c	Red	114
TA10	Savages flat white	Australia	13.7e	54.8ab	4.4c-e	8.0a	15.09a	66.2a	10.2ab	3.3d	5.2c	White	114
TA 11	S.A. white globe	Australia	41.1a-d	79.4a	6.5a	7.1a	0.00b	45.4bc	31.2ab	19.5b-d	3.9c	White	114
TA 69	Baia	Brazil	51.3ab	51.3b	5.2b	5.1c-e	0.00b	0.0e	48.7a	23.1b-d	28.2a	Yellow	90
TA 101	Shinkaizuka	Japan	28.7d	69.9ab	6.8a	6.9bc	0.00b	50.0a-c	43.3ab	6.7cd	0.0c	Yellow	114
TA 102	Sorachiki	Japan	36.8b-d	53.8b	7.2a	6.8ab	7.41ab	21.8d	6.7b	35.2a-c	28.9a	Yellow	114
AC 50	Landrace	India	43.8a-c	57.8ab	4.9b-d	7.4a	1.92b	21.2d	21.2ab	55.8a	0.0c	Yellow	114
	Tainung No. 3	Taiwan	54.7a	63.6ab	4.6cd	6.3bc	0.00b	0.0e	36.7ab	40.0ab	23.3ab	Yellow	114
	Granex 429 (ck)	USA	37.7b-d	79.8a	7.1a	8.1a	0.00b	57.9ab	26.4ab	15.8b-d	0.0c	Yellow	114
c.v. (%)			19.3	20.1	6.8	11.3	195	27.9	68.7	58.1	95.7		

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT). [a]D.M. : days to maturity.

Table 10. Performance of onion varieties for various traits planted in late spring 1993 (GET 6)

AVRDC no.	Variety	Source	Yield (t/ha) Marketable	Yield (t/ha) Total	Bulb diameter (cm) Polar	Bulb diameter (cm) Equatorial	Rot bulb (%)	Bulb diameter (%) Medium	Bulb diameter (%) Small	Bulb color
AC 132	Tropic Gold	Australia	10.68a	13.17a-c	4.8a	4.7c	10.5b	80.7ab	19.3cd	Yellow
AC 133	Ely E. Cream Gold	Australia	6.5bc	8.37c	4.2a	4.6c	14.2b	48.2cd	51.8ab	Yellow
AC 137	Gladalan White	Australia	9.36ab	16.87a-c	4.7a	4.8c	23.7b	77.6a-c	22.4b-d	White
AC 139	Lockyer Gold	Australia	6.17c	9.22c	4.5a	4.4c	21.1b	46.6cd	53.4ab	Yellow
AC 142	T.Y. Grano 502	France	7.82ab	10.51bc	4.6a	4.6c	13.0b	55.1a-d	44.9ab-d	Yellow
AC 148	Texas Grano	Saad	7.04bc	12.39abc	4.5a	4.7c	22.0b	45.8d	54.2a	Yellow
AC 149	T.E. Grano 502 PRR	Saad	8.05ab	9.16c	4.7a	4.5c	9.5b	53.3b-d	46.7abc	Yellow
AC 163	Pom Pei	Holland	4.44c	19.65a	2.9b	6.1a	55.6a	85.0a	15.0d	White
AC 164	Barletta	Holland	4.31c	18.21ab	2.9b	5.5b	54.5a	75.0ab-d	25.0ab-d	White
	Granex 429 (ck)	USA	9.25ab	10.95bc	4.4a	4.7c	9.1b	72.2ab-d	27.8a-d	Yellow
c.v. (%)			17.9	31.4	4.0	7.0	43.4	22.1	35.2	

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).

Table 11. Performance of promising onion lines grown in 1993 summer (GET 7)

AVRDC no.	Variety	Source	Yield (t/ha) Mkt.	Yield (t/ha) Total	Bulb diameter (cm) Polar	Bulb diameter (cm) Equatorial	Bulb diameter (cm) Neck	Bulb size (%) Medium	Bulb size (%) Small	Rot
AC 165	Contessa	USA	10.7cd	13.7de	4.0bc	4.4b-d	1.07cd	31.3bc	46.1ab	22.6b
AC 166	Perla	USA	16.1a-c	18.3a-d	3.6cd	4.0cd	1.17a-c	58.0ab	30.0b-d	12.0b-d
AC 167	Granex 33	USA	4.3d	9.2e	3.4cd	3.8d	1.01d	7.1c	38.9a-c	54.0a
AC 168	Texas Grano 1015Y	USA	22.6a	24.4ab	4.8a	4.8a-c	1.17a-c	72.1a	20.4cd	2.7d
AC 169	Texas Grano 1025Y	USA	20.8ab	21.4a-c	4.3ab	4.8a-c	1.19ab	69.5a	27.8b-d	7.5d
AC 170	Texas Grano 438	USA	23.4a	25.4a	4.5ab	5.3a	1.22a	78.3a	13.8d	7.9d
AC 171	Granex 429, Hybrid	USA	21.8a	22.7ab	4.3ab	5.1ab	1.14a-c	67.9a	28.1b-d	4.0d
AC 172	Red Creole	USA	10.8cd	12.0de	3.3d	4.6a-d	1.09b-d	34.7b	55.0a	10.3cd
AC 173	Texas Grano 502 PRR	USA	13.7bc	16.9bc-e	4.6a	4.5a-d	1.14a-c	36.8b	43.2a-c	20.0bc
	Granex 429 (ck)	USA	21.7a	23.0ab	3.9bc	4.6a-c	1.08bcd	70.1a	23.9b-d	6.0d
c.v. (%)			20.8	19.7	7.4	9.8	5.3	24.1	29.3	38.8

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).

GET 1. In the first trial, out of 24 entries evaluated, 11 were selected for better performance in bulb yield and quality. Var. Granex 429 performed best in terms of bulb yield (73.6 t/ha), followed by XPH 3325 (48.7 t/ha), Rio Hondo (47.9 t/ha), and Regal PVP (46.6 t/ha). The varieties Rio Bravo and Superex produced larger sized bulbs.

GET 2. Fifty-five entries collected from India were evaluated in replicated trials. Bulb yield ranged from 9 t/ha (AC 24) to 74.0 t/ha (Granex 429). Premature bolting was very high in these lines which ranged from 0.0% (AC-1, Granex 429) to 99.3% (AC 53). Most of the lines evaluated in this trial produced premature bolters. Neck thickness was also adversely affected in these lines as most of the lines produced thick-necked bulbs ranging from 1.3 cm (Granex 429) to 2.5 cm (AC-18). As these lines were collected from India, the genotypes performed differently with change in climatic conditions at AVRDC. Thus, suitability to various tropical climatic conditions should be considered in selecting for these traits. Eleven better performing genotypes were identified for further studies (table 8).

GET 3. Sixty-eight entries were evaluated in this trial planted in January 1993. Bulb yield ranged from 11.0 t/ha (TA 25) to 79.8 t/ha (Granex 429). A high percentage of large-sized bulbs were produced by lines TA 69 (48.7%), TA 101 (43.3%), and Tainung No. 3 (36.7%). Compared to these, Granex 429 produced only 26.4% large-sized bulbs. Double bulbs were produced in large numbers by Granex 429 (57.9%) and most of the other germplasm lines (table 9); however, line TA 69 and Tainung No. 3 were free from this defect. Performance of 10 selected entries from this trial is presented in table 9.

GET 4. Out of nine entries tested in this trial, Granex 429 performed best with very high bulb yield (101.0 t/ha). In other varieties, bulb yield ranged from 18.0 t/ha (AC 114) to 71.6 t/ha (AC 112). The only Asian entry in this trial from Nepal (AC 119) performed very well with attractive dark red bulbs of large size, high bulb yield (49.5 t/ha), and very thin neck (1.2 cm).

GET 5 to GET 7. In these trials conducted at later planting dates during March and April the performance of genotypes was severely affected by adverse climatic conditions, likely high temperature and increasing daylength. Bulb yield was reduced in the check variety Granex 429 to a great extent. Other entries were also affected and produced lower yields and reduced bulb size (tables 10 and 11). Some genotypes identified with comparatively better performance were Granex 429, Texas Grano 502, Equanex, Superex, Pom Pei, Barletta, and Texas Grano 1015.

Identification of useful genotypes

These trials (GET 1 to 7) also led to the identification of several useful genotypes for bulb maturity, storage life of bulbs, dry matter content, male sterility, and resistance to Stemphylium blight (table 12).

Earliness

This trait was found in nine lines having bulb maturity less than 100 days after planting with fairly good bulb yield (table 13). The lines TA 55 and TA 56 also displayed very high bulb yield (>80 t/ha). These genotypes were more than 15 days earlier than Granex 429.

Table 12. Promising entries for some important traits from onion germplasm evaluation trials (GET 1 to GET 7)

Traits	Genotypes
Early maturity	TA 4, TA 8, TA 55, TA 56, TA 57, TA 69, TA 70, TA 71, TA 72
Long storage life	AC 50, Rio Bingo, Pusa Red, Yellow Creole, XPH 3325, Jaune de Valence
Resistance to Stemphylium blight	*Allium fistulosum* accessions TA 9,TA 104,TA 105, TA 107, TA 108
High dry matter	AC 23, AC 24, AC 36, AC 44, AC 52, AC 53
Male sterility	AC 26

Long storage life of bulbs

Six genotypes with long storage life of bulbs were identified in an experiment conducted using ambient temperature conditions (28-32°C). These genotypes were observed for 5 mo. Sprouting and rotting losses were mainly taken into account. The genotype AC-50 was identified as best, followed by Rio Bingo and Yellow Creole (table 14).

High dry matter

High dry matter content ranging from 15.9% to 20.1% was recorded in six genotypes. All these lines had poor bulb yield and small bulb size (table 15). In comparison to these, the popular Granex 429 had very poor dry matter (6.1%).

Resistance to Stemphylium blight

Five accessions of *Allium fistulosum*, TA 5, TA 104, TA 105, TA 107, and TA 108 were found resistant to Stemphylium blight in the field experiment conducted under naturally epiphytotic conditions with severe disease incidence (GET 3). None of the *A. cepa* lines out of 110 lines evaluated for this trait was found resistant.

Male sterility

Male sterility is an essential component for the exploitation of heterosis in onion seed production. Stable male sterile lines, preferably using male sterility derived from tropical germplasm, need to be developed for exploiting heterosis. All the onion lines grown during the year which produced flowers were observed for this trait. Line AC 26 had male sterile plants having 100% pollen sterility. This line will be studied further.

Hybridization and Development of Inbred Lines

Several crosses (about 50) were made during the year using important genotypes such as AC 50 (long storage life), AC 26 (male sterile), AC 52 (high dry matter), and *Allium fistulosum* accession TA 108 (resistant to Stemphylium blight) as one of the parents. These were crossed with other high yielding genotypes. There was generally good success in all the crosses except those between *Allium fistulosum* (AC 108) and *Allium cepa* lines, which did not produce any seed. These crosses will be evaluated in the next season.

Selfing was carried out in about 120 plants selected from 20 accessions of onion covering both red and yellow genotypes. These will be evaluated for uniformity and other bulb quality traits. Better performing inbreds will be used in the heterosis breeding project.

Table 13. Performance of germplasm lines identified for earliness towards bulb maturity

AVDC no.	Variety	Source	Yield (t/ha) Mkt.	Yield (t/ha) Total	Bulb diameter (cm) Polar	Bulb diameter (cm) Equatorial	Rot (%)	Double (%)	Bulb size(%) Large	Bulb size(%) Medium	Bulb size(%) Small	Bulb color	Days to maturity
TA 4	IEE/177	Egypt	12.8e	31.4d	4.6c	6.7a	5.3a	47.6a	2.6d	20.9bc	23.5a	White	100
TA 55	Gradalan Brown	Australia	82.1a	89.8a	6.3ab	7.8a	0.0a	7.7bc	70.5ab	20.5bc	1.3b	Yellow	98
TA 56	Gradalan White	Australia	69.0b	85.8a	6.1a-c	7.3a	0.0a	15.4b	61.5ab	20.5bc	2.6b	White	95
TA 57	E. Lockyer Brown	Australia	31.4d	33.2d	4.9bc	5.6ab	2.8a	2.8bc	14.1cd	42.5ab	37.9a	Red+Yellow	90
TA 69	Baia	Brazil	51.3c	51.3c	5.2b	5.1ab	0.0a	0.0c	48.7b	23.1bc	28.2a	Yellow	90
TA 70	Conquista	Brazil	43.9c	44.6c	5.0bc	4.9b	0.0a	1.3c	11.9cd	52.6a	34.2a	Yellow	98
TA 71	Sao Paulo	Brazil	72.8ab	72.8b	6.2ab	5.2ab	0.0a	0.0c	80.8a	16.7c	2.6b	Yellow	98
TA 72	E. Lockyer white	Australia	48.6c	54dc	6.2ab	6.9a	7.7a	0.0c	25.6cd	46.2ab	20.5ab	White	85
	Granex 429 (ck)	USA	30.3d	72.3b	7.1a	8.1a	6.0a	57.9a	26.4c	15.8c	0.0b	Yellow	115
c.v. (%)			13.6	10.0	4.9	16.4	323.8	49.3	32.6	46.6	66.8		

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).

Table 14. Performance of selected onion germplasm lines for bulb storage[a]

Variety	Source	Total bulb yield (t/ha)	Sprouting loss(%)	Rotting loss(%)	Total loss(%)	Brix (%)
Jaune de Valence	France	28.3	0.0	14.3	14.3	6.3
Pusa Red	India	8.3	0.0	15.1	15.1	10.8
Rio Bingo	USA	27.91	0.0	10.4	10.4	6.1
Yellow Creole	USA	13.1	5.0	7.5	12.5	6.2
XPH 3325 F1	UK	48.7	0.0	14.0	14.0	9.2
AC 50	India	57.3	0.0	10.1	10.1	5
Texas Grano 502 (ck)	USA	28.3	0.0	41.6	41.6	6.1
Tainung no.3 (ck)	Taiwan	27.1	12.0	52.0	64.0	12.2
Granex 429 (ck)	USA	73.6	9.2	71.6	80.8	5.9

[a]Bulbs stored in ambient temperature conditions for 5 months.

Table 15. Performance of selected germplasm lines identified for high dry matter

AVRDC no./Variety	Source	Plant ht (cm)	Leaf no. (/plant)	Fresh leaf wt (g)	Bulb diameter (cm) Polar	Equatorial	Neck (%)	Bulb yield (t/ha)	Pre-mature	Pun-gency[a]	Dry matter (%)	Bulb color
AC 23	India	41.9cd	10.5a	31.3a	5.4bcd	3.4c	1.7ab	13.1	96.2a	7.26	16.8 bc	Dark red
AC 24	India	39.5cd	9.0a	16.7b	4.7d	2.8d	1.4bc	9.2	87.2b	6.4	17.6bc	Dark red
AC 36	India	46.1bc	10.5a	30.7a	6.0b	3.9b	1.6a-c	17.4	98.7a	7.46	15.9c	Red
AC 44	India	36.7d	10.6a	28.7a	4.8d	3.4c	1.7ab	11.9	97.4a	6.35	18.2ab	Red
AC 52	India	56.2a	9.9a	27.3a	5.8bc	3.6bc	1.9a	16.9	95.4a	6.73	18.2ab	Dark red
AC 53	India	50.2ab	9.1a	28.3a	5.0cd	3.3c	1.9a	11.2	99.3a	7.53	20.1a	Dark red
Granex 429(ck)	USA	37.6d	10.1a	6.7c	9.2a	6.6a	1.2c	74.1	0.0c	4.14	6.2d	Yellow
c.v. (%)		9.2	9.6	21.8	8.7	6.7	12.9		4.8		7.1	

Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).
[a]Unit of pungency is micromole pyruvic acid/g fresh weight.

Germplasm Evaluation Trial in Garlic

Summary

A preliminary evaluation trial was conducted on the four entries collected locally from Taiwan. Three of these entries are commercial clones grown in Taiwan: the other is cultivated mainly for flower stalk production. Bulb yield and quality traits were evaluated. Individual bulb selections were made for better bulb yield and quality traits.

Introduction

A preliminary evaluation trial was conducted on clones cultivated locally in Taiwan to study the comparative performance of these lines for various traits. A comprehensive replicated trial will be conducted next year after collecting a large number of entries for evaluation.

Material and Methods

Four entries collected locally from Taiwan were grown in an observational-row trial. Planting was carried out on 23 October 1992 in a 4.0 m x 0.75 m bed with a spacing of 15 cm between rows and 10 cm within plants. The field was mulched with rice straw. Observations on bulb yield and other quality traits were recorded.

Results and Discussion

Clone Hsilo was distinctly better in terms of yield, average bulb weight and clove weight followed by variety Hua Suan for all these traits (table 16). The number of cloves per bulb was highest in variety Ho Mei, and, correspondingly, it had the lowest average clove weight. Clone Hua Suan is cultivated mainly for flower stalks. The local garlic clone also produced flower stalks, which were quite distinct from the clone Hua Suan. These two clones were also studied for their flowering behavior.

Table 16. Performance of locally collected garlic lines in spring 1993

Variety	Bulb yield (t/ha)	Bulb diameter (cm)		Avg. bulb wt (g)	No. of cloves/ bulb	Avg. clove wt (g)	Bulb color
		Equatorial	Polar				
Hsilo	10.2	5.5	5.0	53.8	11.2	5.4	White
Ho Mei	7.1	4.5	5.1	33.6	17.4	2.1	White
Hua Suan	8.1	5.1	4.6	40.4	11.0	4.9	Light pink
Local garlic	7.5	4.7	4.5	38.3	12.3	2.8	White

Studies on Flowering and Fertility in Garlic

Summary

Two flowering garlic lines, viz., Hua Suan and a local garlic, were evaluated for flower and fertility traits. These two lines displayed distinct variation in these traits. Hua Suan had fewer flowers and topsets per umbel than the local garlic line. Meiosis was abnormal in Hua Suan, leading to complete pollen sterility. In the local garlic line, variation between the plants was observed for pollen fertility. Plants with high pollen fertility were selected. Hand-pollination resulted in fruit development, and in some fruit embryo development was also observed. Seed setting could not be achieved during the year.

Introduction

Presently, garlic is cultivated by using vegetative planting material because of sterility. This situation has lead to several problems such as: (1) severe yield losses due to virus diseases; (2) problems due to several other diseases carried by vegetative planting material; (3) increased production cost because of high cost of planting material; (4) serious bottlenecks in the movement of germplasm from one place to another; and (5) severe restriction in the genetic maneuvering of this crop, thus hampering its improvement.

Based on these factors, a program has been initiated to study the flowering and seed setting in garlic lines with the following objectives: (1) collection of garlic lines having potential for flowering, (2) flowering and fertility behavior, (3) identification of causes related to sterility in flowering lines, and (4) developing fertile lines in garlic.

Materials and Methods

A total of eight possible flowering lines were collected during the year from Taiwan. Of these, only two lines, Hua Suan and a local garlic, were collected in time for planting. Plants of these varieties were grown in replicated trials in the field during winter. Observations on flowering and presence of topsets were recorded. Topsets were removed using fine forceps in all the umbel heads to allow the flowers to grow. Meiotic studies were carried out in young floral buds and pollen fertility was determined by using the acetocarmine staining method. Hand-pollination was carried out and pollen germination observations on stigma were recorded. Young developing fruit was excised to look into embryo development.

Results and Discussion

All the plants produced flowers in both the varieties Hua Suan and the local garlic. The flowering started during the month of March and continued until May 1993. Both clones produced topsets mixed with flowers in all the umbels. Removal of topsets at an early stage led to proper development of flowers.

Flowering behavior was quite distinct in these two lines. Flower stalk length as well as spathe length was distinctly high in the local garlic line. This line also had more flowers as well as topsets in each umbel (table 17). Flowers were purple and had morphologically normal androecium and gynoecium in both lines. Meiotic studies revealed a high percentage of abnormalities in the Hua Suan clone. These included multivalent formation, unequal separation, lagging chromosomes, etc. The other line had a comparatively lower frequency of abnormalities (table 17). Clone Hua Suan had complete pollen sterility, whereas in the local garlic line variation towards pollen

fertility was evident between the plants. Plants having pollen fertility up to 17.5% were identified. Pollen fertility ranged from 0 to 17.5%. Several plants were identified as having pollen fertility around 5 to 10%. Hand-pollination was carried out; it helped in the development of fruit in the local garlic line. Few developing embryos were observed; however, seed setting could not be obtained during the year. Selections made for pollen fertile lines will be used in further studies.

Table 17. Flowering, meiosis, and fertility studies in two garlic clones in 1993

Variety	Length of flower stalk (cm)	Length of spathe (cm)	No. of flowers per umbel (range)	No. of topsets per umbel (range)	Meiotic abnormalities (%)	Pollen fertility (%)	Fruit development (%)	Flower color
Hua Suan	55.8	6.3	20 (10-32)	28 (12-37)	52	0.0	0.0	Purple
Local garlic	55.6	14.5	33.5 (20-46)	41.3 (25-68)	11	0 - 17.5	26.3	Purple

Germplasm Evaluation in Shallot

All the germplasm lines collected from various countries were tested positive for viruses and are now being used in the virus elimination program. Field evaluation of these lines will be conducted after virus elimination.

Out of 12 germplasm lines collected locally from Taiwan during the year, only one was collected in time for evaluation during the spring season. This line produced good bulb yield (15 t/ha), but there was no uniformity in bulb color, which ranged from deep red to light red. Variations were also observed in flowering ability. Few plants which flowered during the season were studied separately.

Breeding for True Seed Shallots

A sizable number of plants produced flower stalks in a local shallot variety grown during the spring season. Some of these plants produced good bulbs in the beginning and later in the season started flowering, whereas, most of the other flowering plants produced poor bulbs (premature bolters). The plants which produced better bulbs and flowered at a later stage were selected. Selfing as well as hand sibbing was carried out in such plants and some seeds were produced. Seeds were also collected from flowering shallot plants during visits to shallot-growing areas in Taiwan (5 accessions) and Indonesia (2 accessions).

Allium Pathology

Evaluation of Allium Accessions for Resistance to Stemphylium Leaf Blight

Summary

A total of 126 *Allium* spp. accessions were evaluated under natural field conditions at AVRDC for their reactions to Stemphylium leaf blight. One *A. tuberosum* accession, AT 116, and two *A. ramosum* accessions AR 118 and AR 130, were rated as highly resistant. Fifteen accessions among three species — *A. porrum* (TA 7, TA 37, TA 46, TA8 7, AP 120, AP 123, and AP 128); *A. fistulosum* (TA 9, TA 43, TA 104, TA 105, TA 107, TA 108, and AF 117); and *A. schoenoprasum* (ASC 115) — were rated as resistant. No useful level of resistance was identified among the 106 accessions of *A. cepa* tested.

Introduction

A survey of allium crops for fungal leaf diseases in Taiwan during 1993 showed that Stemphylium leaf blight caused by *Stemphylium vesicarium* (Wallr.) F. Simmons was the predominant disease. It occurred on all the crops examined (onion, shallot, garlic, Welsh onion, and leek) and was found on leaves from all fields sampled throughout the year. Lesions begin as water-soaked spots near the leaf tip that become oval in shape, turn light yellow to brown, and expand toward the leaf base. Older lesions turn dark brown to black, frequently forming a zonate pattern when abundant sporulation occurs. Stemphylium leaf blight can cause complete crop failure under conditions conducive to disease development. The purpose of this study was to evaluate accessions in the allium germplasm collection at AVRDC for their responses to Stemphylium leaf blight in an attempt to identify sources of resistance to the disease.

Materials and Methods

Allium spp. accessions planted in the germplasm evaluation trials during the spring of 1993 in the fields at AVRDC were evaluated for their reactions to Stemphylium leaf blight. A total of 126 accessions including 106 *A. cepa*, 7 *A. fistulosum*, 9 *A. porrum*, 2 *A. ramosum*, 1 *A. tuberosum*, and 1 *A. schoenoprasum* entries were evaluated. Young plants were transplanted into the field in January and were arranged in a randomized complete block design. There were 26 to 50 plants per treatment with three replications. Disease development was from natural inoculum. Disease ratings were made in early May by visual observation. Disease reactions were rated on a scale of 1 to 5 in which 1 = very resistant, no symptoms; 2 = resistant, less than 5% of the leaf area affected; 3 = moderately resistant, 6 - 25% of the leaf area infested; 4 = susceptible, 26 - 50% of the leaf area affected, and 5 = very susceptible, 51% or more of the leaf area affected.

Results and Discussion

Severe Stemphylium leaf blight development on the *A. cepa* accessions was indicative of abundant natural inoculum and good conditions for disease development in the test field (table 1). Three accessions, AT 116 (*A. tuberosum*), AR 118 (*A. ramosum*), and AR 130 (*A. ramosum*), did not show any symptoms of Stemphylium leaf blight and were rated as very resistant (table 2). Seven *A. porrum* accessions — TA 7, TA 37, TA 46, TA 87, AP 120, AP 123, and AF 128;

Table 1. Summary of the field evaluation of allium accessions for their reactions[a] to Stemphylium leaf blight, spring 1993

	No. of entries					
	Total entries	Very resistant	Resistant	Moderately resistant	Susceptible	Very susceptible
A. cepa	106	0	0	2	34	70
A. fistulosum	7	0	7	0	0	0
A. porrum	9	0	7	2	0	0
A. tuberosum	1	1	0	0	0	0
A. ramosum	2	2	0	0	0	0
A. schoenoprasum	1	0	1	0	0	0
Total	126	3	15	4	34	70

[a]Very resistant = No symptoms.
Resistant ≤ 5% leaf area affected.
Moderately resistant = 6 - 25% leaf area affected.
Susceptible = 26 - 50% leaf area affected.
Very susceptible = ≥ 51% leaf area affected.

Table 2. Allium accessions identified in the field that possess resistance to Stemphylium leaf blight[a], spring 1993

Entry	Species	Disease rating[b]
AT 166	*tuberosum*	1
AR 118	*ramosum*	1
AR 130	*ramosum*	1
TA 7	*porrum*	2
TA 9	*fistulosum*	2
TA 37	*porrum*	2
TA 43	*fistulosum*	2
TA 46	*porrum*	2
TA 87	*porrum*	2
TA 104	*fistulosum*	2
TA 105	*fistulosum*	2
TA 107	*fistulosum*	2
TA 108	*fistulosum*	2
ASC 115	*schoenoprasum*	2
AF 117	*fistulosum*	2
AP 120	*porrum*	2
AP 123	*porrum*	2
AP 128	*porrum*	2

[a]A total of 126 entries evaluated: 3 were very resistant, 15 were resistant, (not shown: 4 were moderately resistant, 42 were susceptible, and 62 were very susceptible).
[b]Disease rating: 1 = very resistant, no symptoms; 2 = resistant, less than 5% leaf area affected; 3 = moderately resistant, 6 - 25% leaf area affected; 4 = susceptible, 26 - 50% leaf area affected, and 5 = very susceptible, 51% or more leaf area affected.

seven *A. fistulosum* accessions — TA 9, TA 43, TA 104, TA 105, TA 107, TA 108, and AF 117; and a single accession of *A. schoenoprasum*, ASC 115, had less than 5% of their foliage affected and were rated as resistant. None of the *A. cepa* entries in the study were rated very resistant or resistant (table 1). Of the 106 entries tested, two lines were rated moderately resistant but the remainder were rated either susceptible or very susceptible.

These results suggest that sources with good levels of resistance to Stemphylium leaf blight occur among allium accessions at AVRDC. Additionnal accessions will be evaluated for their disease reactions as they become available. Future emphasis in this area of research will be placed on developing a reliable laboratory disease screening protocol with *S. vesicarium* to evaluate additional germplasm sources and breeding populations developed at AVRDC for their reactions to Stemphylium leaf blight.

Survey of Foliar Diseases Affecting Allium Crops in Taiwan

Summary

Three fungal pathogens, *Stemphylium vesicarium*, *Alternaria porri* and *Colletotrichum gloeosporioides*, were identified from 4,280 diseased leaf samples of allium crops collected in Taiwan. Stemphylium blight was by far the most common disease in this survey with over 80% of the diseased leaf samples due to infection by *S. vesicarium*. This is the first report of Stemphylium blight on allium crops in Taiwan.

Introduction

Bulb alliums were included in 1993 among the mandate crops for investigation at AVRDC. As a result, a survey of allium crops being grown in Taiwan was conducted to determine the major foliar fungal diseases affecting these crops. Literature available regarding foliar diseases of allium crops in Taiwan is very limited, but there are reports of the occurrence of purple blotch, *Alternaria porri*; downy mildew, *Peronospora destructor*; anthracnose, *Colletotrichum gloeosporioides*; and black mold, *Stemphylium botryosum*. The purpose of the survey was to serve as an initial step in assessing the importance of fungal diseases as constraints to Allium production in Asia to establish research priorities at AVRDC on diseases of these crops.

Materials and Methods

The disease survey covered the period from January to October 1993 and included onion, shallot, garlic, Welsh onion, and leek. Some 4280 diseased leaf samples were collected from 42 fields at various locations in Taiwan. Sampling sites included fields at Shanhua (AVRDC), Hsilo, Chilsu, Hsuehchia, Hsiaying, Checheng, Ilan, Chian, Hsihu, and Luyeh. Fifty to 200 diseased leaves were collected at random from each field and examined microscopically for diagnostic spores. The percentage of leaf lesions caused by each pathogen at each location was determined to estimate the relative importance of each disease.

Results and Discussion

Stemphylium vesicarium, the causal agent of Stemphylium leaf blight, was the predominant pathogen associated with lesions on the diseased leaves collected from all of the Allium crops. Stemphylium blight occurred in every field sampled throughout the year and was the disease

associated with 83.4% of the leaf samples collected (table 3). Purple blotch, *A. porri*, was found in 23 of the 42 fields sampled but was associated with only 5.3% of the total leaf samples. Its occurrence was very sporadic during the period from January through May (table 3). However, from June through October it was found in all but one field sampled and ranged in frequency from

Table 3. Frequency of occurrence of Stemphylium leaf blight, purple blotch, and anthracnose on diseased leaves collected from allium crops in Taiwan, 1993

Date	Field location	Crop	No. of leaves sampled	Disease occurrence (%) *Stemphylium vesicarium*	*Alternaria porri*	*Colletotrichum gloeosporioides*
5 Jan.	AVRDC (Phy.)	Onion	100	100	0	0
5 Jan.	AVRDC (Ent.)	Onion	100	100	0	0
11 Jan.	AVRDC (Phy.)	Shallot	100	100	4	0
1 Feb.	AVRDC (C.P.)	Onion	100	100	0	0
3 Feb.	Hsilo	Garlic	110	100	0	0
16 Feb.	Chilsu	Garlic	100	100	0	0
16 Feb.	Hsiaying	Garlic	100	100	0	0
16 Feb.	Hsuehchia	Garlic	200	100	0	0
16 Feb.	Hsuehchia	Shallot	100	100	0	0
16 Feb.	Chilsu	Shallot	100	100	2	0
25 Feb.	Ilan	Welsh onion	100	100	1	0
26 Feb.	Checheng	Onion	200	100	7	0
26 Feb.	Checheng	Garlic	100	100	0	0
9 Mar.	Chian	Welsh onion	170	99	0	2
10 Mar.	AVRDC (C.P.)	Onion	100	100	0	0
10 Mar.	Hsihu	Welsh onion	100	100	0	0
11 Mar.	AVRDC (Phy.)	Onion	100	100	0	0
11 Mar.	AVRDC (Ent.)	Onion	100	100	0	0
7 May	Luyeh	Leek	50	100	0	0
7 May	Chian	Leek	50	100	0	0
7 May	Chian	Garlic	50	100	0	0
7 May	Chian	Welsh onion	50	100	0	0
25 Jun.	AVRDC (P.P.)	Onion	100	90	10	15
25 Jun.	AVRDC (P.P.)	Shallot	100	85	7	10
25 Jun.	AVRDC (P.P.)	Welsh onion	100	82	12	13
25 Jun.	AVRDC (P.P.)	Garlic	100	80	6	5
26 Jul.	AVRDC (P.P.)	Onion	100	58	26	18
26 Jul.	AVRDC (P.P.)	Shallot	100	66	4	6
26 Jul.	AVRDC (P.P.)	Welsh onion	100	50	18	15
26 Jul.	AVRDC (P.P.)	Garlic	100	59	8	7
30 Aug.	AVRDC (P.P.)	Onion	100	44	36	13
30 Aug.	AVRDC (P.P.)	Shallot	100	68	3	6
30 Aug.	AVRDC (P.P.)	Welsh onion	100	55	14	17
30 Aug.	AVRDC (P.P.)	Garlic	100	40	12	10
27 Sept.	AVRDC (P.P.)	Onion	100	36	18	9
27 Sept.	AVRDC (P.P.)	Shallot	100	70	0	3
27 Sept.	AVRDC (P.P.)	Welsh onion	100	52	12	12
27 Sept.	AVRDC (P.P.)	Garlic	100	43	3	2
29 Oct.	AVRDC (P.P.)	Onion	100	85	10	1
29 Oct.	AVRDC (P.P.)	Shallot	100	89	2	0
29 Oct.	AVRDC (P.P.)	Welsh onion	100	80	5	2
29 Oct.	AVRDC (P.P.)	Garlic	100	72	4	1
Total/Mean			4,280	83.4	5.3	4.0

2 to 36% among the diseased leaf samples. Similarly, anthracnose, *C. gloeosporioides*, was not detected very often among samples collected from January through May. Except for a single field in which it was not detected, anthracnose was associated with 1 to 18% of the diseased leaf samples collected from June through October. Anthracnose was associated with only 4% of the total diseased leaf samples collected throughout the year.

This apparently is the first report of the occurrence of Stemphylium leaf blight in Taiwan. To find it to be the predominant leaf disease of alliums in Taiwan came as a surprise based on published information which suggests that purple blotch is the most serious leaf pathogen here and elsewhere. Symptoms of the two diseases are very similar, therefore accurate diagnosis requires microscopic observation.

This survey was continued during the remainder of 1993 and will be repeated to determine the pattern of foliar fungal diseases on allium crops in Taiwan in 1994. Virulence studies will be conducted with allium isolates of *S. vesicarium*, *Alternaria* spp., and *C. gloeosporioides* to select specific isolates of each for use in multiple disease resistance screening of allium accessions. Efforts will be initiated in 1994 to assess the relative importance of various fungal diseases in bulb allium in other Asian countries.

Seed Health Testing of Untreated Onion Seed from the Natural Resources Institute, U.K.

Summary

Seedlots of 50 commercial onion cultivars were received from the Natural Rèsources Institute, U.K. for seed health testing. The seed were treated with a 1% sodium hypochlorite solution and subsamples of each seedlot incubated at 24°C and 35°C on moist filter paper for 8 days. Seven potential foliage or storage pathogens of onion were identified — *Aspergillus niger*, *A. fumigatus*, *Fusarium* spp., *Alternaria* spp. *Rhizopus* sp., *Botrytis* sp., and *Penicillium* sp. One or more of these fungi were detected on all 50 seedlots.

Introduction

Many plant pathogens can be seedborne either in the form of infected or infested seed. These seedborne pathogens frequently serve as the primary inoculum for a new crop. Seedborne pathogens and nonpathogens may be disseminated over long distances and introduced into new areas via seed distribution. Utilization of good quality, pathogen-free seed is the first step in successful crop production. Several fungal pathogens have been associated with seed of onions and allied crops. To assess the potential role of seedborne pathogens in onion, seed of 50 commercial cultivars obtained from the Natural Resources Institute, (NRI), U.K. were assayed for associated fungi and bacteria.

Materials and Methods

Dr. Lesley Currah provided seedlots of 50 short-day onion cultivars from the NRI collection in the Vegetable Gene Bank at Horticulture Research International, Wellesbourne, Warwick, U.K. These cultivars represent a broad geographical collection, having been obtained from several countries.

Separate assays were conducted on each seedlot at 24°C and 35°C to detect associated microorganisms. Seed were treated for 1 min in a 1% sodium hypochlorite solution, rinsed twice in sterile distilled water, and transferred aseptically to sterile petri plates with moist filter paper. Four hundred seed of each cultivar were tested, with four replications of 100 seed each, at each temperature. After 8 days of incubation, microscopic observations were made to identify microorganisms associated with each seed, and notes were made on seed germination.

Results and Discussion

Eight different fungi and unidentified bacteria were associated with the seed. Seven of the fungi — *Aspergillus niger*, *A. fumigatus*, *Fusarium* spp., *Alternaria* spp., *Rhizopus* sp., *Botrytis* sp., and *Penicillium* sp. — are potential foliage or storage pathogens of onion (table 4). One or more of these fungi were detected on all 50 seedlots. *A. niger* and *A. fumigatus* occurred most commonly, being detected on 72% (24°C) and 98% (35°C) of the seedlots, respectively. Bacteria associated with the seed were not identified. Assays at the two temperatures, 24°C and 35°C, caused some shift in frequency of recovery of the microorganisms. The higher temperature increased recovery of *A. fumigatus*, *Chaetomium* sp., *Botrytis* sp., and bacteria while suppressing recovery of the other fungi. Mean seed germination among all cultivars was 75% at 24°C and 14% at 35°C.

These results show that several onion storage pathogens are frequently associated with onion seed. It is not known if the seedborne pathogens play an important role in subsequent storage decays when crops are grown from contaminated seedlots. The occurrence of *Alternaria* spp. in 42% of the seedlots raises some concern that seed may serve as an important source of inoculum for development of purple blotch in onion crops. The absence of *Stemphylium vesicarium* in the seed assays was of particular interest in view of recent surveys which show Stemphylium leaf blight to be the most prevalent leaf disease of allium crops in Taiwan.

Table 4. Microorganisms associated with seed of 50 onion seedlots[a] incubated on moist filter paper at 24°C and 35°C

Microorganisms	24°C		35°C	
	Seedlots (%)[b]	Individual seeds(%)	Seedlots(%)	Individual seeds(%)
Aspergillus niger	72	2.30	46	0.55
Aspergillus fumigatus	84	1.96	98	8.20
Fusarium spp.	46	0.30	20	0.08
Chaetomium sp.	14	0.24	36	0.30
Alternaria spp.	42	0.21	22	0.13
Rhizopus sp.	56	0.64	24	0.22
Botrytis sp.	2	0.01	12	0.10
Penicillium sp.	24	0.13	18	0.07
Others	4	0.02	0	0
Bacteria	68	0.61	86	2.01

[a]Provided by Natural Resources Institute, U.K., the seedlots represent a collection of cultivars from several countries.

[b]Values based on assays of 400 seed per seedlot; four replications of 100 seed each.

Virus Elimination and Virus Indexing of Garlic and Shallot

Summary

All vegetatively progagated allium crops such as garlic and shallot are infected by virus, causing yield losses of 20-70%. AVRDC is developing a virus elimination scheme for its germplasm collection that will ensure that no virus is accidentally introduced into Taiwan or exported to other countries during germplasm exchange. Three virus groups were found on garlic and shallot during a survey of farmers' fields and local markets in Taiwan: poty-, carla-, and closteroviruses. Coinfection with several viruses was a common phenomenon. Infection with onion yellow dwarf virus (OYDV) and shallot latent virus (SLV) appeared to predominate. Studies were conducted to optimize the virus elimination procedure. A phostoxin fumigation treatment of 12-24 h was found to be optimal without any detrimental effect on plant growth and will be applied routinely for the elimination of mites and insects on all incoming germplasm. Meristems excised from unsprouted garlic and shallot cloves had an average survival rate of > 90%, and plantlets developed from such meristems were virus-free. This was not the case when meristems were excised at later growth stages. A heat treatment of 38°C for 39 days before meristem excision resulted in almost complete virus elimination from infected garlic cloves. Similarly, a heat treatment of 33°C for 35 days resulted in absence of virus in meristem-derived shallot plantlets. Meristem survival was not affected by the heat treatment in either garlic or shallot. Therefore, in cases where virus elimination cannot be achieved by meristem tip culture alone, cloves may be subjected to heat prior to meristem excision to improve virus elimination. Similarly, the placement of meristems into a medium containing 50 mg/l of virazole was found to improve virus elimination.

A routine virus elimination scheme was initiated which uses meristem tip culture (0.3 mm) of 24-h phostoxin fumigated cloves and three ELISA tests of the meristem-derived plantlets up to the second maturity cycle. Ten virus-free garlic and two virus-free shallot lines have been obtained using this scheme.

Introduction

It has been shown that all vegetatively propagated allium crops are virus infected. Virus elimination schemes are urgently needed because virus infection often results in high losses in yield and quality. Such schemes, however, have rarely been implemented because of insufficient knowledge of the viruses involved and the lack of diagnostic tools to detect them. AVRDC, which is in the process of assembling a large germplasm collection of tropical *Allium* species, has initiated studies to optimize virus elimination and virus indexing of vegetatively propagated alliums to characterize the most common viruses and to develop reliable diagnostic probes for their detection.

Materials and Methods

Optimum growth stage for meristem excision

Four garlic lines (White Leaf, Black Leaf, China Pei San, and China Honan Suan) and one shallot line from Thailand were used. Meristems of 0.3-0.5 mm were excised from plant materials at the following growth stages: unsprouted clove (stage 1); sprouted clove with a shoot approximately 1 cm long (stage 2); sprouted clove with leaves approximately 5 cm long (stage

3); sprouted clove with 10- to 15-cm-long leaves (stage 4) and from sprouted cloves with 15- to 20-cm-long leaves (stage 5) (fig. 1). The cloves were left to sprout in Vermiculite®. For each growth stage and line, 10 meristems were excised as described in the AVRDC 1992 Progress Report and placed on Murashige and Skoog (MS) medium in 10-m-long tissue culture tubes. Cultures were maintained in a growth room at a constant temperature of 23-25°C and a 16-h photoperiod using 40-watt daylight fluorescent tubes providing a light intensity of approximately 5 Klux at tube level. Virus infection was assessed twice by a dot DAS ELISA test on nitrocellulose (NC) membranes at the time of meristem excision (of tissue immediately adjacent to the meristematic tissue and of tissue just below the outer membrane/skin of the cloves) and when leaves approximately 7 cm long had developed from meristem-derived plantlets. Two antisera were used: one with specificity to onion yellow dwarf virus (OYDV) and shallot latent virus (SLV), and a second with specificity to OYDV, SLV, garlic common latent virus (GCLV), and leek yellow stripe virus (LYSV).

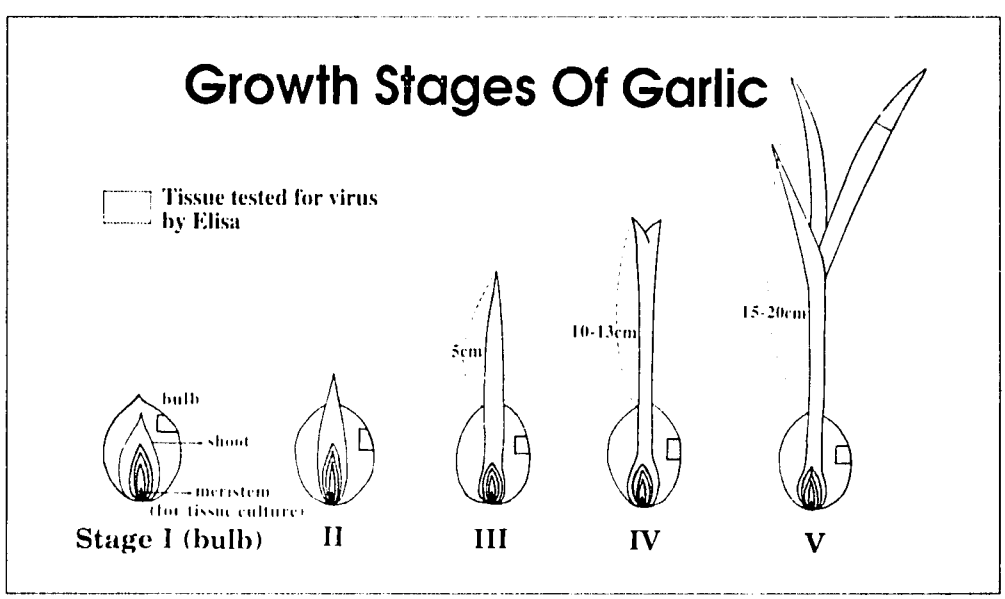

Fig 1. Different growth stages of garlic tested for meristem excision

Effect of phostoxin fumigation with or without subsequent heat treatment on growth of garlic and shallot

Two garlic lines (Black Leaf and China Tsang Shan) and two shallot lines (Taiwan Local and Thailand Local) the dormancy of which had been broken by a 1-2 mo cold treatment at 4°C were used. Four different phostoxin fumigation treatments (0, 6, 12, and 24 h) were applied using 100 bulbs/line for each treatment. After fumigation, the cloves were planted individually into 9-cm plastic pots containing autoclaved potting medium and Nan Ti Wong plant medium (1:1). The pots were transferred to an insect-proof screenhouse until the plants had developed four to five leaves approximately 10 cm long. The potted plants were then placed in a growth room (16-h photoperiod provided by daylight fluorescent lights giving 2 Klux at plant level) where they were subjected to stepwise dry air heat treatments as follows:

- garlic: stepwise temperature increase from 30 to 38°C over 10 days, followed by 38°C for 21 days (treatment 3).
- shallot: 30°C/7 days, followed by 33°C for 28 days (treatment 3).

In treatment 4, the soil was pretreated with 15ml/pot of the nematicide Oxamyl (24%) at 750x. Emerging plants were sprayed after 1 and 2 wk with the bacteriocide Atakin at 1000x and the fungicide Kasugamycin at 800x before they were subjected to the heat treatment. Treatment 5 consisted of an additional hot water formaldehyde treatment after fumigation before the bulbs were grown out in the heated growth room: 12 h in 20-25°C H_2O, then 1 h/H_2O+1% HCHO (35%) at 44.5°C, followed by 1 h/H_2O + 1% HCHO (35%) at 43°C. There were two checks (treatments 1 and 2) which did not receive any heat treatments: bulbs planted directly in soil mixture (Nan Ti Wong plant medium) after fumigation (treatment 1) and bulbs planted in soil mixture amended with 15 ml of the nematicide Oxamyl (24%) 700x; plants were sprayed after 1 and 2 wk with the bacteriocide Atakin 100x and with the fungicide Kasugamycin at 800x (treatment 2).

An indirect dot ELISA test on NC membranes was conducted on leaf tissue of the plants before the heat treatment and on clove tissue after the heat treatment. Plant survival was measured 1 month after planting by counting the percentage of live plants.

Effect of heat on cloves or bulbs before meristem excision on meristem survival and virus elimination

Four garlic lines (White Leaf, Black Leaf, China Pei Suan, and China Ho Nan San) and three shallot lines (Shanhua Local, Taiwan Local, and Thailand Local) were used. Stepwise heat treatments were conducted as follows:

Garlic cloves: treatment 1 (50 days): 30°C, 7 days; 36°C, 14 days; 38°C, 29 days;
treatment 2 (60 days): 30°C, 7 days; 36°C, 14 days; 38°C, 39 day;
treatment 3 (70 days): 30°C, 7 days; 36°C, 14 days; 38°C, 49 day.

Garlic bulbs: treatment 1 (60 days) and treatment 2 (70 days), corresponding to treatments 2 and 3 above;
treatment 3 (80 days): 30°C, 7 days; 36°C, 14 days; 38°C, 59 days.

Shallot bulbs: treatment 1 (42 days): 30°C, 7 days; 33°C, 35 days;
treatment 2 (49 days): 30°C, 7 days; 33°C, 42 days.

Heat treatments were conducted on dry cloves/bulbs subjected to cold treatment at 4°C to break dormancy. The cloves/bulbs were kept on perforated aluminum shelves in a growth room

where the temperature was provided by a heater and where relative humidity was kept at 50-60%. Light was not provided. A first ELISA test on NC membranes was conducted after the heat treatment on the cloves just before meristems of 0.3-0.6 mm were excised as previously described. When plantlets had developed leaves approximately 5 cm long, the leaves were subjected to another ELISA test.

Effect of virazole on meristem survival and virus elimination

Three garlic lines (China Tsang Shan, China Pei Suan, and Black Leaf) and one shallot line (local shallot) were used. Meristems were excised from 40 unsprouted cloves per line and placed on MS medium as previously described. After 10 days, those meristems that grew well were transferred to MS medium amended with either 20, 30, or 50 mg/l of the virocide virazole (MSV medium). After 6 wk on MSV medium, a 0.1 to 0.2-cm-long shoot was re-excised and placed on MS medium. An ELISA test was conducted at the same time on the remaining leaves of 10 plantlets per line per virazole concentration.

Survey for viruses of garlic and shallot in Taiwan

Thirty samples of fresh bulb garlic and 11 samples of fresh shallot were collected from the main production areas (Hsilo, Huwei, and Chialisin) in Taiwan and AVRDC fields. Thirteen samples of dried garlic and 26 dried shallot bulbs were also collected from various markets. Twenty-four Welsh onion and one Chinese chive sample were collected from several locations in southern and central Taiwan. Each sample consisted of 20 bulbs. Of each sample, three bulbs were selected. A DAS ELISA test was conducted on two cloves of each of the three bulbs using polyclonal antisera to OYDV, LYSV, GCLV, and SLV and monoclonal antibodies to SLV, closterovirus, and potyviruses.

Virus elimination and indexing of garlic and shallot germplasm

Fig. 2 shows the scheme adopted for routine virus elimination and indexing in alliums. Garlic and shallot cloves are subjected to a 24-h phostoxin fumigation treatment followed by a 6-8-wk cold treatment at 4°C to break the dormancy if necessary. The outer 'skin' is removed and a small piece of clove tissue underneath is excised for a first ELISA test (= ELISA 0). The remaining clove is placed in 70% ethanol for 1 min. After two rinses in sterile distilled water, the cloves are surface sterilized for 15 min in 1% Clorox. Following three rinses in sterile distilled water, meristems of 0.3-0.6 mm are aseptically removed. The excised meristems are placed on MS medium in 10-cm long tissue culture tubes which are kept at 23-25°C for a 16-h photoperiod with 1 Klux at tube level. After 10-14 days, when the meristem tips are growing well and show green color, the tubes are moved to 5 Klux. After another month the plantlets are transferred to MS medium containing 0.5mg/l NAA until they have developed three to four leaves. This stage is normally reached around 6-8 wk after meristem excision. At that time a piece of the leaf at least 5 cm long is removed for a second ELISA test (ELISA 1). Indirect dot blot ELISA tests are performed on NC membranes using two polyclonal antisera: one which detects OYDV and SLV and another which detects OYDV, SLV, GCLV, and LYSV. Plantlets in which no virus is detected are transferred to plastic pots with autoclaved soil medium and Nan Ti Wang plant medium (1:1) and kept in an insect-proof greenhouse at 22°C and 60-90% RH. Two to three weeks later the plants are transferred to 15-cm clay pots and allowed to grow into mature plants. A third ELISA test (ELISA 2) is conducted 2 months after transplanting. A fourth ELISA (ELISA 3) (as described earlier) is conducted on mature plants, using a 3-cm leaf section of one of the

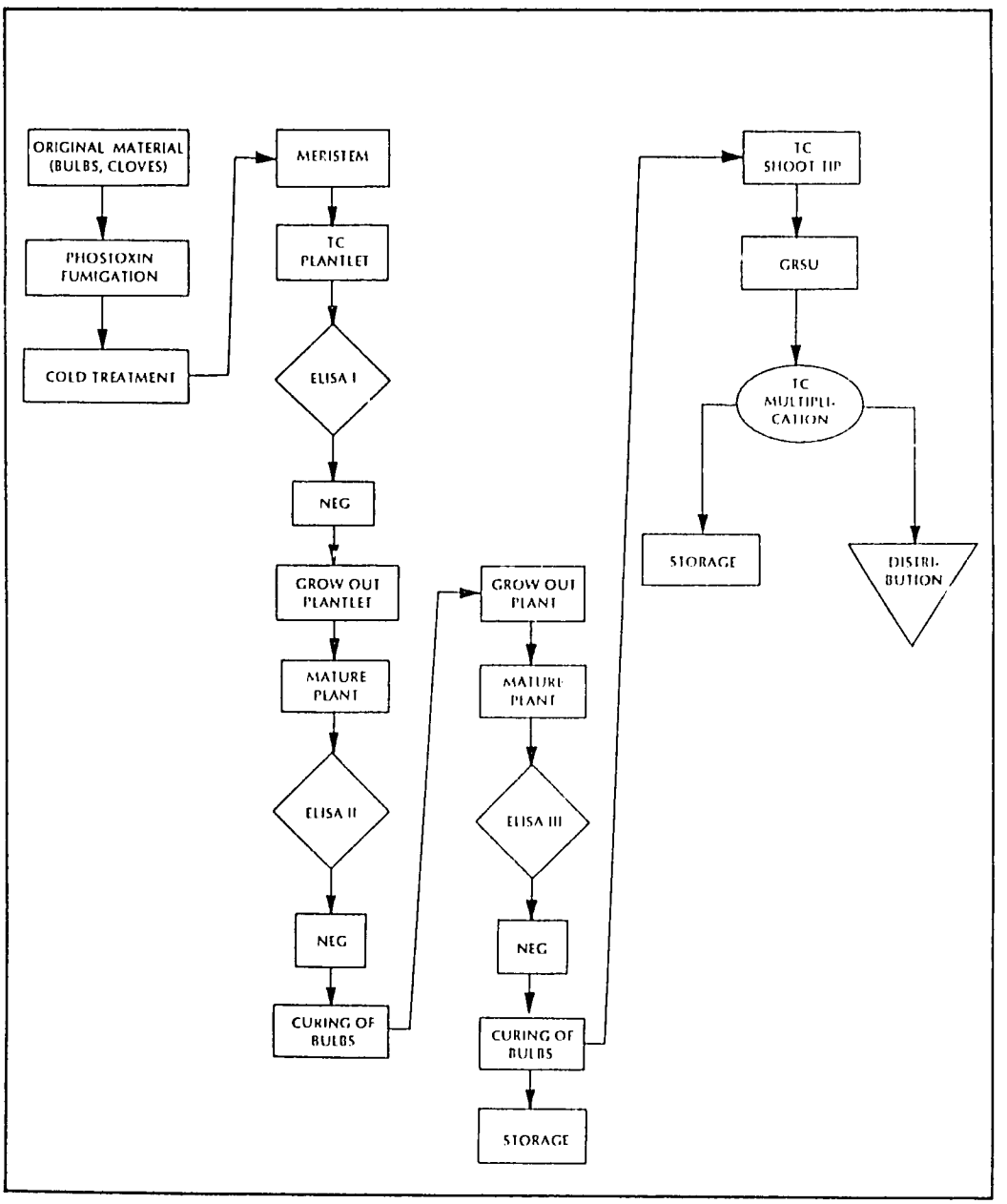

Fig. 2. Virus elimination and indexing scheme for *Allium* sp.

leaves (first maturity cycle). ELISA-negative plants are then allowed to dry in an insect-proof greenhouse for about 1-2 wk by withholding water. After breaking the dormancy (shallot 3 wk at 4°C; garlic 2 mo at 4°C), the dry cloves are replanted in sterile soil medium and allowed to grow out again to maturity (second maturity cycle). At this time a fifth ELISA test (ELISA 4) is conducted. If this test is negative again, the cloves are dried as described earlier and transferred to the Genetic Resources and Seed Unit for further use. Twelve garlic and one shallot line were subjected to this scheme in 1992-93.

Results and Discussion

Optimum growth stage for meristem excision

It is evident that virus infection was high in all lines before meristem excision (table 5). Virus infection ranged from 70 to 100% in garlic and was about 80% in shallot. As expected, virus infection adjacent to the meristematic tissues was significantly less than in tissues near the outer skin of the cloves. However, it was also observed that sprouted cloves had a higher percentage of virus infection near the meristematic tissue than the unsprouted cloves. Possibly the active cell growth of the meristematic tissues also stimulated virus replication and multiplication. Meristem survival in garlic was 100% for meristems excised at stages 2, 4, and 5. The survival rate of meristems excised from stage 1 and stage 3 cloves was 90 and 88%, respectively.

Shallot meristem survival was 100% when meristems were excised at stages 2, 3, and 4. When excised at stages 1 and 5 meristem survival was 90 and 70%, respectively. No virus was detected in tissue-cultured plantlets of garlic developed from explants taken from unsprouted cloves and from stage 1 cloves. Plantlets developed from sprouted cloves at later growth stages had varying percentages of virus infection. No virus infection was detected in any of the tissue-cultured shallot plantlets developed from explants at any of the five growth stages.

Effect of phostoxin fumigation with or without subsequent heat treatment on growth of garlic and shallot

None of the three fumigation treatments had any detrimental effect on plant growth of either garlic or shallot (table 6a). However, when phostoxin treatment of cloves was followed by hot water/formaldehyde treatment, plant growth was drastically reduced. This effect was also observed in garlic check plants which were subjected only to hot water formaldehyde but not to phostoxin fumigation. Phostoxin had no effect on virus incidence in garlic and shallot (table 6b).

Virus incidence in shallot was not reduced after heat treatment. Heat treatment did, however, considerably reduce, although not eliminate, virus incidence in garlic (table 6b).

Effect of heat on cloves or bulbs before meristem excision on meristem survival and virus elimination

Meristem survival of garlic was not affected by the 50- and 60-day heat treatments (table 7a). However, the 70-day treatment was highly detrimental, causing death of the bulbs/cloves and slow growth of the meristems. The 50- and 60-day heat treatments before meristem excision seemed to considerably reduce virus infection in the tissue-cultured plantlets. Virus was detected in only one of the four lines of the 60-day heat treatment and viruses. Garlic bulbs seemed to tolerate longer heat treatment than garlic cloves (table 7a).

Table 5. Percent survival and virus infection of garlic and shallot plantlets taken from meristems at different growth stages of the original plant material

Growth stage and line[a]	Virus infection before meristem excision[b] (%) Tissue below outer membrane OYDV SLV	OYDV GCLV LYSV	Tissue adjacent to meristem OYDV SLV	OYDV GCLV SLV LYSV	Meristem survival (%)	Virus infection after meristem excision[b] (%) Leaf tissue of meristem-derived plantlet[c] OYDV SLV	OYDV GCLV SLV LYSV
Stage 1							
garlic 1	0[d]	80	0	10	90	0	0
garlic 2	20	100	20	20	70	0	0
garlic 3	0	100	0	0	100	0	0
garlic 4	0	90	0	0	100	0	0
shallot 1	80	50	0	0	90	0	0
Stage 2							
garlic 1	0	100	0	0	100	0	0
garlic 2	0	100	0	0	100	0	0
garlic 3	10	100	0	0	100	0	0
garlic 4	10	100	10	100	100	0	0
shallot 1	30	0	0	0	100	0	0
Stage 3							
garlic 1	10	90	10	80	90	0	0
garlic 2	0	100	0	30	100	0	0
garlic 3	0	100	0	10	60	0	0
garlic 4	0	100	0	90	100	17	0
shallot 1	50	10	10	10	100	0	0
Stage 4							
garlic 1	70	70	10	70	100	0	0
garlic 2	100	100	0	20	100	13	0
garlic 3	90	80	100	100	100	33	33
garlic 4	100	100	30	70	100	(25)	(25)
shallot 1	20	0	0	0	100	0	0
Stage 5							
garlic 1	70	90	0	90	100	0	0
garlic 2	100	100	50	30	100	0	0
garlic 3	90	90	10	30	100	(11)	0
garlic 4	100	100	40	50	100	0	0
shallot 1	10	0	0	0	70	0	0

[a]Garlic 1 = local Black Leaf; garlic 2 = local White Leaf; garlic 3 = China Pei Suan; garlic 4 = China Ho Nan Suan, shallot 1 = local Thailand.

[b]Assessed by indirect dot blot ELISA on NC membranes.

[c]Assessed by indirect dot blot ELISA on tissue-cultured plantlets when leaves were approximately 7 cm long. Number in parentheses indicate weak ELISA reactions.

[d]10 cloves per line and growth stage were tested.

Table 6a. Percent survival[a] of garlic and shallot plants grown from phostoxin-fumigated bulbs

Treatment	No fumigation					6-h fumigation					12-h fumigation					24-h fumigation				
Line	1[b]	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Garlic																				
Local	90	83	87	91	72	93	83	88	88	69	94	90	89	87	72	92	90	88	90	56
China Local	94	92	94	95	79	98	94	94	95	72	95	92	93	91	58	96	100	94	90	37
Shallot																				
Local	70	82	78	96	96	92	100	97	95	91	100	98	100	90	75	97	96	96	96	67
Thailand Local	100	100	100	100	93	100	100	100	100	78	100	100	100	100	69	100	100	100	100	63

[a]Measured at 30 days after planting.
In the case of garlic local, 100-200 cloves were planted per treatment.
In the case of garlic China, 110 cloves were planted per treatment.
In the case of shallot, 30-40 cloves were planted per treatment.
[b]Numbers refer to different treatments after fumigation.
1 = Check 1: bulbs planted in soil mixture (Nan Ti Wong plant medium) directly after fumigation.
2 = Check 2: bulbs planted in soil mixture amended with 15 ml of Oxamyl (24%) 750x (nematicide); plants were sprayed after 1 and 2 weeks with Atakin (bacteriocide) 100x and Kasugamycin 800x (fungicide).
3 = Bulbs planted in the soil mixture directly after fumigation; heat treatment of whole plants when leaves had reached 10 cm.
4 = Bulbs planted in soil mixture, as described in 2; heat treatment when leaves had reached 10 cm.
5 = After phostoxin fumigation, bulbs were treated with hot water/formaldehyde (12-h H_2O at 20-25°C, 1-h H_2O + 1% HCHO [35%] at 44.5°C, followed by 1-h H_2O + 1% HCHO [35%] at 43°C) before they were planted in soil mixture; heat treatment of whole plants when leaves had reached 10 cm.

Table 6b. Percent virus incidence in heat-treated plants derived from phostoxin-and heat-treated cloves

Line	Before heat treatment[a]		After heat treatment[b] Treatment 3[c]		Treatment 4		Treatment 5	
	OYDV SLV	OYDV SLV GCLV LYSV	OYDV SLV	OYDV SLV GCLV LYSV	OYDV SLV	OYDV SLV GCLV LYSV	OYDV SLV	OYDV SLV GCLV LYSV
Garlic								
Local	84	98	39	33	96	73	78	76
China local	100	99	70	60	63	60	60	56
Shallot								
Local	95	86	90	79	96	91	100	81
Thailand local	95	87	NT	NT	95	94	95	88

[a]The values are the average percentages of incidence recorded on plants (at the 15-cm leaf stage) of all five treatments (= 250 plants) before they were subjected to the heat treatments; leaf tissue was used for the dot DAS ELISA tests.

[b]The values are the average percentages virus incidence recorded on 24 plants each of all three phostoxin treatments (24, 12, 6 h) (= 96 plants); clove tissue was used for the ELISA tests.

[c]Treatment 3 = After fumigation, bulbs were planted directly in Nan Ti Wong plant medium; heat treatment of whole plants when leaves had reached 10 cm.
Treatment 4 = After fumigation, bulbs were planted in Nan Ti Wong plant medium amended with 15 ml of the nematicide oxamyl; plants were sprayed after I and 2 weeks with Atakin/Kasugamycin; heat treatment of whole plants when leaves had reached 10 cm.
Treatment 5 = After fumigation, bulbs were treated with hot water/formaldehyde before they were planted in soil; heat treatment of whole plants when leaves had reached 10 cm.

Shallot, which is more sensitive to heat, was only subjected to 33°C for 42 and 49 days. Meristem survival was not reduced at either heat schedule (table 7b). All viruses appeared to be eliminated, since no virus was detected in the tissue-cultured plantlets developed from any meristems of such heat-treated bulbs.

Effect of virazole on meristem survival and virus elimination

Before meristem excision, all garlic lines were 100% virus-infected, whereas virus infection of shallot was 45%. Meristem survival for garlic was 100% on 20, 30, and 50 mg/l MSV (table 8). Similarly, meristem survival of shallot was 100% at any of the virazole concentrations.

Two of the garlic lines (China Tsang Shan and local Black Leaf) were virus-free at any of the virazole concentrations used. However, the line China Pei San still had 31% and 12.5 % virus-infected plantlets on 20 and 30 mg/l MSV medium, respectively. No virus was detected in any plantlets grown on the 50 mg/l MSV medium.

Table 7a. Effect of heat treatment of garlic cloves and bulbs on meristem survival and virus incidence

Line	Check (no heat)					50-day heat (38°C/29 days)			60-day heat (38°C/39 days)			70-day heat (38°C/49 days)		
	Virus (%) infection before meristem excision[b] (%)			Virus (%) infection after meristem excision (%)			Virus (%) infection after meristem excision[c] (%)			Virus (%) infection after meristem excision[c] (%)			Virus (%) infection after meristem excision (%)	
	OYDV SLV	OYDV GCLV LYSV SLV	Meristem survival (%)	OYDV SLV	OYDV GCLV LYSV SLV	Meristem survival (%)	OYDV SLV	OYDV GCLV LYSV SLV	Meristem survival (%)	OYDV SLV	OYDV GCLV LYSV SLV	Meristem survival (%)	OYDV SLV	OYDV GCLV LYSV SLV
Cloves[a]														
White Leaf	100	100	95	14	0	98	22	0	95	0	0	dead	dead	dead
China Pei Suan	100	100	85	0	0	98	30	0	100	7	0	75	18	19
China Honan Suan	100	100	90	6	13	95	67	0	100	0	0	93	0	0
Black Leaf	95	90	90	17	0	90	12	0	90	0	0	dead	dead	dead
Bulbs[a]														
White Leaf	97	100	90	80	3	NT	NT	NT	100	70	0	50	50	0
China Pei Suan	100	100	100	2	5	NT	NT	NT	100	0	0	90	0	0
China Honan Suan	96	98	100	8	1	NT	NT	NT	100	10	0	100	0	0

[a]Cloves: single cloves were subjected to the heat treatment; bulbs: intact bulbs were subjected to the heat treatment.
[b]Assessed immediately after the heat treatment by dot ELISA on NC membranes on clove tissue just below the outer skin.
[c]Assessed as above on clove tissue immediately after heat treatment.
[d]Assessed on the leaves of the tissue cultured plantlets (at the 7-cm leaf stage) derived from meristems excised from heat-treated cloves or bulbs.

Table 7b. Effect of heat treatment on meristem survival and virus incidence of shallot cloves

Line	Check (no heat)					42-day heat (33°C/35 days)					49-day heat (33°C/42 days)				
	Virus infection before meristeming (%)		Meristem survival (%)	Virus infection after meristeming (%)		Virus infection before meristeming (%)		Meristem survival (%)	Virus infection after meristeming (%)		Virus infection before meristeming (%)		Meristem survival (%)	Virus infection after meristeming (%)	
	OYDV SLV	OYDV GCLV LYSV SLV		OYDV SLV	OYDV GCLV LYSV SLV	OYDV SLV	OYDV GCLV LYSV SLV		OYDV SLV	OYDV GCLV LYSV SLV	OYDV SLV	OYDV GCLV LYSV SLV		OYDV SLV	OYDV GCLV LYSV SLV
Shanhua Local	NT	NT	NT	NT	NT	20	5	90	0	0	0	0	100	0	0
Thailand Local	80	5	100	14	0	0	0	100	0	0	10	0	100	0	0
Taiwan Local	85	80	95	0	0	NT	NT	NT	NT	NT	65	50	100	0	0

Table 8. Effect of virazole on meristem survival and virus elimination

Line	Virus infection before meristem excision[a] (%)		Meristem survival[b] (%)	Virus infection on MSV medium after meristem excision[c] (%)					
				20mg/l		30mg/l		50mg/l	
	OYDV SLV	OYDV GCLV LYSV SLV		OYDV SLV	OYDV GCLV LYSV SLV	OYDV SLV	OYDV GCLV LYSV SLV	OYDV SLV	OYDV GCLV LYSV SLV
Garlic									
China Tsang Shan	100	88	93	0	0	0	0	0	0
Black Leaf Local	100	100	33	0	0	0	0	0	0
China Pei San	100	100	88	91	0	36	0	0	0
Shallot									
Local	45	5	100	0	0	0	0	0	0

[a] Assessed on 40 cloves by dot blot ELISA.
[b] Assessed on 40 meristems per line per treatment. Meristem survival was the same on all three virazole concentrations.
[c] Assessed on 20 meristem-derived plantlets after 7-8 wk in tissue culture (10 days on MS and 42 days on MSV).

Survey for viruses of garlic and shallot in Taiwan

All garlic samples except one (from the Shanhua market) were infected with virus. Coinfection with several viruses was a common phenomenon (tables 9a-9c). All virus groups (poty-, carla-, and closteroviruses) were detected. Infection with OYDV and SLV appeared to predominate. Only two samples from farmers' fields in Chialisin were found infected with a closterovirus. Only weak reactions were obtained with polyclonal antisera to LYSV and GCLV. It is possible that these were either unspecific reactions or weak positive reactions, reflecting a very low titre of these two viruses in the tested garlic samples.

The situation was similar for shallot. All shallot samples were infected, usually with OYDV and SLV. In 13 samples a strong ELISA reaction was obtained with antiserum to LYSV. GCLV was present in two samples and a closterovirus in six samples.

Table 9a. Survey for viruses of garlic in Taiwan

Location	No. of samples collected	Potyvirus					Carlavirus					Clostero-virus	
		POTY	OYDV		LYSV	GCLV	SLV						
		M_1[b]	P_1[c]	P_2	P_1	P_1	P_1	P_2	M_1	M_2	M_3	M_1	M_2
Hsilo (F)[a]	15	6[d]	2	11	(2)	-	(4)	4	4	3	-	-	(2)
Huwei (F)	10	4	2	2	(2)	-	(1)	1	(1)	1	-	-	-
Tainan (M)	12	6	-	9	-	-	(8)	9	7	5	-	-	(1)
Shanhua (M)	1	-	-	-	-	-	-	-	-	-	-	-	-
Chialisin (F)	4	1	3	2	(1)	(1)	(1)	3	4	4	(3)	2	2
AVRDC (F)	1	1	1	1	-	-	-	-	-	-	-	-	-

[a] F = field, M = market.
[b] M = monoclonal antibodies.
[c] P = polyclonal antiserum.
[d] Number denotes the number of samples with strong reaction to antiserum in DAS ELISA. Numbers in parentheses denote the number of samples with weak reaction to antiserum.

Table 9b. Survey for viruses of shallot in Taiwan

Location	No. of samples collected	Potyvirus					Carlavirus					Clostero-virus	
		POTY	OYDV		LYSV	GCLV	SLV						
		M_1[b]	P_1[c]	P_2	P_1	P_1	P_1	P_2	M_1	M_2	M_3	M_1	M_2
Chialisin 1 (F)[a]	3	(1)[d]	(1)	-	(3)	-	(1)	(2)	2	2	(1)	-	-
Chialisin 2 (F)	3	-	3	(3)	3	(3)	(3)	3	3	3	1	-	-
Chialisin 3 (M)*	3	-	3	1	(3)	-	(3)	3	3	3	(3)	-	-
Chialisin 4 (M)*	6	-	1	(1)	1	(4)	(2)	5	6	6	1	-	-
Huwei (F)	3	(1)	(2)	(1)	(2)	(2)	-	(3)	3	2	(1)	-	-
Hsilo (F)	2	-	-	(1)	(2)	(2)	-	(3)	3	2	(1)	-	-
Shanhua 1 (M)	4	-	-	-	1	1	-	(4)	(1)	(1)	1	1	-
Shanhua 2 (M)	3	-	2	(2)	2	(3)	(1)	3	3	3	1	-	-
Tainan (M)	3	-	2	(2)	(3)	-	-	(1)	3	3	(2)	-	-
Hsuechia (M)	6	-	6	3	5	(5)	(5)	1	1	(5)	(6)	5	4
Anting (M)	1	-	-	1	1	1	(1)	1	1	1	-	-	-
AVRDC	1	-	-	-	-	-	1	1	1		1	-	-

[a] F = field, M = market, * originated from Indonesia.
[b] M = monoclonal antibodies.
[c] P = polyclonal antiserum.
[d] Number denotes the number of samples with strong reaction to antiserum in DAS ELISA. Numbers in parentheses denote the number of samples with weak reaction to antiserum; - = no reaction in DAS ELISA.

Table 9c. Survey for viruses of Welsh onion and Chinese chive in Taiwan

Location	No. of samples collected	Potyvirus POTY M_1[b]	Potyvirus OYDV P_1[c]	Potyvirus OYDV P_2	Potyvirus LYSV P_1	Potyvirus GCLV P_1	Carlavirus SLV P_1	Carlavirus SLV P_2	Carlavirus SLV M_1	Carlavirus SLV M_2	Carlavirus SLV M_3	Clostero-virus M_1	Clostero-virus M_2
A. fistulosum													
Huwei (F)	12	-	(2)	-	(8)	-	2	4	4	2	4	-	-
Hsilo (F)	4	-	(2)	-	(4)	-	(3)	3	3	(3)	2	-	-
Hsichou (F)	6	1	-	-	(1)	-	(1)	1	2	2	(1)	-	-
AVRDC (F)	2	-	-	-	-	-	-	1	-	-	-	-	-
A. tuberosum													
AVRDC (F)	1	-	-	-	-	-	-	1	1	1	1	-	-

[a]F = field, M = market.
[b]M = monoclonal antibodies.
[c]P = polyclonal antiserum.
[d]Number denotes the number of samples with strong reaction to antiserum in DAS ELISA. Numbers in parentheses denote the number of samples with weak reaction to antiserum; - = no reaction in DAS ELISA.

Virus infection is obviously not the same in garlic and shallot. This may be because much of the shallots both for field-planting as well as for sale in the markets are imported from other countries.

Virus elimination and indexing of garlic and shallot germplasm

Average meristem survival of garlic was 97% (tables 10a and 10b). Virus was detected in 21% of the tissue-cultured plantlets (ELISA 1). In ELISA 2 (conducted on plantlets grown out for 2 mo), an average of 15% of the plantlets were found to still harbor virus. These virus-infected plantlets were eliminated. In ELISA 3 (first maturity cycle) and ELISA 4 (second maturity cycle) no virus was detectable. The average meristem survival of shallot was 92%.

Conclusions

Optimum growth stage for meristem excision

The high percentage of virus infection observed in cloves of garlic and shallot is the reason for AVRDC's commitment to subject all local and foreign germplasm to a rigorous virus elimination/indexing scheme. Therefore, for routine virus elimination we plan to excise meristems from unsprouted cloves because an average meristem survival of approximately 90% can be obtained and without infection in plantlets developed from these meristems.

Effect of phostoxin fumigation with or without subsequent heat treatment on growth of garlic and shallot

Phostoxin fumigation of bulbs and cloves eliminates contamination with insects, nematodes, and mites. Since the latter are vectors of several viruses of *Allium* spp., it is, therefore, very important to eradicate them in our virus elimination and indexing facilities. None of the phostoxin treatments had any adverse effect on plant growth, so phostoxin fumigation will be routinely used on all materials that will be subjected to virus elimination. Hot water/formaldehyde treatment, which is often recommended against bacterial and nematode contaminations, will not be routinely used in our operations, since it drastically reduces plant growth, especially after

phostoxin fumigation. If heat treatment of whole plants is considered in future, the soil and plants will be treated with bacteriocides and nematicides instead of applying H_2O/HCHO to the cloves/bulbs. However, since heat treatment of whole plants not only requires much space but is also labor-intensive, we will attempt heat treatment of cloves instead of whole plants.

Effect of heat on cloves or bulbs before meristem excision on meristem survival and virus elimination

The data suggest that the 60-day heat treatment completely eliminated certain viruses such as GCLV and LYSV. Longer treatments (70 days) at this temperature lead to death of the garlic cloves and are, thus, not recommended. Furthermore, they did not appear to have any other positive effect on virus reduction in the plantlets developing from meristems of such heat-treated cloves. Heat treatments of shallot cloves at 33°C for 35 and 42 days did not negatively affect meristem development and virus could be completely eliminated. Thus, in the case of shallot, heat treatment of bulbs may be considered if we cannot achieve effective virus elimination by meristem tip culture alone.

Table 10a. Virus elimination and virus indexing of shallot as of 1993

Item		Before meristeming	After meristeming 1[a]	2[b]	3[c]	4[d]
Thailand I						
Total no. of lines		1				
No. of meristems excised		26				
No. of lines survived			23 (88.5%)			
No. of plantlets tested			12	6	6	3
No. of ELISA[e]-positive plantlets			0	0	0	0
Positive for	OYDV+SLV		0	0	0	0
	OYDV+GCLV +LYSV+SLV		0	0	0	0
No. of virus-free lines						1
Thailand II						
Total no. of lines		1				
No. of meristems excised		9				
No. of lines survived			9 (100%)			
No. of plantlets tested			8	5	5	
No. of positive plantlets			0	0	0	
No. of cloves tested		5				
No. of ELISA-positive cloves		0				
Positive for	OYDV+SLV	0	0	0	0	
	OYDV+GCLV				0	
	+LYSV+SLV	0	0	0		
No. of virus-free lines					1	

[a]ELISA test conducted on meristem-derived plantlet (when leaf approximately 5 cm long) while still in the test tube.
[b]ELISA test conducted on plants grown out in soil for 2 mo.
[c]ELISA test conducted on plants grown out in soil (in insect-proof screenhouse) for approximately 5 mo.
[d]ELISA test conducted on second generation of plants grown out in soil (in insect-proof screenhouse for approximately 1/2 mo) from cloves of meristem-derived plantlets.
[e]Dot ELISA on NCM membranes.

Table 10b. Virus elimination and virus indexing of garlic as of 1993

Item	Before meristeming	After meristeming 1[a]	2[b]	3[c]	4[d]
Thailand I					
Total no. of lines (dry cloves)	7	7			
No. of meristems excised	277				
No. of lines survived	261 (94.2%)				
No. of cloves tested	262 (7 lines)				
No. of plantlets tested		159 (7 lines)	35 (7 lines)	30 (7 lines) (5 lines)	14
No. of positive plantlets		11 (6.9%, 5 lines)	0	1 (1 line)	0
No. of ELISA[e]-positive cloves	151 (57.6%, 7 lines)				
Positive for OYDV+SLV	94 (62.3%, 6 lines)	2 (18.1%, 2 lines)	0	1 (100%, 1 line)	0
OYDV+GCLV		9 (81.8%, 3 lines)			
+LYSV+SLV	130 (86.1%, 7 lines)				
GCLV	0				
SLV	0				
TMV	0				
No. of virus-free lines				7	5
Thailand II					
Total no. of lines (dry cloves)	1				
No. of meristems excised	20				
No. of meristems survived	19 (95%)				
No. of cloves tested	20				
No. of ELISA-positive cloves	8 (40%)				
Positive for OYDV+SLV	3 (37.5%)				
OYDV+GCLV +LYSV+SLV	7 (87.5%)				
No. of virus-free lines					
Israel					
Total no. of lines	1 (bulbils)				
No. of meristems excised	26				
No. of lines survived	26 (100%)				
No. of bulbils tested	26				
No. of plantlets tested		26	4		
No. of positive plantlets		22 (84.6%)	3 (75%)		
No. of ELISA-positive bulbils	26 (100%)				
Positive for OYDV+SLV	9 (34.6%)	4 (18.2%)	3 (100%)		
OYDV+GCLV +LYSV+SLV	26 (100%)	22 (100%)	3 (100%)		
No. of virus-free lines					

Table 10b. Continued.

Item	Before meristeming	After meristeming 1[a]	2[b]	3[c]	4[d]
France					
Total no. of lines	10				
No. of meristems excised	34 (10 lines)				
No. of meristem survived		34 (100%)			
No. of plantlets tested		19 (8 lines)	10 (7 lines)	5 (3 lines)	
No. of positive plantlets		7 (36.8%, 4 lines)	0	0	
No. of cloves tested	32 (10 lines)				
No. of ELISA[e]-positive cloves	19 (59.4%, 8 lines)				
Positive for OYDV+SLV	5 (26.3%, 4 lines)	7 (100%, 4 lines)	0	0	
OYDV+GCLV +LYSV +SLV	19 (100%, 8 lines)	0	0	0	
No. of virus-free lines				3	
Taiwan					
Total no. of lines (Hua Suan)	1				
No. of meristem excised	15				
No. of meristem survived		15 (100%)			
No. of cloves tested	15				
No. of ELISA-positive cloves	7 (46.7%)				
Positive for OYDV+SLV	6 (85.7%)				
OYDV+GCLV +LYSV+SLV	7 (100%)				
No. of leaves tested	15				
No. of positive leaves	15 (100%)				
Positive for OYDV+SLV	15 (100%)				
OYDV+GCLV +LYSV+SLV	15 (100%)				
No. of plantlets tested		4	3	1	
No. of positive plantlets		0	0	0	
Positive for OYDV+SLV	0	0	0		
OYDV+GCLV +LYSV+SLV	0	0	0		
No. of virus-free lines				1	

[a]ELISA test conducted on meristem-derived plantlet (when leaf approximately 5 cm long) while still in the test tube.
[b]ELISA test conducted on plants grown out in soil for 2 mo.
[c]ELISA test conducted before harvest of plants grown out in soil in insect-proof screenhouse (approximatley 5 mo).
[d]ELISA test conducted on second generation of plant grown out in soil (in insect-proof screenhouse for approximately 1/2 mo).
[e]Dot ELISA on NCM membranes.

Effect of virazole on meristem survival and virus elimination

Contrary to a previous experiment (see AVRDC 1992 Progress Report) where meristems failed to develop when they were directly placed on MSV media, all meristems in this experiment developed into plantlets, because they were first given a 10-day virazole-free regeneration period on MS medium. Therefore, when dealing with heavily infected lines where meristem tip culture is not enough to obtain virus-free plants, the growth of the explants on MSV medium after their establishment on MS medium should be considered.

Survey for viruses of garlic and shallot in Taiwan

The survey has shown that most garlic and shallot are infected by virus, often despite any visible symptoms. This is one of the reasons why the virus elimination scheme will also be applied to both local and exotic accessions. We want to make sure that AVRDC distributes only virus-tested materials to its partners. The different reactions obtained with monoclonal antibodies against one virus suggest that virus strains may exist.

Virus elimination and indexing of garlic and shallot germplasm

The absence of virus in shallot after meristeming and the low virus detection in meristemed garlic in the first and second ELISA tests is evidence of the efficiency of our virus elimination procedure. Apparently, the size of our excised meristems is so small that virus has not yet moved into it. At present, we do not see any need to routinely subject the cloves (or plants) to an additional heat treatment prior to meristeming or grow the explants in medium containing virazole. However, should we encounter accessions from which we cannot eliminate virus with the adopted method, we will consider the use of one of these additional treatments.

Allium Physiology

Application of Random Amplified Polymorphic DNA (RAPD) for Identification of Garlic Clones

Summary

The potential use of random amplified polymorphic DNA (RAPD) for clonal identification was investigated using a garlic germplasm collection maintained at the Tainan District Agricultural Improvement Station (DAIS), Taiwan. We were able to create 32 RAPD bands with genomic DNA from 30 garlic clones using five randomly selected primers. Two primers, OPI7 and OPI17, could distinguish between light-leaf and dark-leaf clones. The dendrogram analysis of RAPD bands using an AMBIS MP2 program revealed that the degree of similarity within 30 clones was 92%. Similarity levels within the light-leaf clones and dark-leaf clones were 94% and 96%, respectively. The SAS average linkage cluster analysis also revealed low variation within light-leaf and dark-leaf clones. This high similarity indicates that these garlic clones in the Tainan DAIS germplasm collection were likely obtained from a narrow geographical area.

Introduction

Distinguishing between closely related plant cultivars is often difficult. This is certainly true with many clones of garlic, a vegetatively propagated crop. Its variation is mainly the result of natural mutation or artificial selection. Morphological characteristics such as leaf shape and color, stem stiffness, flowering or nonflowering characteristic, growth habit, and clove shape and color are the usual means by which clonal variations are determined. However, some garlic clones are so phenotypically similar that identification by observable traits becomes very difficult. Due to this phenotypic similarity, confusion exists among persons charged with growing, breeding, marketing, or otherwise concerned with garlic clonal identification. A more sensitive tool to accurately identify garlic genotypes would, therefore, be of value.

Within the past several years, molecular biological techniques have been applied to the area of plant cultivar identification. One such technique, DNA fingerprinting, which employs analysis of random amplified polymorphic DNA (RAPD), has been particularly useful. RAPDs are generated by the amplification of genomic DNA with a single primer of arbitrary nucleotide sequence. Its polymorphism has proven to be a very sensitive tool for separating closely related plants. In this study we checked whether RAPDs could be used to differentiate a major garlic collection of 30 clonal accessions maintained at Tainan DAIS in Taiwan.

Materials and Methods

Plant materials

Plant samples were taken from newly emerged leaves from 30 clones listed in table 1, grown at the Yi-chu station of Tainan DAIS. Among them, CITC-10, CITC-11, and CITC-12 were collected from Indonesia and the rest locally, of which some were recent introductions from China. Based on their agronomic characteristics, they had been grouped into five types.

Table 1. Garlic clones used in the RAPD analysis

Clonal no.	Clonal name	Leaf color	Genomic grouping	Agronomic grouping
1	Wang-zi-she flowering type	Light	II	I
2	Xi-pu flowering type	Light	II	I
3	Guan-liao flowering type	Light	II	I
4	Early-maturing flowering type	Light	II	I
5	Flowering type	Light	VII	III
6	Wang-zi-she northern type	Intermediate	II	IV
7	Jiang-su-tai-chang (northern type)	Intermediate	II	IV
8	Northern type	Intermediate	II	IV
9	CITC-11	Dark	V	II
10	CITC-10	Dark	V	VI
11	CITC-12	Dark	VI	II
12	Yi-lan san-jiao	Light	II	III
13	Feng-shan Sel. No. 1	Dark	III	II
14	Flowering type selection	Light	II	III
15	Chia-yi No. 1	Dark	III	II
16	Chia-yi No. 2	Light	II	III
17	Xi-luo No. 2	Intermediate	III	II
18	Xi-luo No. 4	Dark	III	II
19	Xi-luo wide black leaf	Dark	I	II
20	Xi-luo two black leaves	Dark	I	II
21	He-mei white-ieaf	Intermediate	IV	II
22	White leaf (Xi-luo)	Intermediate	IV	II
23	New black leaf	Intermediate	II	III
24	He-mei black leaf	Dark	III	II
25	He-mei early maturing, wide leaf	Dark	III	II
26	Xi-gang-pu	Dark	III	II
27	Black wide leaf	Dark	III	II
28	Zhuang-wei new south	Light	II	II
29	San-xing (Ta-yi)	Light	II	VI
30	Yuan-shan-nei-cheng	Light	II	VI

DNA isolation

Three grams of fresh young leaf tissue were obtained and pooled from 15-20 garlic plants of each clone. Total genomic DNA was isolated based on Young (1992). Leaf tissue was ground to a fine powder with a mortar and pestle in the presence of liquid nitrogen, then stored at -80°C until DNA extraction. Ground leaf powder was extracted with 11 ml of extraction buffer at pH 8.0 (100 mM Tris-HCl; 50 mM EDTA; 500 mM NaCl; 1.25% SDS; 30 mM $NaHSO_3$) at 65°C for 15 min. After 65°C incubation, 3.5 ml of 5M potassium acetate was added and kept in ice for 60 min and

then centrifuged at 3000 rpm for 15 min, followed by the collection of the supernatant. The supernatant was filtered through miracloth, and an equal volume of isopropanol was added and mixed well for 60 min to precipitate the DNA. The precipitated DNA was hooked out carefully by a modified Pasteur pipette and washed with 70% ethanol before being transferred to a 1.5 ml Eppendorf tube. After vacuum drying for 12 min, DNA was resuspended by adding 400 µl of TE buffer (pH 7.5) at 65°C. Extracted DNA was further treated with RNase at a final concentration of 50 µg/ml at 37°C for 120 min to remove RNA. The DNA concentration was determined by running aliquots of DNA on 0.8 agarose gel with l DNA standards.

Polymerase chain reaction (PCR)

The PCR was performed by using Cetus Gene Amp Core reagents. A 25 µl reaction solution containing 0.625 unit of *Taq* polymerase, 1 x reaction buffer, 100 µM of each dNTPs, 5 pico-mole primer (Operon, CA, USA), 3 mM $MgCl_2$ and 50 ng genomic DNA was used as a template. A control PCR tube containing all components but no genomic DNA was run with each primer to check for contamination. DNA amplification was performed in a Perkin-Elmer Cetus Programmable Thermal Cycler (Model 480, Perkin-Elmer Cetus). The reaction was overlaid with 1 drop of mineral oil and the thermal cycle used was: 94°C (2 min) for initial strand separation, 36°C (1 min) for annealling, and 72°C (2 min) for extension. This temperature profile was run for three cycles, and then followed by 94°C (1 min), 36°C (1 min), and 72°C (2 min) for 40 cycles, and finally 72°C (5 min) for extension. Amplification products were analyzed by electrophoresis in 1.4% agarose gels and detected by staining with ethidium bromide. The gels were photographed under UV light with Polaroid film 667. Size markers used were pBR328 DNA (Bgl I + Hinf I) and l DNA Bst EII digests.

Data analysis

The polymorphism generated with each primer was scored for the presence (1) or absence (0) for each band and operational taxonomic unit (OTU). Analyses were carried out with polymorphic DNAs with an AMBIS Micro PM system as well as SAS average linkage cluster analysis. The AMBIS system employed a program which worked by producing a similarity matrix from the stored image file, and then constructing a dendrogram via the unweighted pair-group average method with arithmetic averages (UPGMA).

Results and Discussion

Twenty random 10-mers were tested in this study, but only five primers (table 2) showed clear polymorphisms among 30 garlic clones. Thirty-two bands (ranging from 1500 to 300 bp) were obtained from these primers (table 3). Two of them were unique to all clones, six specific to light-leaf clones, and four specific to dark-leaf clones. No band related to flowering trait of garlic could be found. Two primers, OPI7 and OPI17, could distinguish between light-leaf clones and dark-leaf clones.

A dendrogram was created with RAPD data derived from OPI7 and OPI17 (fig. 1). At the highest rank (i.e., 93% similarity level) on the dendrogram, light-leaf clones can be separated from dark-leaf clones. Similarity levels were 95% and 96% for light-leaf clones and dark-leaf clones, respectively. Similarity near 100% was found for clones 28 and 29; clones 10 and 25; and clones 19 and 20. In comparing within clones 23, 29, 28 and 2; clones 16, 8, 6, 12 and 4; clones 11 and 17; clones 22, 21, 24, 20, 19, 18, 25, and 10; and clones 13 and 14, the similarity level is as high as 99%. Three previously identified as intermediate leaf color clones (17, 21, 22) were

Table 2. Random primers used in the RAPD study of garlic clones

Code	Sequence (5'-3')
OPI 03	CAGAAGCCCA
OPI 07	CAGCGACAAG
OPI 13	CTGGGGCTGA
OPI 17	GGTGGTGATG
OPI 18	TGCCCAGCCT

Table 3. Classification of the 32 RAPD bands in 30 garlic clones

Characteristics	Band no.
Unique for 30 clones	2
Specific for light-leaf (LL) clones	6
Specific for dark-leaf (DL) clones	4
Polymorphic in LL	5
Polymorphic in DL	8
Monomorphic in LL but polymorphic in DL	1
Monomorphic in DL but polymorphic in LL	1
Polymorphic for 30 clones	5

found identical with dark-leaf clones when detected with OPI7, with 100% similarity level. Four intermediate leaf color clones (6, 7, 8, 23), with 100% similarity when detected with OPI17, were found closer to light-leaf clones when detected with OPI7.

The results of integrated data analysis by SAS average linkage cluster analysis are similar to those from the AMBIS dendrogram analysis. Two major groups were formed in relation to light and dark leaf. The intermediate leaf color clones were grouped as AMBIS system. When more clusters were processed, clones 20 and 19 formed the third cluster, followed by 9 and 10, 5, 12, and 22 and 21.

The results reported here show that RAPD may be a reliable and effective means to detect genomic background. This is also an indication of the relatively high degree of similarity among garlic germplasm maintained at the Tainan DAIS, some of which originated from China and Indonesia. This high degree of similarity indicates that these garlic clones were likely obtained from a narrow geographical area.

Bulbing Response to Daylength of Some Tropical Bulbing Alliums

Summary

Fourteen onion cultivars developed for tropical regions were tested for bulbing response in four daylengths (10, 12, 14, and 16 h). None of the 14 cultivars bulbed at 10 and 12 h of daylength in the final observation 90 days after sowing (DAS). Precocious bulb formation and leaf senescence were promoted by longer daylengths (i.e., 14 and 16 h) with inadequate leaf growth. Furthermore, there were cultivar differences in bulb formation and leaf senescence at longer daylengths. N 53 (AC 43), Selection 14 (AC 45), and Brownsville (AC 132) did not form bulbs at the time of the final observation of 90 DAS.

Two entries each of onion, shallot, and garlic were also tested for bulbing response as described earlier. All bulb alliums were sensitive to long daylength in bulbing response, but both onion and shallot were more sensitive than garlic and resulted in lesser number of leaves.

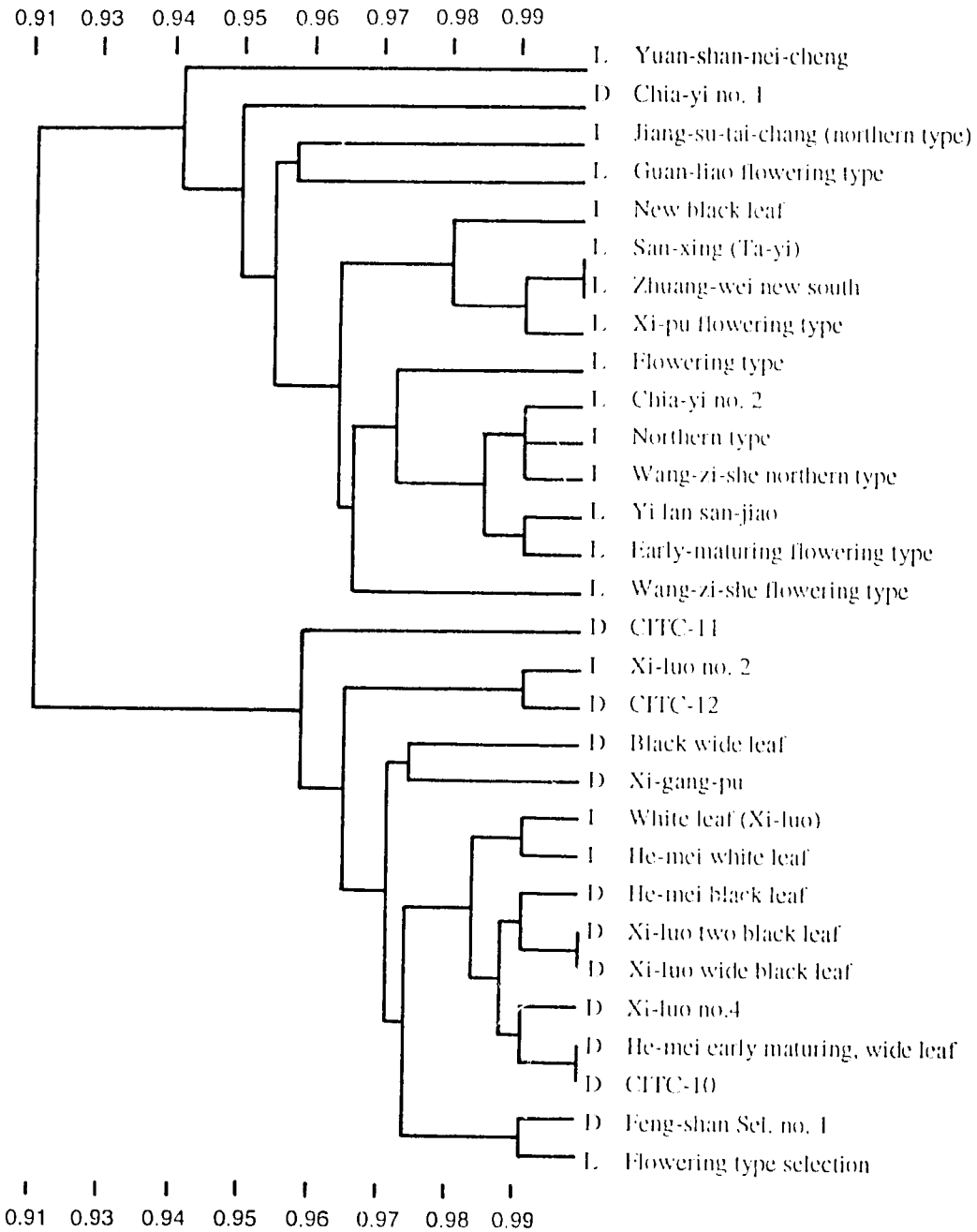

Fig. 1. Similarity analysis of 30 garlic clones using the dendrogram analysis. Dendrogram was created with merged RAPD data using OPI7 and OPI17 as random primers

It appears that the threshold daylength for bulbing among the test entries is between 12 to 14 h of daylength. Short-day bulb alliums in the tropics must acquire adequate leaf growth before initiating and forming bulbs to reach maximum bulb size. To achieve this in production, they must produce ample leaf number at daylength less than threshold daylength before being exposed to critical daylength for bulb initiation and enlargement.

Introduction

The requirement of long daylength to induce bulbing in bulb alliums has been well documented. In general the bulbing response is greater with increasing daylength. Daylength is considered the major determinant of bulbing in garlic, onion and shallot. However, there is a large diversity of onion cultivars selected for growth in different daylength conditions. The bulb alliums which can be grown in tropical regions are often referred to as short-day (but are physiologically long-day) cultivars or clones. And in the tropics where yearly daylength change ranges from 11 to 13 h, temperature instead has been suggested as the more important factor. However, there is no precise information on the bulbing response of short-day bulb alliums to daylength longer than the norm in the tropics. The objective of this study was to investigate the daylength response of short-day bulb allium cultivars that have been developed or evolved in the tropical regions.

Materials and Methods

Experiment 1

Seeds of cultivars Superex (AC 131), Brownsville (AC 132), Tropic Gold (AC 133), East Early Creamgold (AC 134), East Locker Brown (AC 136), Gladalan White (AC 137), Hybrid Granex (AC 138), Gladalan Brown (AC 139), Lockyer Gold (AC140), Onion Rouge (AC 141), Texas Yellow Grano 502 (AC 142) Granex 429, N53 (AC 43), and Selection 14 (AC 45) were sown directly into small seedling pots containing soil, vermiculite, and compost mixture (2:1:1) on 9 July 1993. After emergence, seedlings were thinned to one per pot, fertilized, and watered at regular intervals.

Seedling pots were placed on a mobile cart. Right after emergence, seedlings were given different daylength treatments. Seedlings were sunlit for 10 h every day. The illumination during the remaining day hours was by incandescent and grow-lamps giving 1000 lux at plant height. Daylengths of 10, 12, 14, and 16 h were used. There were four plants per treatment.

Plants were observed for bulb formation at 60, 70, and 80 DAS. At 90 DAS, fresh weight, diameter and length of bulb, plant height, leaf number, and total fresh weight were recorded.

Experiment 2

Seeds of two locally adapted onion cultivars, Granex 429 and Yellow Granex PRR, were directly sown in seedling flats on 20 April. 1993. Forty days later, i.e., 9 May, they were transplanted to pots (15 cm diam x 13 cm ht) containing a fine sandy loam soil and grown under greenhouse conditions. At the same time, two cultivars each of garlic (Black Leaf No. 1 and No. 2) and shallot (Local and Red) were planted. They were grown in growth chambers at 20-25°C with 12-h light for two months. Growth chambers had 60% RH, and photosynthetic photon flux densities were 150 to 180, and 350 to 450 µmol/m/s for growth chamber and greenhouse, respectively. On 29 July, seedlings were maintained at four different daylengths as described earlier.

Forty-five days after the initial treatment, i.e., 13 September, plants were sampled for growth and bulbing observations. There were three replicates for each treatment.

Results and Discussion

Fig. 2 shows the bulbing response of 14 onion cultivars to 14 and 16 h of daylength as observed at 60, 70, 80, and 90 DAS. All 14 cultivars bulbed at 16 h of daylength; some cultivars reached 100% bulbing and neck lodging with very small bulb size and meager overall growth at 70 DAS. Under 14 h of daylength AC 43, AC 45, and Brownsville (AC 132) did not form bulbs but all other cultivars did. On the other hand, none of the 14 cultivars formed bulbs at 10 and 12 h of daylength in the final observation at 90 DAS. The results reported confirm that the bulbing process is more rapid as the daylength is increased, and daylength requirement for bulbing differs among cultivars. The longer the day, the sooner leaf growth ceases and the sooner the bulb ripens. It appears that the threshold daylength for bulbing among tested cultivars is between 12 and 14 h. Although the variation over the year in daylength in the tropics is within a narrow range of approximately 11 to 13 h, some extremely sensitive cultivars readily initiate and form bulbs without adequate leaf growth under this photoperiodic condition. This phenomenon is detrimental to bulb enlargement because of limited supply of photosynthates.

Based on the harvest index data (table 4), all three bulbing alliums are long-day plants in terms of bulb formation. Long daylength promoted early maturity of onion, shallot, and garlic, resulting in less total fresh weights 45 days after the initial daylength treatment. Leaf numbers of onion and shallot decreased substantially under long-day conditions. Both onion and shallot appeared to be very sensitive to long daylength in bulbing response. In contrast to these results, however, both onion cultivars produced relatively larger bulbs. This is likely due to their ability to accumulate sizable nonbulbing leaves under short-day conditions for 60 days before being exposed to different daylength treatments.

In conclusion, bulbing allium production in the tropics requires short-day cultivars. However, this does not mean these cultivars are physiologically short-day plants in terms of bulbing, a term which has a different and specific meaning. They are all still physiologically long-day plants, but have relatively shorter threshold daylength. The results reported here show that short-day cultivars require adequate leaf growth before initiating and forming bulbs to attain maximum bulb size. For this to happen in production, they must begin leaf growth at daylength less than threshold daylength before being exposed to threshold daylength for bulb initiation and formation. In terms of varietal improvement, the results also suggest that the selection of short-day bulb alliums is possible in the seedling stage by exposing the seedlings to artificial light.

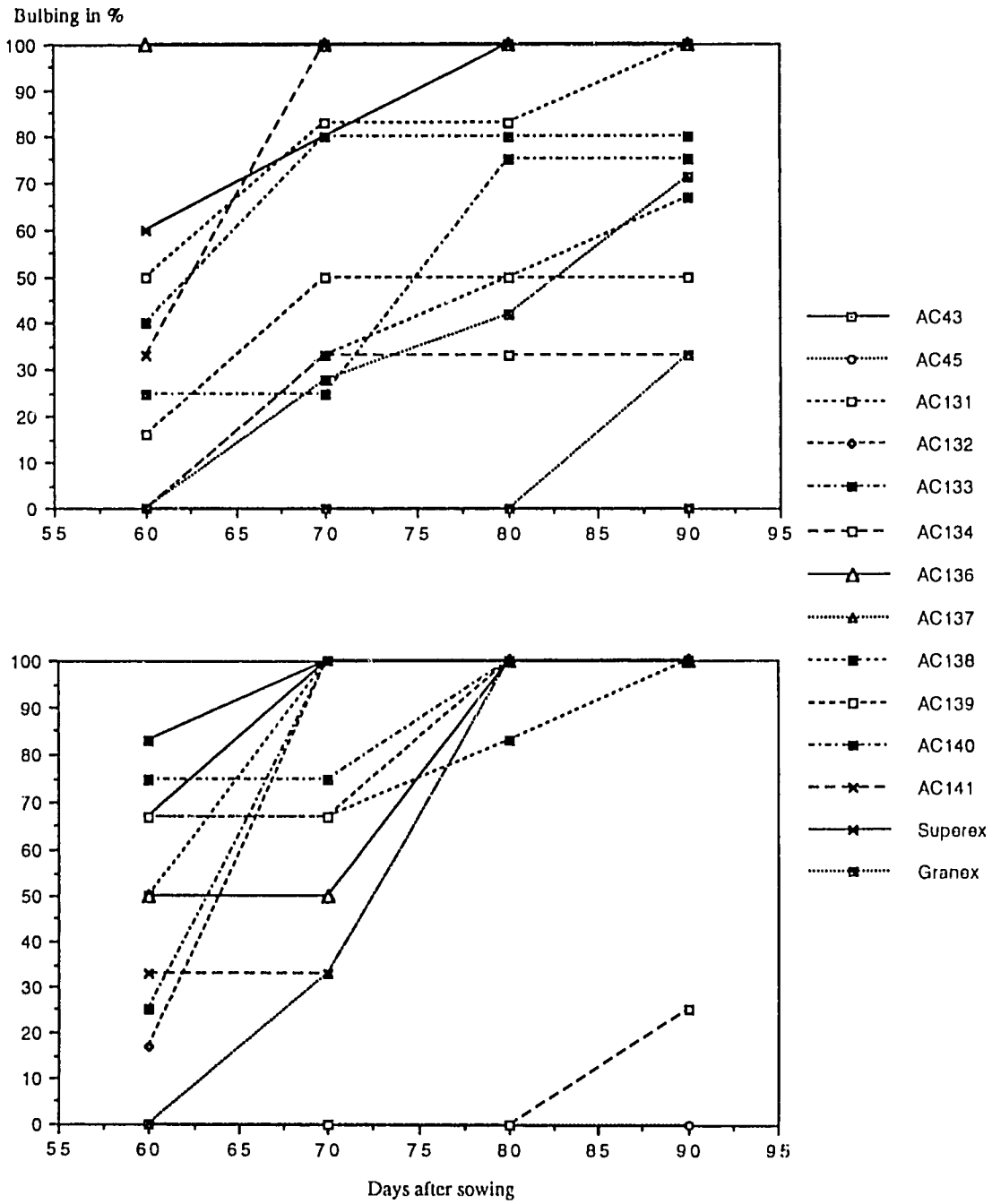

Fig. 2. Bulbing response of 14 onion cultivars to two daylengths: top, 14 h of daylength; bottom, 16 h of daylength

Table 4. Effect of daylength on bulb and total fresh weights and harvest index of allium cultivars

Cultivar	Daylength (h)	Bulb FW (g/plant)	Total FW (g/plant)	HI (%)	Leaf no./ plant
Onion	10	7.46 e[a]	45.71 b	16.3 d	6.8 ab
Granex 429	12	15.11 d	54.2 a	27.9 c	7.1 ab
	14	32.88 b	45.88 b	71.5 b	5.4 a-c
	16	39.60 a	48.19 b	82.4 a	3.7 c
	10	7.15 e	45.15 b	15.6 d	7.7 a
Yellow Granex	12	18.67 d	35.19 a	33.9 c	7.3 ab
	14	26.05 c	34.35 c	76.0 ab	5.0 a-c
	16	30.20 bc	36.84 c	83.0 a	4.4 b
Shallot	10	8.46 d	48.81a	17.1d	65.2 a
Local	12	14.96 c	43.64 b	34.7 c	44.7 b
	14	15.59 c	28.51 c	55.2 b	23.9 cd
	16	19.51 ab	32.88 c	59.0 b	31.3 c
	10	9.06 d	45.04 ab	20.1 d	57.9 a
Red	12	21.01 a	41.79 b	50.6 b	33.9 c
	14	15.16 c	20.24 d	76.0 a	21.2d c
	16	17.76 b	21.92 d	82.0 a	17.0 d
Garlic	10	6.64 bc	49.43 b	13.5 cd	8.8
Black Leaf 1	12	7.62 b	54.11 a	14.5 cd	9.0
	14	12.74 a	45.11 c	28.6 b	9.9
	16	10.90 a	38.21 d	28.7 b	9.3
	10	5.59 c	46.91 bc	11.7 d	9.3
Black Leaf 2	12	8.49 b	48.46 bc	17.7 c	10.3
	14	12.90 a	50.03 b	26.0 b	10.2
	16	12.39 a	36.39 d	34.4 a	9.9

[a]Means in the same column of the same cultivar followed by the same letter are not significantly different at 5% level (DMRT).

Tissue Culture System for Garlic and Onion

Summary

Efforts were made to establish a tissue culture system for the propagation and genetic transformation of garlic and onion. B-5 medium with NAA 0.1 mg/l and 2-ip 0.5 mg/l, or NAA 0.5 mg/l and 2-ip 2 mg/l were suitable for adventitious shoot formation and multiplication of halved shoot-tip of sprouting garlic cloves. MS media with NAA 0.5 mg/l and BA 5 mg/l, or NAA 0.5 mg/l and 2-ip 5 mg/l were suitable for adventitious shoot formation and multiplication of onion bulb scale-bases.

Introduction

Garlic is an apomictic plant. This deters the progress of cross-breeding for varietal improvement. Thus, improvement of this crop may have to rely on genetic transformation. Furthermore, vegetative propagation of garlic is slow, seasonal and readily infected with viruses. The objective of this study is to establish a tissue culture system for garlic germplasm preservation, multiplication, and genetic transformation. This study also tested onions as references: an effective tissue culture

system of onion would be useful for maintenance and multiplication of male-sterile lines for hybrid seed production.

Materials and Methods

Garlic

Dormant and sprouting bulbs of Black Leaf clone were used. Cloves were separated from the bulb, their protective membranes removed, and then sterilized with 70% ethanol for 30 sec. The storage leaf was removed, and the whole or halved shoot-tip with basal plate, measuring 6-8 mm in length, and shoot-tip alone, were dissected as explants. B-5 and MS media at pH 5.8 containing 0.8% agar, BA, 2-ip and/or NAA were used. Explants were cultured in test tubes (10 cm in length) containing 10 ml of media under 25°C and 12 h 3000 lux light conditions. Different sucrose concentrations (2-8%) were tested to promote multiple shooting.

Onion

Sprouting bulbs of Yellow Granex and Granex 429 were used. After removal of several layers of leaf scales, bulbs, about 40 mm, were sterilized with 70% ethanol for 1 min. They were then cut transversely at the widest point, and outer scales of the lower half were peeled off. The basal plates with two to three small leaf scales (3 x 10 mm) were used as explants.

The basal medium (BM) at pH 5.8 consisted of half-strength of MS salts, 100 mg/l myo-inositol, 0.5 mg/l thiamine-HCl, 1.0 mg/l pyridoxine-HCl, 5.0 mg/l nicotinic acid, 30 g/l sucrose, and 0.8% agar. The medium was supplemented with BA, 2-ip and/or NAA. Cultures were kept under 25°C with 12 h of 3000 lux light.

Results and Discussion

Garlic

On B-5 supplemented with 0.1 mg/l NAA + 0.5 mg/l 2-ip or 0.5 mg/l NAA + 2 mg/l 2-ip, whole shoot-tips with basal plates grew better than shoot-tips alone. Most cultures were single shooting. Plantlets derived from shoot-tips with basal plate were healthy and strong. Some of these plantlets could be multiplied by cutting at the basal portion.

Dormant cloves were easier than sprouting cloves for explant preparation. High sucrose concentrations were not effective in promoting shoot proliferation of all three types of explants, but improved the vigor of shoots. Most shoots on the media with higher sucrose concentrations also tended to form bulbils. These bulbils could sprout after about 3 mo (fig. 3) and should be good sources for multiplication.

Halved shoot-tips with basal plate of the dormant cloves and sprouting cloves produced adventitious shoots on B-5 media with 0.5 mg/l 2-ip and 2 mg/l 2-ip. Combination of 0.1 mg/l NAA + 0.5 mg/l 2-ip, or 0.5 mg/l NAA + 2 mg/l 2-ip further increased shoot number (table 5). Sprouting cloves were better than dormant cloves for multiplication. Explants from sprouting cloves multiplied to about 10 shoots within 6-7 wk (fig. 4), in which period plants had been subcultured once. Results suggest that clove vigor was important for shoot proliferation.

All multiplied shoots could be easily rooted by subculturing in MS media with 1 mg/l NAA.

Onion

Leaf scale pieces cultured on BM containing 0.5 mg/l NAA and 5 mg/l 2-ip gave rise to a mass of more than 20 adventitious shoots within 6-7 wk (fig. 5). The same explants, cultured on BM

with 0.5 mg/l NAA + 5 mg/l BA and 3 mg/l NAA + 10 mg/l BA after being cultured under darkness on BM with 10 mg/l NAA + 10 mg/l BA for 3-4 wk, also produced more than 20 adventitious shoots within 5-6 wk (table 6).

Adventitious shoots, produced either from leaf bases or scale explants, could be easily rooted by subculturing in MS medium containing 1 mg/l NAA. The mass of adventitious shoots was trimmed to 10-20 mm high and separated into halves or quarters at each subculture. Some of the shoots thickened at the base of the plantlet to form bulbils. Once the bulbil formed, the multiplication rate of adventitious shoot seemed to be reduced.

Fig. 3. Sprouting of garlic bulbils after 3 months of in vitro culture

Table 5. Response of halved shoot-tips with basal plate from sprouting cloves of garlic in B-5 media with NAA and 2-ip

Media supplement	Total no. of cultures	No. of cultures with shoots	Shoot no./ culture
0.1 mg/l NAA + 0.5 mg/l 2-ip + 2% sucrose	7	5	4.2
0.1 mg/l NAA + 0.5 mg/l 2-ip + 3% sucrose	8	7	1.8
0.1 mg/l NAA + 0.5 mg/l 2-ip + 8% sucrose	3	1	4.0
0.5 mg/l NAA + 2.0 mg/l 2-ip + 3% sucrose	9	6	4.9
0.5 mg/l NAA + 2.0 mg/l 2-ip + 4% sucrose	4	2	3.5
0.5 mg/l NAA + 2.0 mg/l 2-ip + 8% sucrose	6	4	1.5

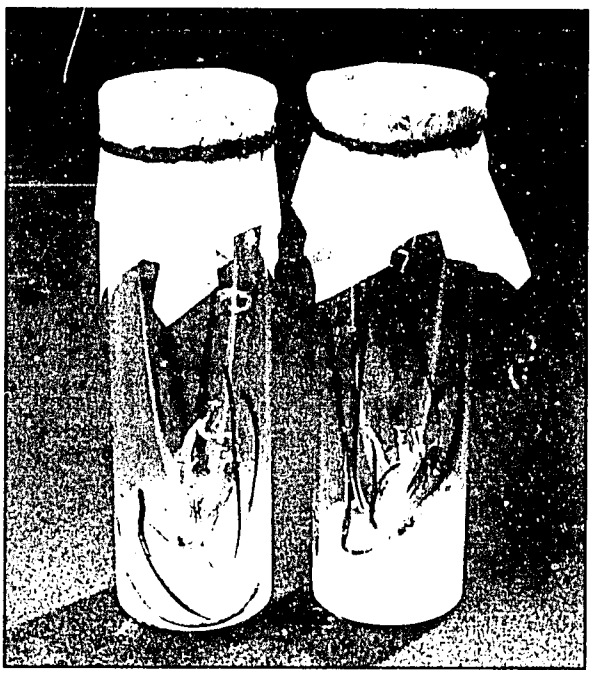

Fig. 4. Shoot proliferation of garlic halved shoot-tip with basal plate cultured for 5 wk on B-5 medium with 0.5 mg/l NAA and 2 mg/l 2-ip, in which period explants had been subcultured once

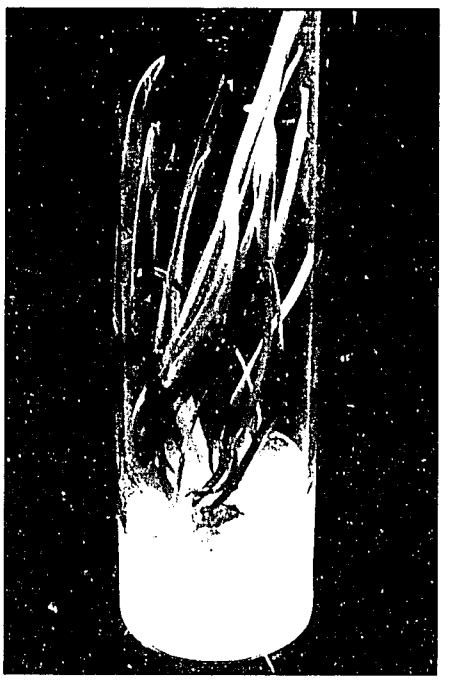

Fig. 5. Multiple shoots of onion, Granex 429, cultured on BM with 0.5 mg/l NAA and 5 mg/l 2-ip for 5 wk

Table 6. Response of leaf-scale pieces of onion in modified MS media (BM) with NAA, 2-ip and/or BA

Media	Total no. of cultures	No. of cultures with shoots	No. of plantlets with multiple shoots
BM + 0.5 mg/l NAA + 5.0 mg/l 2-ip	23	16	8
BM + 10 mg/l NAA + 10 mg/l BA then BM + 3 mg/l NAA + 10 mg/l BA	11	9	5
BM + 10 mg/l NAA + 10 mg/l BA then BM + 0.5 mg/l NAA + 5.0 mg/l BA	8	7	3

Crucifer Breeding

Development of Heat-Tolerant Chinese Cabbage Composite Populations

Summary

In the late summer of 1992, three B_4 composite populations and a number of families of three bee-pollinated composite populations derived from progeny testing using S_1 families (B_4/PTS_1), Chinese cabbage populations were grown in the field to select components for selfing, intercrossing, and further bulking. During the 1992-93 cool season, the composite was produced by randomly intercrossing within populations in an isolated screenhouse. All selections were selfed by hand to produce inbred seeds. Selfed seeds of B_4/PTS_1 families with high heat-tolerant frequency were also bulked in equal proportion and grown in pots after directly inducing to flower to produce composite in the same way. These bulked composite populations were grown in the field in the midsummer of 1993 to evaluate their heat tolerance. Differences among composite populations were not significant except that composite III had a significantly higher head shape index. There were no significant differences in head weight and solidity of heads among all entries, indicating the possibility of selecting a high level of heat tolerance from them. The composite populations will be further selected for heat tolerance and for increased frequency of heat-tolerant genes.

Introduction

The main goal of the Chinese cabbage improvement project is to tropicalize the crop and obtain an economically reasonable yield level. Recently, the development of a few genetically diverse heat-tolerant composites was adopted as a general strategy. This strategy was designed to ensure the maximum utilization of previously developed genetic materials and to preserve them for further research.

In 1992-93 we continued to work on the three composite populations that had been developed earlier. We also planted them in the 1993 hot season to observe their general performance under high temperatures and to see if the procedure should be adjusted.

Materials and Methods

In midsummer 1992, three bulked bee-pollinated composite (B_4) populations were compared to the standard heat-tolerant check, ASVEG No. 1. At the same time, selfed (S_1) families from the third composite cycle (B_3S_1) were planted in the field to evaluate for heat tolerance. They were sown on 11-12 June and transplanted to the field on 30 June or 1 July 1992.

In the late summer of 1992, new populations were composed of selected heat-tolerant plants of the B_3 cycle (designated as cycle B_4) and from selfed seeds (B_3S_1) of families with a high frequency of heat tolerance (designated as cycle B_4/PTS_1 which means they are derived through

progeny testing using S_1 families) for observation and selection. Three new B_4 populations were sown on 7 August and transplanted on 3 September 1992. Selfed seeds of B_4/PTS_1 families were sown on 12 August and transplanted on 4 September 1992. Both Composite I (Chang Puh-type) and Composite II (ASVEG 1-type) consisted of 22 B_4/PTS_1 populations, each with a standard heat-tolerant check, ASVEG No.1. Composite III (semitropical type) contained 23 B_4/PTS_1 populations with ASVEG No.1 as the check. Each plot unit consisted of two 1.5-m-wide, 4-m-long double-row beds. The spacing was 50 cm between rows and 40 cm between plants.

The criteria for selection were as follows: frequency of heat-tolerant plants, rate of bolting, incidence of disease (such as softrot, downy mildew, Alternaria, and tipburn), and other horticultural traits (e.g., vigor, maturity, and head shape). During the 1992-93 cool season, synchronization of flowering among the selected components was carried out for the three B_4 groups. After being selfed by hand, groups were randomly arranged in an isolated screen cage for mass pollination by honeybees. Selections of the three B_4/PTS_1 groups were selfed only by hand. Seeds from each selection were harvested individually and composited in an equal proportion to create new base populations of the composite. These new base populations were evaluated for heat tolerance in the 1993 hot season.

In December 1992, another three batches from selfed seeds of B_4/PTS_1 families were sown in petri dishes. They were transferred to the vernalization chamber (5°C) to induce flowers after germination. Seedlings were transplanted to clay pots after the treatment. Each group was moved to an isolated screen cage for mass pollination by honeybees. Seeds from each plant were collected individually and composited in an equal proportion to create new populations. These new base populations were also evaluated for heat tolerance in the 1993 hot season.

In the 1993 hot season trial, those new base populations selected from the 1992 summer and winter trials were observed. A randomized complete block design with three replications was employed. The field layout was the same as that in the late summer trial of 1992. The composite populations were evaluated for heat tolerance and other major horticultural traits.

Results and Discussion

Seventy-five selections each were chosen from the three B_4 composites. However, only 50 plants of Composite I, 46 of Composite II, and 60 of Composite III survived after they were transferred to pots. The selections that survived were induced to flower synchronously. Seeds were produced for new bases of composites. Selfed or intercrossed seeds were harvested separately from individual plants. They were the components of each group for further uses.

In the 1992 late summer trial, several selections were also made from the other three B_4/PTS_1 composites: 65 plants from composite I, 64 from Composite II, and 67 from Composite III. After they were transferred to pots, only 37 plants of Composite I, 39 of Composite II, and 34 of Composite III survived. The survivors were induced to flower and selfed seeds were collected.

The 1993 summer trial was severely damaged by pests (flea beetles then diamondback moths) due to the extraordinary drought after transplanting. Almost every entry was damaged by pests to a certain extent except the hybrid check, ASVEG No.1, which escaped damage because of its extremely early maturity (table 1). These entries tended to be late maturing, and they suffered more from diseases and the insect attack. Their rates of heading, harvest, and yields were low.

In general, differences among composite populations were not significant (table 1) except for long head conformation. Composite III had a significantly higher head shape index. There were no significant differences in head weight and solidity of the heads between the composites and

the heat-tolerant check ASVEG No. 1, indicating that it is possible to select a high level of heat tolerance from among the composites.

Table 1. Performance of composites[a] compared to the heat-tolerant check ASVEG No. 1, AVRDC, summer 1993

Entry	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Head weight (kg)	Head shape index	Solidity (g/ml)	Heading rate (%)	Soft rot (%)
Composite I (B_5)	12.2 bc	45 bc	63 c-e	0.57	1.8 b	0.41	71 c	4
Composite I (B_3S_1/B_1)	12.6 abc	48 ab	63 c-e	0.58	1.8 b	0.48	72 c	5
Composite I (B_3PTS_1/S_1)	9.1 bc	49 ab	58 c-e	0.47	1.7 b	0.41	73 c	6
Composite II (B_5)	15.4 ab	41 c	83 ab	0.57	1.7 b	0.39	88 ab	4
Composite II (B_3S_1/B_1)	13.3 a-c	47 a-c	68 b-d	0.58	1.6 bc	0.41	77 bc	7
Composite II (B_3PTS_1/S_1)	8.7 bc	47 a-c	54 de	0.48	1.6 bc	0.47	77 bc	10
Composite III (B_5)	13.8 a-c	52 a	71 bc	0.58	2.2 a	0.39	78 bc	8
Composite III (B_3S_1/B_1)	13.1 a-c	52 a	59 c-e	0.68	2.3 a	0.41	72 c	11
Composite III (B_3PTS_1/S_1)	8.4 c	52 a	50 e	0.49	2.3 a	0.49	72 c	13
ASVEG No. 1	19.3 a	32 a	97 a	0.59	1.4 c	0.53	97 a	0
c.v. %	27.9	7.3	12.9	21.3	6.8	15.5	9.9	

[a]Means within the same column followed by the same letter are not significantly different at 5% (DMRT).

Conclusions and Recommendations

In general, differences among composite populations were not significant except for the long head conformation which was more preponderant in composite III. No significant differences in head weight and solidity of the heads between the composites and ASVEG No. 1 indicated that a high level of heat tolerance can be selected from among the composites. These populations should be further selected to increase the frequency of heat-tolerant genes.

Development of Heat-Tolerant Chinese Cabbage Populations with Long Head Shape

Summary

Selected families with the desired long head shape and dense head formation (indication of heat tolerance) were taken from four segregating populations. Most of the selected families were medium-early to medium-late maturing with compact, medium-long to long heads. Some F_5 families from an intercross population were medium maturing with very long heads which were the typical 'bamboo-type' heads of B 61. Several S_2 families derived from the maternal line selection (MLS) of 77M(3)-27 were medium-early maturing with long and large heads. In general, the segregating materials deviated appreciably from the 'bamboo-type' head conformation of B 61. Selections with the longest head types were taken for intrafamily intercrossing with the aim of recapturing the head conformation of B 61 and the heat tolerance of tropical parents in the subsequent generation.

Introduction

One of the major hindrances in popularizing AVRDC's tropical Chinese cabbage in some countries is its round to near-round head conformation. Consumers are apparently familiar with cultivars with a elongated head shape, particularly 'Wong Bok' which is popular in the tropical highland production regions. A breeding project was initiated in 1985 to develop heat-tolerant varieties with cylindrical or elongated head shape to meet the consumer preference in the tropics. In 1993, several populations developed from various sources were planted for further selection.

Materials and Methods

Four batches of segregating populations selected in the fall of 1992 and screened against heat tolerance in the summer of 1993 were planted for further selection. Batch 1 consisted of 12 F_5 families from intercrosses between promising and cylindrical-headed inbred lines of the backcross program. Batch 2 consisted of 17 F_4 families from triple crosses between promising, cylindrical-headed inbred lines with heat-tolerant inbred lines. Batch 3 included 33 S_2 families which were derivatives of the maternal line selections from 77M(3)-27. Batch 4 included 15 S_2 families derived from MLS of 77M(3)-35. Forty individuals from each selected family were planted. In addition, 40 plants of ASVEG No.1 were also planted in each batch as a general check for heat tolerance. The segregating families and the checks were planted to the field on 1.5-m beds. Unit plots consisted of double-row and 4-m-long beds. Spacing between rows within each bed was 50 cm and between plants within rows, 40 cm.

Seeds were sown on 20 August and seedlings were transplanted to the field on 9–10 September 1993. Selection of progenies emphasized the combination of compact head formation with elongated head shape.

Results and Discussion

Table 2 shows the general characteristics of the selected families from segregating populations possessing the combination of the desired elongated and compact heads. The first two batches were related to promising and cylindrical-headed inbred lines. The rest were selections from MLS of open-pollinated varieties. Most selected families tended to be medium-early to medium-late maturing with compact and medium-long to long heads. As expected, ASVEG No.1 matured the earliest with very compact and medium-sized heads.

Table 2. Summary of selection for heat-tolerant families with elongated head shape from various segregating populations, AVRDC, late summer 1993

Population	No. of families	General maturity[a]	Heat tolerance[b]	Head size[c]	Disease[b]
Batch 1	12	M–L	3 – 6	M–LL	1 – 3
Batch 2	17	ME–L	3 – 8	M–L	1 – 3
Batch 3	33	E–M	4 – 9	M–LL	1 – 2
Batch 4	15	E–ML	3 – 7	M–ML	1 – 4
ASVEG No. 1 (ck)		VE	10	M	4

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

Some F_5 families of intercross population were medium maturing with very long heads, typical of the 'bamboo-type' heads of B 61. These selections produced heads that were very tight on the bottom and middle parts, but partly loose at the top. Several S_2 families derived from MLS of 77M(3)-27 were medium-early maturing with long and large heads.

In general, the segregating materials deviated appreciably from the 'bamboo-type' head conformation of B 61. Selections with the longest head types were taken for intrafamily intercrossing with the aim of recapturing in the subsequent generation the head conformation of B 61 and the heat tolerance of tropical parents. These selections will be further tested and stabilized. Self-incompatibility of the selections will be examined during the selfing process to isolate potential inbreds for hybrid development.

Development of Heat-Tolerant Common Cabbage

Summary

To develop heat-tolerant common cabbage inbred lines for hybrid or open-pollinated varieties, 98 accessions were grown in the field during the summer wet season, but only 61 nonhybrid accessions and 2 hybrid checks had enough seedlings for observation. Among the 61 nonhybrids evaluated, only five accessions showed relative heat tolerance. Based on heat tolerance, disease resistance, and general performance, 76 plants were selected and 49 of them were successfully induced to flower to produce selfed seeds for further breeding work. Another 25 hybrids were also observed in this season. Among them, only three commercial varieties performed well in terms of heat tolerance and resistance to black rot.

In the 1992 plantings, seven accessions, including two F_1 hybrids, F_2 populations of two F_1 hybrids, two breeding lines, and one open-pollinated cultivar, were observed in the first autumn planting. Eighty plants were selected and 58 of them were induced to produce seeds. In another planting, 20 nonhybrid accessions with good performance in the earlier planting and three hybrid checks were replanted to confirm the selection. Four hundred and two plants were selected, but 113 selections produced seeds.

In the 1993 hot-wet trial, all nine accessions were heat-tolerant because of their rather high heading rates and relatively acceptable yields. Most accessions were medium-early maturing with flat heads, except the two oblong varieties, BB 113 and BB 116, which had compact and small heads. BB 113 was extremely early which matured 41 DAT, while BB 116 was relatively late maturing at 61 DAT. Further conformation trials are necessary before incorporating these heat-tolerant materials into the common cabbage breeding project.

Introduction

Heat-tolerant common cabbage hybrids have been developed and released to cabbage growers in the tropics by several seed companies. However, seeds of these hybrids are inordinately priced. The quality of the seeds also tends to be lower than those grown in the high elevation or during the cool season in the lowland. National programs clamor for less expensive seeds of tropical varieties. The development of heat-tolerant common cabbage for the tropics is a goal of the center's Crop Improvement Program for crucifers.

Materials and Methods

1992 summer trial. Two plantings were done at the 1992 summer trial. Ninety-six nonhybrid accessions and two check hybrids were grown at the first planting. Among the 96 accessions were one Chinese kale, one Chinese cabbage, one cherry radish, one collard, and five kale. The sources of the seeds were GRSU, TARI, and the Sanchuong Branch Station of Taoyuan DAIS. Forty-eight seeds of each accession were sown on 9 July and seedlings were transplanted to the field on 6 August 1992. The second planting was sown on 13 July and transplanted on 6 August 1992. There were 25 hybrids at the second planting. Heat tolerance, disease resistance, and general performance were observed and some selection was done to produce seeds for further experiments.

1992 autumn trial. Seven accessions were sown on 15 October and 500 plants of each were transplanted to the field on 23 November 1992. The accessions included two F_2 populations of two hybrids, KY Cross, and Shiafong No.1 (the former was propagated at AVRDC and the latter was provided by TARI), two breeding lines (BB 023 and BB 024) from Sanchuong Branch Station of Taoyuan DAIS, and three checks (KY Cross, Shiafong No.1 [both are F_1 hybrids], and Yehshern, open-pollinated local cultivar). Heat tolerance, disease resistance, and other desirable traits were observed.

Another planting had 20 nonhybrid accessions which had good performance in earlier plantings. They were sown on 16 October for more intensive selection purposes. To improve the germination rate, seeds were sown in petri dishes and incubated under favorable conditions. Germinated seedlings were individually transferred to polyethylene pots and raised under net tunnels. Two F_1 hybrids, KY Cross and Shiafong No.1, and one open-pollinated cultivar, Yehshern, were used as checks. They were transplanted to the field (up to 200 plants of each family) on 24 November 1992.

1993 hot-wet season trial. In the hot-wet monsoon season of 1993, nine new accessions were grown under hot and humid conditions to evaluate their heat tolerance, disease resistance, and general performance. They were BB 109, Sunshia F_1 hybrid from Seoul Seed Co. of Korea; BB 110, Chunchiou F_1 hybrid from Noongsheng Seed Co. of Taiwan; BB 111, Lianguan Cabbage from China; and six F_1 hybrids from Takii Seed Co. of Japan: BB 112, KK Cross; BB 113, Golden Cross; BB 114, Y-R Summer 50; BB 115, Southern Treasure; BB 116 Tight Globe; and BB 117, Green Stone. These accessions were sown on 1 April along with two hybrids from Japan, namely, BB 006 Shiafong No.1, a popular heat-tolerant variety, and BB 008 KY Cross, the most popular variety in Taiwan, and one open-pollinated cultivar, namely, BB 020 Yehshern, as checks. Seedlings were nursed in polyethylene pots under screen net tunnel. They were transplanted to the field on 29 April 1992.

For all trials, RCBD with two replications was used. Each unit plot consisted of one 5-m-long, double-row bed. The spacing was 150 cm between beds, 50 cm between rows, and 50 cm between plants within the row. Beds were mulched with rice straw on the top to reduce weeds and infection due to continuous heavy rains.

Results and Discussion

1992 summer trial. Most seeds provided by GRSU were old and had very poor germination rates. Collections from TARI and TSIPS were almost in similar condition. At the first planting, only 63 entries, including the two hybrid checks, germinated. Healthy and vigorous seedlings were transplanted to the field on 6 August. Seedlings from seedlots had poor germination rates

and were generally weak and retarded. They were transplanted after being maintained in the nursery for a prolonged period of nursing. In spite of this, they were less vigorous and easily damaged by heat and moisture stress (minimum daily air temperatures above 25°C; more than 500 mm cumulative monthly precipitation) after transplanting. Rejuvenation of these seeds was recognized to be a high priority in the improvement of this crop. GRSU multiplied 10 accessions in the 1993-94 cool season.

Among the 67 germinated accessions, Shiachong performed relatively well with a heading rate of 75%, an acceptable flat head shape and moderate black rot resistance. KY Cross did not form compact heads in the trial. Only five nonhybrids showed some levels of heat tolerance. They were: BB 014, BB 015, BB 016, and BB 017 (all provided by TSIPS), and BB 024 (from the Sanchuong Branch Station of Taoyuan DAIS).

Based on heat tolerance, disease resistance, and general performance, 76 plants were selected from the nonhybrid accessions in the summer trial to develop heat-tolerant common cabbage inbred lines for hybrid and/or open-pollinated variety development. Fifty-five plants survived after transferring to individual pots; 49 surviving selections were successfully induced to flower and selfed seeds were produced for further breeding work.

Among the 25 hybrids evaluated, Shiafong No. 1 performed best, with a heading rate of 80%, the acceptable flat head shape, and moderate resistance to black rot. Shiafong No. 1 was followed by Lambada with a 65% heading rate and small round heads, but it was sensitive to black rot. The third one, Shiachong, was only moderately heat-tolerant (indicated by its 40% heading rate), but had acceptable flat heads and was resistant to black rot.

1992 autumn trial. Except for BB 007 (F_2 seeds of Shiafong No. 1 provided by TARI) which did not germinate, the F_2 seeds of KY Cross propagated at AVRDC and two breeding lines, BB 023 and BB 024, germinated better compared to previous plantings because of better germination and seedling care. All accessions produced plenty of seedlings (500 each) for transplanting to the field. In this planting, 85 plants were selected; 76 of them survived after they were transferred to individual pots. Fifty-eight survivals were induced to flower and successfully produced seeds for further breeding work.

Survival selections which failed to produce seeds in the cool season of 1992-93 were kept in the greenhouse during the summer season and were rejuvenated by cutting for the next cool season. Due to limited amount of selfed seeds, consequent trials were delayed until favorable weather conditions in the autumn of 1993 for further selection.

AVRDC's experience with Chinese cabbage shows that the survival rate of selections taken in the midsummer in Taiwan is relatively low. To ensure effective selection, remnant seeds of the best 20 families from the 1992 summer trials were replanted for more intensive selection in the 1992 late summer/fall. The germination rate in this additional planting was improved by germinating them in controlled temperature chambers. Seedlings were generally stronger than those in the first planting by improving the nursery management. Many entries had sufficient seedlings (200 each) for transplanting. In this planting, 402 plants were selected and 295 of them survived after they were transferred to individual pots. Only 113 survivals were induced to flower and successfully produced seeds because these high latitude-originated varieties did not survive well after vernalization at 5°C and 24 h continuous light.

1993 hot-wet season trial. Table 3 shows the performance of new common cabbage accessions in the hot-wet season of 1993. All traits, except for the percentage of heads infected by softrot, were significantly different among various varieties. The open-pollinated check cultivar BB 020 Yehshern yielded very poorly (0.5 t/ha) and produced loose (0.43 g/ml in

solidity), small heads (0.28 kg/head) with very low heading rate (13%), resulting in a low harvest rate (6%). Other entries carried heat tolerance genes as evidenced by rather high heading rates. Only BB 115 Summer Treasure and BB 117 Green Stone outyielded the checks. Most entries were medium-early maturing with flat-shaped heads shown by (< 1.0) the head shape index (HSI). Two accessions had oblong-shaped heads indicated by higher HSI (1.2-1.3) with compact and small heads. BB 113 Golden Cross was extremely early maturing (41 DAT) while BB 116 Tight Globe was relatively late maturing (61 DAT). Further trials for conformation are necessary before incorporating these heat-tolerant materials into the common cabbage breeding project.

Table 3. The performance of common cabbage accessions[a] in the hot-wet season trial at AVRDC, 1993[b]

Entry	Variety	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Head weight (kg)	Head-shape index	Solidity (g/ml)	Heading rate (%)	Soft rot (%)
BB 006	Shiafong No. 1	14.9 a-c	51 b	82 d	0.69 abc	0.8 bc	0.46 cd	91 a	10
BB 008	KY Cross	18.9 a	51 b	82 d	0.86 a	0.7 c	0.47 b-d	88 a	19
BB 020	Yehshern	0.5 d	–	6 f	0.28 e	0.8 bc	0.43 ce	13 b	0
BB 109	Sunshia F_1	8.7 c	51 b	63 e	0.52 c-e	0.9 b	0.51 b-d	83 a	7
BB 110	Chunchiou F_1	16.6 ab	51 b	88 cd	0.71 a-c	0.7 c	0.44 cd	91 a	10
BB 111	Lianguan	13.4 a-c	58 ab	91 bc	0.56 b-d	0.9 b	0.48 b-d	94 a	6
BB 112	KK Cross	14.1 a-c	55 ab	91 bc	0.59 a-d	0.8 bc	0.34 d	97 a	7
BB 113	Golden Cross	12.8 a-c	41 c	100 d	0.48 c-e	1.3 a	0.69 a	100 a	0
BB 114	Y-R Summer 50	17.2 a	54 ab	97 ab	0.66 a-c	0.9 b	0.44 cd	97 a	3
BB 115	Southern Treasure	20.1 a	54 ab	94 a-c	0.80 ab	0.9 b	0.58 a-c	100 a	3
BB 116	Tight Globe	9.1 bc	61 a	97 ab	0.35 de	1.2 a	0.65 ab	97 a	0
BB 117	Green Stone	20.3 a	54 ab	94 a-c	0.81 ab	0.8 bc	0.60 a-c	97 a	0
	c.v. %	20.5	7.1	3.8	17.1	8.8	13.5	8.2	

[a]Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).
[b]Sown on 1 April and transplanted on 29 April 1993.

Flowering Trials on Common Cabbage

Summary

A series of flowering trials were conducted under natural cool conditions to observe the flowering behavior of some cabbage accessions. The accessions were sown at various times in mid-September, October, and November 1992. BB 010, a Chinese kale, was observed to flower the easiest completing flowering in 58 DAS. Chinese kale may be a good source of easily flowering gene. BB 020, a local Taiwanese common cabbage, not only flowered easily but also had some acceptable traits. It could be the best source of flowering genes for the tropical common cabbage improvement project.

Three kinds of mechanical plant treatments were done; all of them facilitated bolting and flowering. Cutting across the head was the best way of producing more branches than cutting the top half of the head. Plants with cut and trimmed whole head had good branching, but this treatment only favored the late maturing variety.

Another series of flowering trials were conducted under artificial conditions by combining vernalization (5°C for 25, 35, and 45 days) and daylength treatments (24 h of light or darkness). Plants grown under these six combinations flowered earlier than under the natural condition. KY Cross, a later bolting variety under natural cool seasons, responded to treatments better than Shiafong No.1. When the duration of vernalization was long enough, it could displace the long-day requirement, as indicated by no significant differences between combinations with two light conditions (i.e., 24-h continuous light vs. complete darkness). Twenty-five days of low temperature treatment were sufficient to show the effect.

Introduction

Seed production of crucifers in the tropics is difficult due to the inadequate winter chilling to induce bolting and flowering. High temperatures result in abnormal floral development: enlarged sepals, defective anthers, and low pollen viability. Therefore, the seed set is poor.

Many *Brassica* species are induced to flower by low temperatures. Effects of low temperatures on common cabbage are evident only when growing plants are treated. Common cabbage is considered as the green plant vernalization type. A lot of *Brassica* species pertain to quantitatively long-day plants. The longer the daylength is, the more extensive and earlier the flowering becomes. Many *Brassica* species which respond to vernalization are also sensitive to long-day stimulation to flowering. The interaction of these two factors are either supplementary or complementary. Thus, long-day stimulation may quantitatively displace the low temperature requirement. A combination of vernalization and long day is required for the maximum flowering of common cabbage.

In the initial stage of the common cabbage improvement project, it is necessary to conduct a series of experiments to observe the flowering behavior of accessions under AVRDC's natural cool season conditions and to search for some treatments to facilitate bolting and flowering.

Materials and Methods

Based on results of earlier plantings, five open-pollinated varieties, three breeding lines, one Portuguese cabbage variety, and one Chinese kale variety were sown in 1992 along with two F_1 hybrids, KY Cross and Shiafong No.1, as checks. Three plantings were done to compare the flowering behavior of these 12 accessions. They were sown on 16 September, 16 October, and 16 November, and transplanted on 14 October, 13 November, and 16 December, respectively. Because of insufficient seeds, one open-pollinated variety, Nantou, was grown only at the first planting, and the Chinese kale, Sihu Black Leaf, was grown at the first and second planting.

Another trial on the effect of mechanical treatment was performed in these three plantings. A split-plot in randomized complete block design with two replications was employed in this experiment. A main unit plot consisted of one 5-m-long, double-row bed. The spacing was 150 cm between beds, 50 cm between rows, and 50 cm between plants. The following treatments were randomly employed in each main plot with a check: (a) the head was cut across; (b) the top half of the head was cut; (c) the whole head was cut and trimmed. Each unit subplot consisted of five plants per treatment. Days to flowering was recorded and averaged across all accessions at the same treatment.

In the experiment determining the relationship between the duration of the vernalization with daylength, two F_1 hybrids, KY Cross and Shiafong No.1, were sown on 16 September and transplanted to the field (200 plants each) on 14 October 1992. Ninety plants with normal heads were selected from each variety. Sixty of them were induced to flower under different vernalization conditions, while the rest were used as checks and borders. The vernalization treatment began on

14 December 1992. Vernalization was tested under 5°C with six different combinations of low-temperature duration (25, 35, and 45 days) and light duration (24-h continuous light and complete darkness). The design of the experiment was randomized complete block with two replications. There were five plants for each treatment. Each plant was completely trimmed on the head and roots, leaving only a little root zone, and wrapped in newspaper and a plastic bag. Data collected included days to flowering, frequency of flowering, and other relevant data on flowering characteristics, e.g., extent of branching, devernalization rate, and others.

Results and Discussion

BB 010 Sihu Black Leaf, a Chinese kale included in the first two plantings (1 and 2), was observed to flower the easiest. In the first planting, it took only 58 days for kale to complete flowering after sowing (30 DAT; table 4). Chinese kale may be a good source of the flowering genes for incorporation into common cabbage so that the seed production constraints in tropical countries may be solved.

Table 4. Flowering behavior[a] of common cabbage-related varieties at AVRDC, natural cool season 1992-93

Entry	Variety	Planting[b] 1	2	3	Mean
BB 002	Valitascos X[n]	162 c	151 d	135 d	150 d
BB 006	Shiafong No. 1	189 b	190 bc	195 b	192 b
BB 008	KY Cross F_1	241 a	205 ab	216 a	221 a
BB 008F_2	KY Cross F_2	255 a	219 a	218 a	231 a
BB 010	Sihu Black Leaf	58 g	61 g	–	–
BB 018	Darp[n]	188 b	177 c	164 c	176 c
BB 019	Nantou	119 ef	–	–	–
BB 020	Yehshern	119 ef	117 ef	114 fg	117 f
BB 021	Taiwu	138 de	132 de	122 ef	130 e
BB 022	Wukarn	149 cd	141 d	125 de	138 e
BB 023	A5-7	108 f	108 f	111 g	109 f
BB 024	A6-7	115 ef	117 ef	115 e-g	116 f
	c.v. %	7.6	7.1	5.4	6.8

[a]Days to flowering after sowing. Means within the same column followed by the same letters are not significantly different at 5% level (DMRT).
[b]Planting 1: sown on 16 September and transplanted on 14 October 1992.
Planting 2: sown on 16 October and transplanted on 13 November 1992.
Planting 3: sown on 16 November and transplanted on 16 December 1992.

BB 002 Valitascos X[n], a Portuguese cabbage included in all three plantings, performed contrary to expectations that it would flower easily with its nonheading character. This open-pollinated variety presented a tremendous variation in flowering. Some flowered at 80 DAS, but some did not even flower when the three planting trials were terminated. In the long run, it took longer to flower than most other common cabbages. Among the 10 common cabbage accessions, three Japanese varieties (Shiafong No.1, KY Cross F_1, and KY Cross F_2) had more difficulty in flowering than Taiwanese locals. The F_1 and F_2 populations of KY Cross had more difficulty in flowering than Shiafong No.1. All accessions from Taiwan flowered relatively easily with the

only exception of BB 018. Yehshern (BB 020) had been a leading open-pollinated variety in Taiwan and was introduced to Japan to be the Y parent of KY Cross. Considering the easy flowering character and its broad genetic base, Yehshern may be good a germplasm source of the easy flowering gene for incorporation into common cabbage.

Table 5 shows consistently significant results of three plantings in the observational trials. All three kinds of mechanical treatments were very helpful to enhance bolting and flowering. Treatments A and B were both more effective than treatment C. Treatment A seemed to be the best because it enhanced more branches than treatment B (data not shown).

There were no signs of devernalization in these six treatments. Regardless of variety, plants grown under the six combinations significantly flowered earliest than under natural conditions (table 6). KY Cross, a later bolting variety under natural conditions, responded to low temperature and long-day treatments more than Shiafong No. 1. When the effect of low temperature duration on flowering was compared, the 25-day duration treatments flowered the earliest while the 45-day ones tended to take longer to flower. These results show that 25 days of low temperature treatment or probably less, was enough to induce flowering. Exposure to sufficient durations of low temperature could displace the long-day requirement of common cabbage, as indicated by the nonsignificant differences within the two light durations. To search for the best combination of vernalization and long-day treatment, more follow-up research should be done.

Table 5. Effect of different mechanical treatments on the flowering behavior[a] of 10 common cabbage varieties at AVRDC, natural cool season 1992-93

Treatment	Planting[b] 1	2	3	Mean
A: the head was cut across	152 c	143 c	133 c	143 c
B: the top half of the head was cut	152 c	142 c	138 c	144 c
C: the whole head was cut and trimmed	175 b	157 b	164 b	165 b
D: ck	187 a	181 a	171 a	180 a
Mean	167	156	152	158
c.v. %	7.7	7.0	5.4	6.8

[a]Days to flowering after sowing. Means in the same column followed by the same letters are not significantly different at 5% level (DMRT).
[b]Same planting and transplanting dates as in table 4.

Table 6. Effect of six different vernalization conditions under 5°C on the flowering behavior[a] of two common cabbage varieties at AVRDC, cool season 1992-93

Treatment	Combination	Duration	Light	Variety Shiafong No. 1	KY Cross
1	T_{25} L00	25 days	Complete darkness	68 bc	65 c
2	T_{25} L24	25 days	Continuous light	64 c	66 c
3	T_{35} L00	35 days	Complete darkness	69 bc	68 c
4	T_{35} L24	35 days	Continuous light	67 bc	67 c
5	T_{45} L00	45 days	Complete darkness	73 b	73 b
6	T_{45} L24	45 days	Continuous light	72 b	73 b
7	ck	Natural temperature	Natural light	100 a	111 a
	c.v.%			3.5	1.9

[a]Days to flower after treatment. Means in the same column followed by the same letters are not significantly different at 5% level (DMRT).

International Cooperation

Seed Distribution

In 1993, a total of 482 seed packets of crucifer crops were distributed to 53 cooperators in 27 countries. Most of the seeds consisted of open-pollinated and/or F_1 hybrid cultivars, together with local checks and AVRDC's standard heat-sensitive check. A limited number of shipments of parental lines of F_1 hybrids were also provided to national programs for in-country seed production experiments. Sixty-one seed packets of five elite Chinese cabbage inbreds were distributed by ARC to Asian countries. Reports of the promising performance of AVRDC breeding materials from various cooperators were received during the year and summarized below.

China. Numerous Chinese cabbage accessions collected from China were screened against turnip mosaic virus (TuMV). Two accessions were identified to be immune to all five strains of TuMV. These new materials are being used in the Chinese cabbage breeding project.

Forty-seven Chinese cabbage varieties were sent to China, and 35 heat- and moisture-tolerant vegetable accessions, including 13 Chinese cabbages, were received from the Institute of Vegetables and Flowers, CAAS. In addition, four Chinese cabbage hybrids, three common cabbage breeding materials, two cytoplasmic male sterile (CMS) cabbage lines and their maintainers were obtained. These CMS lines will be used in the cabbage breeding project.

Indonesia. Mr. Suryadi, a researcher in the Brassica Breeding Section of the Lembang Horticultural Research Institute (LEHRI), conducted a series of trials under lowland conditions at Subang Station (90 m above sea level) and Kramat Station (5 m above sea level) to evaluate the phenotypic performance of AVRDC inbred lines, open-pollinated, and hybrid varieties. Two AVRDC open-pollinated varieties — 77M(3)-26 and 77M(3)-40 — were formally released in Indonesia and named Sangihe and Talaud, respectively. Seed production trials were conducted under highland conditions at LEHRI, Lembang (1250 m above sea level) to multiply seeds of inbred lines and produce commercial seeds of released varieties in a larger scale. Ten kilograms of Chinese cabbage seeds of Talaud were produced to fulfill partial requirements of farmers. New crosses among inbred lines introduced from AVRDC were also made. BPH-901702, a new hybrid combination, was superior to the check Talaud in 1992 trials. A number of selected AVRDC varieties, such as Hybrid No. 82-46 and Hybrid No. 82-157, together with outstanding new combinations, were included in an ongoing multilocation trial to test their adaptability.

Philippines. Mr. Eugene C. Cahiles and Ms. Rizalina C. Guibao, researchers of the Vegetable Section of the Bohol Agricultural Production Center, conducted yield trials at Tubigon, Bohol, to evaluate two open-pollinated and six hybrid entries from AVRDC vs. the standard heat-sensitive check, B 40. A dry season trial was sown on 11 September and transplanted on 5 October 1992. Results are presented in table 7. Varietal differences were significant between the heat-sensitive check and AVRDC heat-tolerant varieties in terms of yield, maturity, harvest rate, head shape index, and softrot infection. The late maturity of the heat-sensitive check caused high softrot infection and lowered the harvest rate, resulting in low yield. The standard heat-tolerant check, Hybrid No. 62, which had been formally released in the Philippines as Reyna Elena, yielded the highest followed by Hybrid No. 85202 and 85216. Hybrid No. 85202 with an outstanding longer head shape (HSI of 1.9) is expected to match, if not surpass, Reyna Elena (HSI of 1.1) in terms of local preference which is determined to some extent by head conformation.

Table 7. Yield and other characteristics[a] of AVRDC entries in a dry season trial at the Bohol Agricultural Promotion Center, Tubigon, Bohol, Philippines, 1992[b]

Entry	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Head weight (kg)	Head shape index	Solidity (g/ml)	Heading rate (%)	Soft rot (%)
77M(3)-40	10.9 de	43 bc	52 bc	570 cd	1.4 cd	0.70 a	75	21
77M(2/3)-46	17.1 cd	43 bc	70 ab	547 d	1.4 cd	0.68 a	91	13
Hybrid No. 82-156	15.2 d	44 b	75 ab	546 d	1.2 de	0.66 a	78	3
Hybrid No. 82-157	13.8 d	44 b	70 ab	454 d	1.2 de	0.60 ab	80	2
Hybrid No. 83-20	23.0 bc	43 b	88 a	716 bc	1.3 d	0.57 ab	90	0
Hybrid No. 85202	24.9 ab	44 b	97 a	747 b	1.9 b	0.56 ab	100	2
Hybrid No. 85216	24.5 ab	42 c	87 a	735 b	1.4 cd	0.49 bc	90	0
Hybrid No. 62	29.7 a	42 c	97 a	907 a	1.1 e	0.48 bc	98	0
B 40 (HS ck)[c]	5.5 e	49 a	37 c	436 d	2.8 a	0.40 c	91	48
c.v. %	18.8	1.6	19.7	14.4	5.2	14.0	11.9	

[a]Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).
[b]Sown on 11 September and transplanted on 5 October 1992.
[c]HS = heat-sensitive.

Table 8 shows similar results to the dry season trial. These two seasonal trials showed that Hybrid No. 85202 possessed the desired combination of elongated head shape and dense head formation which matched local preference more than Reyna Elena did.

Table 8. Yield and other characteristics[a] of AVRDC entries in a wet season trial at Bohol Agricultural Promotion Center, Tubigon, Bohol, Philippines, 1993[b]

Entry	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Head weight (kg)	Head shape index	Solidity (g/ml)	Heading rate (%)	Soft rot (%)
77M(3)-40	21.0 b	47 a	94 a	686 bc	1.5 bc	0.61	95	0
77M(2/3)-46	20.6 b	45 b	88 b	669 bc	1.4 c	0.57	95	6
Hybrid No. 82-156	23.9 ab	45 b	98 a	731 b	1.3 cd	0.55	98	0
Hybrid No. 82-157	25.5 ab	45 b	93 ab	820 ab	1.3 cd	0.67	95	1
Hybrid No. 83-20	29.4 a	45 b	92 ab	961 a	1.3 cd	0.60	96	5
Hybrid No. 85202	27.0 ab	45 b	83 bc	972 a	1.6 b	0.63	98	15
Hybrid No. 85216	23.2 ab	45 b	79 c	909 a	1.5 bc	0.59	96	17
Hybrid No. 62	29.4 a	45 b	93 ab	950 a	1.3 cd	0.67	98	5
B 40 (HS ck)[c]	14.1 c	47 a	77 c	550 c	2.9 a	0.54	91	8
c.v. %	14.7	1.9	7.7	11.2	5.9	7.8	4.6	

[a]Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).
[b]Sown on 13 January and transplanted on 1 February 1993.
[c]HS = heat-sensitive.

Crucifer Entomology

Effect of Temperature on Parasitism of Diamondback Moth by *Oomyzus sokolowskii*

Summary

We investigated the effect of temperature ranging from 10°C to 35°C on the parasitism of diamondback moth (DBM), *Plutella xylostella*, larvae by a hymenopterous parasite, *Oomyzus sokolowskii*. Fourth instar DBM larvae and 2-day-old *O. sokolowskii* adults were conditioned for 6 h by maintaining the insects at different temperature settings: 10, 15, 20, 25, 30, and 35°C. *Oomyzus sokolowskii* adults were then released over DBM larvae for 24 h at each temperature. DBM larvae in each treatment were then maintained at 25°C until all pupated in parasite or DBM pupae. The percentage parasitism was 0 at 10°C, 24.0 at 15°C, 50.4 at 20°C, 68.4 at 25°C, 76.3 at 30°C, and 95.1 at 35°C. High parasitism at 30°C and 35°C indicates that this parasite is suitable for the control of DBM in the tropical lowlands. Parasite mortality ranged from 4.5% to 14.6%, and it was not related to temperature.

Introduction

Diamondback moth, *Plutella xylostella*, is considered as the most destructive pest of vegetables in general and of crucifers in particular throughout Asia. Insect larvae feed on all aboveground portions of crucifers. As a result of insect feeding, quality and yield of the produce are adversely affected. At present, farmers mostly use chemical insecticides to control this pest. As a result of ideal temperature for development and availability of host-plants throughout the year in tropics, the insect breeds over 15 generations per year. This high breeding potential coupled with indiscriminate use of insecticides has resulted in DBM becoming resistant to most chemical insecticides. Thus, it has become very difficult to control DBM in Asia. AVRDC aims to develop integrated control measures based on the use of DBM's natural enemies. In this regard we have imported certain parasites to control DBM in Asia. *Oomyzus sokolowskii* was imported in mid-1992 for such purpose. Very little published information exists on the suitability of this parasite for two distinct agroecological conditions – cool highlands and hot-dry lowlands – where crucifers are grown and where DBM is a serious pest. Temperature differs substantially in these two agroecological areas. We, therefore, decided to study the effect of temperature on the parasitism of DBM by *O. sokolowskii*.

Material and Methods

Three to 5-day-old *O. sokolowskii* adults and third and fourth DBM larvae were maintained separately at various temperatures: 10, 15, 20, 25, 30, and 35°C for 6 h to condition both host and parasite at these temperatures. Fifty *O. sokolowskii* adults were then confined with 50 DBM

larvae feeding on cabbage leaf placed in a 15-cm diam 30-cm-long acrylic cylinder both sides of which were covered with fine muslin cloth. Four such cylinders containing parasite adults and host larvae, each cylinder being one replicate, were each maintained at 10, 15, 20, 25, 30, or 35°C for 24 h. During this period *O. sokolowskii* adults laid eggs in DBM larvae. After 24 h, DBM larvae were transferred to 25±2°C and reared until pupation. At pupation time the number of larvae pupating in DBM pupae and parasite pupae were recorded and percent parasitism was calculated by dividing the number of parasite pupae by 50 and multiplying the product by 100. A simple linear regression between the temperature and percentage parasitism was calculated.

Results and Discussion

The parasitism of DBM by *O. sokolowskii* at various temperatures is summarized in fig. 1. As the temperature rose from 10°C to 35°C, parasitism rose proportionately. There was a highly significant positive correlation (r = 0.987) between the temperature and percentage parasitism. High parasitism at 30°C and 35°C indicates that this parasite is suitable for the control of DBM in the lowland areas of the tropics. Parasite mortality ranged from 4.5% to 14.6% and it was not related to temperature. This parasite has now been introduced in crucifer growing areas of Taiwan, Thailand, and Malaysia.

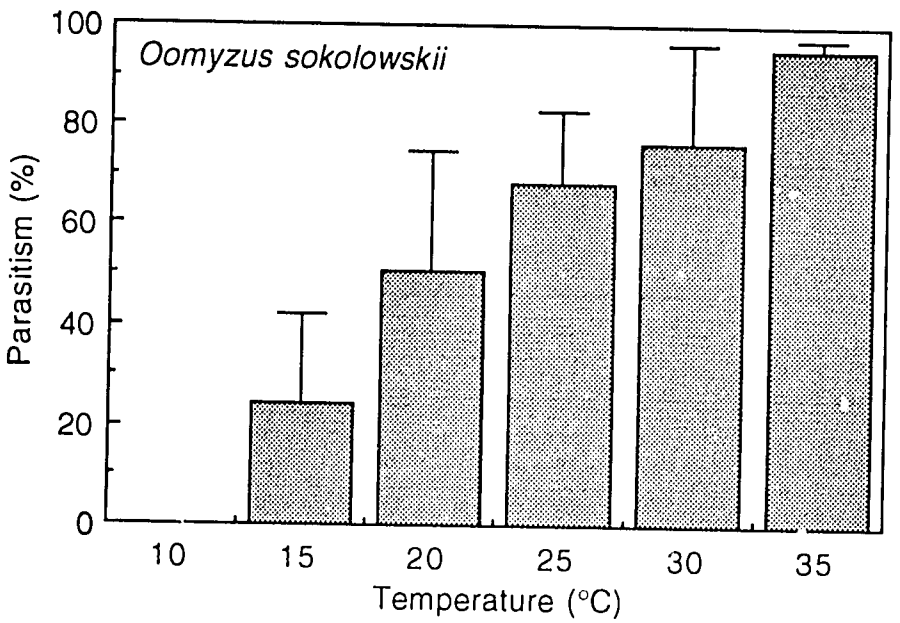

Fig. 1. Parasitism of DBM larvae by *Oomyzus sokolowskii* at various temperatures

Relationship Between Diamondback Moth Larval Population Density and Parasitism by *Oomyzus sokolowskii*

Summary

In this field experiment we studied the dependence of rate of *Oomyzus sokolowskii* parasitism on the density of diamondback moth (DBM), *Plutella xylostella*. In a parcel of land planted to common cabbage we introduced 500 DBM adults to initiate pest infestation. Two days later we introduced 1000 *O. sokolowskii* adults. An additional 500 parasite adults each were also introduced 2, 3, and 4 wk later. Once a week we monitored the larval population of DBM on cabbage plants and parasitism of DBM larvae by *O. sokolowskii* or *Cotesia plutellae*, a larval parasite of DBM that is already established in lowland areas of Taiwan and most of Asia. DBM larval population increased steadily 10 days after insect release up to harvest from 2 to 22 per 10 plants. Parasitism of DBM larvae by *O. sokolowskii* increased steadily from 1.3% to 21.9% but that of *C. plutellae* decreased from 48% to 3.1% during this period. In our earlier study we found similar decrease in parasitism of *C. plutellae* from beginning towards the end of the season even in the absence of any parasite. Based on our present findings, it appears that introduction of *O. sokolowskii* helps supplement DBM control achieved by *C. plutellae*.

Introduction

Among the four parasites that AVRDC is using in biological control of diamondback moth, two, *Oomyzus sokolowskii* and *Cotesia plutellae*, are found in hot and humid lowlands. *Cotesia plutellae* occurs in several countries in Asia, but *O. sokolowskii* does not. AVRDC has imported this insect with the purpose of introducing it in lowland areas. We are conducting research in various biological parameters of this insect to judge its suitability in various agroecological regions. In this particular test we studied the relationship of DBM larval density and rate of their parasitism by *O. sokolowskii*.

Materials and Methods

A 0.1-ha parcel of land was worked into 1.5-m beds and planted to 1-mo-old cabbage seedlings. Ten days after transplanting we introduced 500 DBM adults in the field to initiate insect infestation. Two days later we introduced 1000 *O. sokolowskii* adults in the same area. Additional parasite adults were also introduced 2, 3, and 4 wk later. Once a week we monitored the larval population of DBM on cabbage plants and parasitism of DBM larvae by *O. sokolowskii*. Since DBM larvae were also parasitized by *C. plutellae* which occurs naturally in lowland areas of Taiwan, we also recorded the number of DBM larvae parasitized by *C. plutellae*. The percent parasitism was calculated by dividing the number of parasite pupae by the total number of DBM larvae per 10 plants and dividing the product by 100.

Results and Discussion

DBM population increased steadily from 10 days after adult release up to harvest from 2 to 22 larvae per 10 plants. Parasitism of DBM larvae also increased steadily from 1.3% to 21.9%. There was significant correlation ($r = 0.844$) between larval population density and level of parasitism (fig. 2). It appeared that this parasite is also host population density-dependent.

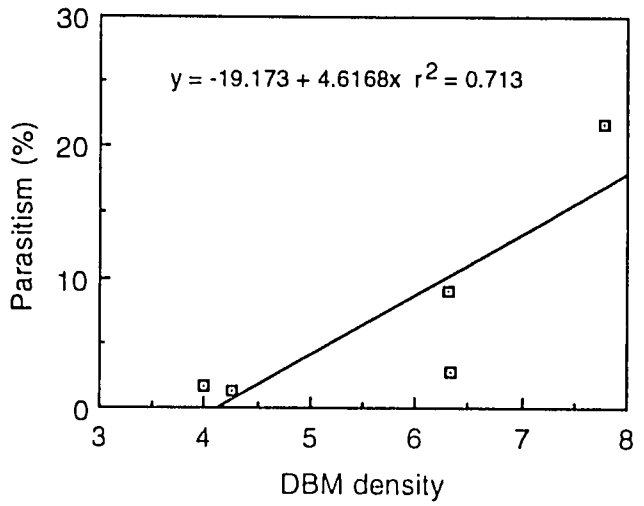

Fig. 2. Relationship of population of DBM larvae and parasitism by *O. sokolowskii*

Parasitism of DBM by *C. plutellae* decreased from 48% at 10 days after insect release to 3.1% at harvest time. In an earlier study, we found a similar decrease in parasitism of DBM by *C. plutellae* from the beginning to the end of the crop season whether other parasites are present or not. Our present findings show that introduction of *O. sokolowskii* does not compete but supplements DBM control achieved by *C. plutellae*.

Control of Diamondback Moth by *Oomyzus sokolowskii*

Summary

Prior to the introduction of *Oomyzus sokolowskii* in farmers' fields for the control of diamondback moth, *Plutella xylostella*, we conducted a study at AVRDC to investigate the potential of this parasite under field conditions. A parcel of land planted to common cabbage was divided into three 27 m x 13.5 m plots. Each area was subsequently confined on all four sides and the top by fine mesh nylon net to prevent movement of insects between the plots. In two plots we introduced 1000 DBM adults each, and the third plot was maintained insect-free. One week later, in one of the two plots where DBM was introduced, we released all *O. sokolowskii* adults emerging from 1000 parasitized cocoons. An additional 500 parasite cocoons were each released 2, 3, and 4 wk later. We monitored extent of DBM parasitism throughout the season and yield and marketable cabbage heads at harvest. Parasitism of the DBM larvae varied from 2% to 21.7%. At harvest, in the plot where only DBM was released, only 26.1% heads were marketable whereas in the plot where both pest and parasites were introduced, 44% of the heads were marketable. Total yield was 6.8 t/ha in the DBM-only plot and 12.8 t/ha in the DBM-with-parasite plot. The increased yield and marketability was due to the beneficial effect of the parasite. In the plot where neither DBM nor parasite were introduced, the yield was 21.4 t/ha and 76.1% of the cabbage heads were marketable.

Introduction

A major portion of AVRDC's research on crucifers deals with the control of diamondback moth, *Plutella xylostella*, a very destructive pest of crucifers throughout Asia. We emphasize the use of biological control agents to combat this pest. In mid-1992 AVRDC imported *Oomyzus sokolowskii* from Cape Verde Islands in West Africa via the International Institute of Biological Control. In late 1992 and early 1993 we conducted several investigations to study biological parameters of this insect to determine its suitability to different agroecological conditions where crucifers are grown. In this experiment we investigated the potential of *O. sokolowskii* in reducing the population of DBM in large cages constructed in the field.

Materials and Methods

A parcel of land was rototilled and worked into 1.5-m beds and divided into three equal portions, each measuring 27 m x 13.5 m. Each portion was covered on all four sides by 2-m-high fine mesh nylon net. The bottom half of the net was lined with a thin plastic sheet to prevent movement of *O. sokolowskii* from one cage to the next. The top of each cage was also covered by the same type of nylon net. One-month-old DBM-free common cabbage seedlings were transplanted inside each cage. Normal cultural practices were used to raise the crop. No insecticide was applied. Ten days after transplanting we introduced 1000 DBM adults inside each of two cages; the third cage was maintained DBM-free. One week after DBM release we introduced all adults emerging from 1000 *O. sokolowskii* parasitized cocoons. All adults emerging from 500 cocoons were also introduced again 2, 3, and 4 wk later. We monitored the population of DBM larvae and pupae per 20 plants taken from three 3 x 10 m areas inside each cage. We removed 20 third and fourth instar DBM larvae from each sampled area and raised them until pupation in the laboratory. At pupation we recorded the number of parasitized and DBM cocoons and calculated percent parasitism. At harvest we uprooted all plants in three 3 m x 10 m area in each cage, and recorded the number of plants in the sampled area, the weight of each cabbage head, and total yield in each cage.

Results and Discussion

In the cage where parasites were released, parasitism of DBM larvae by *O. sokolowskii* ranged from 1 to 22%. Parasitism which was very low, hovering around 2% early in the season increased to 22% 2 wk before harvest. DBM larval population which remained low (around 5 larvae/plant) throughout most of the season increased to 22.4 larvae per plant a week before harvest. We were unable to judge the reason for this sudden increase in population. The rate of parasitism was obviously not adequate to prevent DBM population build-up. In the plot where DBM only was introduced larval population was high and reached 36.9 larvae/plant a week before harvest. Cabbage heads, on the average, weighed 1.4 kg/head. The head weight increased to 1.5 kg in the plot where DBM and *O. sokolowskii* were released. In the control plot where no DBM nor parasite were released, each cabbage head weighed 1.6 kg. Only 26.1% of the heads were marketable in DBM-only plots; marketability increased to 44% in the plot with parasite but it was far below 76% in the control plot where no insect was released. Cabbage yield was 6.8 t/ha in the DBM-only plot; it increased to 12.8 t/ha due to parasite introduction, but was still below the 21.4 t/ha obtained in the control plot where neither DBM nor parasite were introduced. Marketable heads rather than head weight contributed to yield increase. Introduction of *O. sokolowskii* increased head weight, marketable heads, and practically doubled the yield of cabbage. These data indicate that introduction of *O. sokolowskii* to control DBM can reduce DBM infestation and increase cabbage yield.

Crucifer Pathology

Biology and Epidemiology of Alternaria Leaf Spot of Chinese Cabbage

Black leaf spot (Alternaria leaf spot) of crucifers primarily caused by *Alternaria brassicicola* and *Alternaria brassicae* is an important disease of Chinese cabbage and other cruciferous crops including cabbage, cauliflower, and broccoli. During 1992–93 a series of experiments was conducted under laboratory, glasshouse, and field conditions to establish conditions conducive for infection, describe the symptoms of disease, establish the pattern of epidemics in space and time under different seasonal conditions, and screen Chinese cabbage accessions for resistance. Infection of Chinese cabbage by *A. brassicicola* and *A. brassicae* is related to periods of leaf wetness duration, i.e., periods of rain or dew. Leaf wetness duration of at least 12 h is required for infection. Symptoms of infection vary according to the inoculum dose. Single spore infections lead to hypersensitive reactions and non-expanding lesions while multiple spore infection leads to expanding lesions which sporulate as concentric rings. Newly emerging leaves become infected as they expand due to deposition of spores. Disease increases both temporally and spatially. Initial results indicate that disease spreads down the rows with little spread between rows. Results further indicate that the distribution of disease in plots was not aggregated around the line sources suggesting that infections arose from sources outside the plots. Three-week-old seedlings of 159 Chinese cabbage accessions were inoculated (10^5 conidia/ml of a mixture of *A. brassicicola* and *A. brassicae*) and evaluated after a 6-day incubation in a growth room at 24°± 2°C and 90±5% RH for their disease responses. Eight moderately resistant lines were identified: B 6, B 41, B 127, B 132, B 140, B 142, B 144, and B 150. No highly resistant sources were found among the accessions tested.

Studies on Clubroot of Chinese Cabbage

Clubroot caused by *Plasmodiophora brassicae* is a very damaging disease on most crucifers grown in temperate climates or tropical highlands, especially Chinese cabbage. Several field trials were conducted on clubroot of Chinese cabbage at AVRDC during 1991 and 1992 primarily to determine the effect of certain management practices on the development of the disease. Studies were conducted to determine the effect of transplant age, pre-transplant fertilizer regime, and nursery pot size on subsequent disease severity and yield of Chinese cabbage. In general, the amount of root clubs and concomitant crop yield loss were reduced by using 4- to 5-wk-old transplants compared to direct sown or 1- to 3-wk-old transplants, presumably due to the shorter exposure period of the crop to the pathogen when using the older transplants. Increased frequency of fertilization of transplants while in the nursery reduced the amount of root clubs that developed later in the field, but crop yield was also reduced. Comparison of nursery pot size (3, 6, and 8 cm) with subsequent root club development and yield showed that clubbing was greatest and crop yield lowest with 3-cm transplants. There was no difference in the amount of club formation between 6- and 8-cm transplants, but yields were greater from 8-cm transplants.

Eggplant Breeding

Observation and Evaluation of Eggplant Cultivars and Germplasm

Summary

A total of 105 eggplant collections which included 63 commercial varieties, 39 germplasm collections from Southeast Asia, and 3 local varieties were used in an observation and evaluation trial. A wide range of diversity was observed among the entries in yield and horticultural characteristics.

Most of the commercial varieties performed very well. The yields of the top 20 eggplant varieties ranged from 58.5 t/ha to 72.3 t/ha compared to 45.5 t/ha and 38.1 t/ha for two local varieties, Farmers Long F_1 and Pingtung Long, respectively. Eggplant varieties exhibited important traits such as erect plant growth, less branching, early maturity, large fruit, more fruit, high yields, and fruit size good for processing. Some of these genetic resources will be used in the eggplant breeding project.

Introduction

Eggplant (*Solanum melongena*) is a common vegetable in the tropics and subtropics. It is largely grown as an important commercial vegetable crop in Bangladesh and India. In Asia, the major eggplant producing countries are India (300,000 ha), China (176,000 ha), Indonesia (83,000 ha), Japan (18,000 ha), and Philippines (16,000 ha).

To date, AVRDC's eggplant germplasm collection is comprised of more than 500 accessions. A worldwide collection of eggplant cultivars was assembled in early 1992 with the help of the major seed companies in the U.S., Japan, Australia, Europe, the Middle East, and Southeast Asia. An experiment was conducted to: (1) observe and evaluate the collected commercial cultivars and parts of germplasm collections; (2) select promising varieties for further testing; (3) identify desirable genotype and postulate for tropical lowland cultivation; and (4) search for genetic materials to be used in the eggplant breeding project.

Materials and Methods

A total of 105 entries, including 63 varieties from commercial seed companies with a predominance of F_1 hybrids, 39 germplasm accessions from GRSU, and 3 local check varieties were employed in this observation and evaluation trial. Trial entries were sown on 1 September and transplanted on 25 September 1992. Seedlings were transplanted to raised beds (1.5 m x 6 m) with a single row in each bed (plot), 12 plants per plot and a 50-cm space between plants. The entries were planted in two blocks and replicated twice.

Cultural management was based on the standard procedures adopted by farmers for eggplant production. Black polyethylene mulches were provided for weed control. Yield data and major

horticultural characters were collected and recorded. Fruit was harvested weekly from five plants (excluding border plants) in each plot for eight consecutive weeks.

Results and Discussion

Diversity of collections. Great diversity of plant type, fruit size, fruit shape, and fruit color was observed among the 105 entries. Based on fruit color and shape, the 105 varieties can be classified into different categories as shown in table 1. Cylinder, oval, and teardrop were the major fruit shapes among these entries. Seventy-eight out of 105 varieties had purple fruit which was a major fruit color in eggplant.

Table 1. The diversity of color and shape of fruits among 105 varieties of eggplants

Color	Shape				
	Cylinder	Oval	Teardrop	Novelty	Total
Purple	28	23	25	2	78
Green	7	10	1	7	25
White	0	0	1	1	2
Total	35	33	27	10	105

Plant types. Plant types among varieties varied from erect, much-branched subshrub to bushy spreading. Plant heights of the 105 entries ranged from 78 cm to 136 cm with a mean of 109 cm (fig. 1). Majority of the varieties had plant heights ranging from 100 to 120 cm. A large variation in number of branches was found among the entries which had 5.1 to 10.4 branches per plant (fig. 1). The average number of branches was 7.1 per plant. Pruning and defoliation are common cultural practices used by the eggplant growers. These operations are very costly where labor is expensive as in Taiwan. The relationship between plant type, pruning, yield, and its components will be studied.

Maturity. The distribution of days to maturity for the 105 entries is shown in fig. 1. About 80% (84 varieties) of the entries matured in 110-125 days after sowing (DAS). The earliest maturing varieties were Sengro No. 2 F_1, Sanshi Naga F_1, Millionaire F_1, and M 701 F_1 while the latest maturing variety was TS 96 (Kopek).

Number of fruit per plant. A large proportion of the entries produced less than 20 fruit per plant during the first eight harvests (fig. 1). The highest number of 80 fruit per plant was given by TS 17 (Rapun), a variety from Malaysia with small fruit. The average number of fruit per plants was 24, while the lowest was 6 fruit/plant. In general, there was a negative association between number of fruit and fruit size. The more fruit per plant, the smaller the fruit.

Fruit size. There were great variations in fruit size in terms of fruit weight. Florida High Bush, TS 49, Tasca F_1, and Black Bell F_1 gave the highest fruit weight of above 400 g. The fruit weights of 105 entries ranged from 17 to 466 g with an average of 209 g (fig. 1). Among the varieties, 32%, 24%, and 26% of them produced fruit size in the categories of 100-200 g, 300-400 g, and $\leq$ 100 g, respectively.

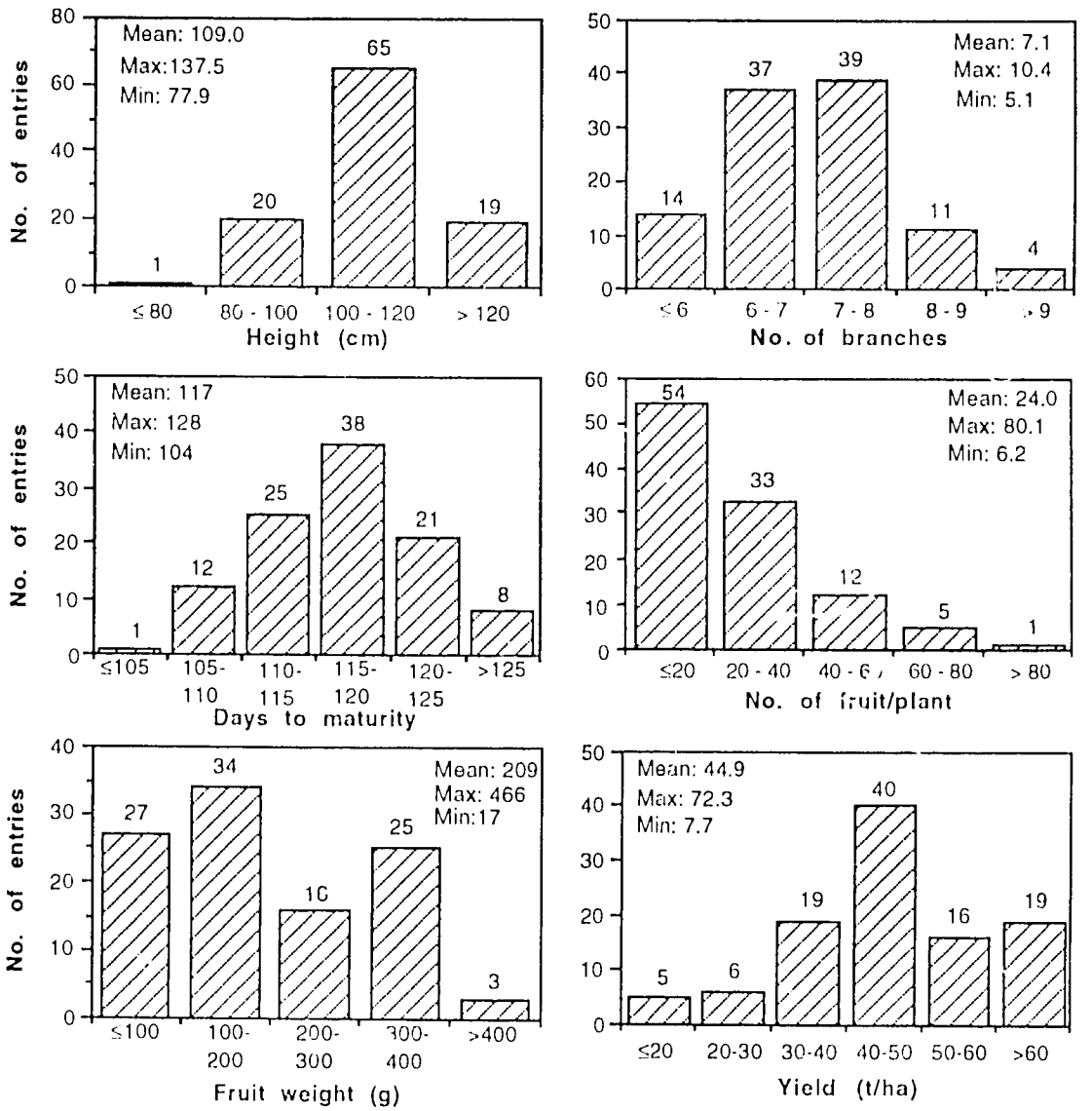

Fig. 1. The distribution of horticultural characteristics among 105 entries of eggplants

Yield. The distribution of yields of 105 entries in six groups of yield is given in fig. 1. The yield of 105 entries ranged from 7.7 t/ha to 72.3 t/ha with a mean of 44.9 t/ha. The highest yield was obtained by Nite King F_1, while the lowest yield came from TS 99. About 38% of the entries produced yields between 40-50 t/ha. Among all entries, 19 varieties (18%) which yielded more than 60 t/ha were considered a high-yielding group.

Overall performance. The yields and horticultural characteristics of the top 20 eggplant varieties are given in table 2. These varieties produced 58.5–72.3 t/ha of marketable yields. Compared with Farmers Long, a hybrid from Known You Seed Co., these varieties had higher yields ranging from 29% to 59%. The yield increases were much higher (54-90%) when compared to Pingtung Long, an OP variety. The four best varieties were Nite King F_1 (Petoseed), Black Bell F_1 (Petoseed), Taro Wase F_1 (Mikado), and Bonesa F_1 (Daehnfeldt). The high yield was generally attributed to the combination of number of fruit per plant and fruit size. The results of this variety observation and evaluation trial show that high yielding and good quality eggplant varieties are available in the commercial seed companies. Selected promising varieties from either commercial seed companies or germplasm collections will be further tested in replicated advanced yield trials.

Table 2. Horticultural characters and yields of top 20 varieties of eggplant in comparison with local varieties[a]

Variety name	Plant height (cm)	No. of branches	DTF	DTM	Fruit color[b]	Fruit shape[c]	Fruit wt (g)	Fruit size L (cm)	Fruit size W (cm)	Fruit size L/W	Fruit no./ plant	Mkt. yield (t/ha)
Nite King F_1	106	7.4	59	119	DP	O	318	12.8	8.9	1.4	18.2	72.3
Black Bell F_1	113	5.8	63	114	DP	TD	410	15.2	8.2	1.9	13.8	71.9
Taro Wase F_1	103	7.5	61	118	DP	TD	377	14.1	8.2	1.7	14.5	68.8
Bonesa F_1	108	6.4	63	118	DP	O	372	16.8	8.0	2.1	14.3	67.2
Hybrid 29	109	7.9	66	120	DP	O	402	11.9	10.2	1.2	13.5	65.4
Soma F_1	113	7.2	59	115	DP	O	351	15.9	9.4	1.7	13.8	65.4
Edna	112	6.4	59	115	DP	TD	331	17.3	7.9	2.2	16.2	65.3
Solara F_1 RS	128	7.8	60	116	DP	C	335	20.9	6.9	3.0	15.3	65.2
Tasca F_1	121	7.6	63	118	DP	O	410	14.5	9.3	1.6	12.0	64.6
Nubia F_1	111	7.6	60	113	DP	O	400	13.5	8.0	1.7	12.7	62.8
Bonesa F_1	113	7.8	60	118	DP	O	386	16.3	8.5	1.9	12.4	61.9
TS 123	97	7.1	63	119	GW	N	184	18.2	6.3	2.9	26.1	61.8
Oria F_1	124	7.1	60	117	DP	TD	369	17.5	7.8	2.2	12.9	61.6
Burpee Hybrid	114	6.5	63	118	DP	O	344	14.1	9.3	1.5	13.6	61.4
TS 61 (Hijau)	95	5.6	59	117	GW	N	245	16.1	7.3	2.2	19.5	60.9
Murena F_1 RS	106	7.7	63	117	DP	O	353	15.8	8.8	1.8	13.4	60.0
Black Gnome	101	5.8	63	124	RB	C	116	19.3	4.0	4.8	52.6	59.9
Othello	107	6.5	64	120	DP	TD	385	15.1	9.0	1.7	11.8	59.9
Epic F_1	117	5.7	63	113	DP	TD	321	19.2	7.8	2.5	14.3	59.5
TS 88 (Ihijau)	91	6.0	59	116	G	C	200	14.9	6.5	2.3	22.3	58.5
Farmers Long F_1[d]	114	5.6	63	122	DP	C	103	28.2	2.7	10.4	38.6	45.5
Pingtung Long[d]	102	5.9	63	116	P	C	140	26.3	3.4	7.7	21.2	38.1
Means of 105	109	7.1		117			196			3.2	25.2	46.1

[a]Planting dates: sowing: 1 September 1992; transplanting: 25 September 1992.
[b]Fruit color: DP: dark purple; G: green; GW: green with white stripes; P: purple; RB: red brown.
[c]Fruit shape: C: cylinder; N: novelty; O:oval; TD: teardrop.
[d]Local varieties.

Identification of important traits. Some important traits were identified from the entries:

- Erect plant type: Megal F_1, Sicilia F_1, Onita F_1, Vernal F_1, Market Supreme, TS 111.
- Less branching: TS 121, Violetta Di Firenze, TS 61 (Hijau), Farmers Long F_1, Epic F_1.

- Early maturity: Sengro No. 2 F_1, Sanshi Naga F_1, Millionaire F_1, M 701 F_1, Rikuzennaga F_1.
- Large fruit: Florida High Bush, TS 49, Tasca F_1, Black Bell F_1, Market Supreme.
- Small fruit: TS 98 (Glatik), TS 17 (Rapun), TS 103B (Terung Hijau Kecil), TS 91 (Hijau Besar).
- Greater number of fruit/plant: TS 17 (Rapun), TS 89, TS 55 (Terung Lalap), TS 87 (Glatik), TS 91 (Hijan Besar).
- High yield: Nite King F_1, Black Bell F_1, Taro Wase F_1, Bonesa F_1, Hybrid 29, Soma F_1.
- Good processing qualities: Rikuzennaga F_1, Slim Jim, Black Gnome, TS 2.

All these resources need to be reexamined for the respective traits in replicated trials. The correlation between important traits will be studied. An attempt was made to postulate an ideotype of eggplant for tropical lowland production. However, more studies involving plant growth and development, yield components, crop physiology, etc. are needed.

Seasonal Variation in Growth, Yield, and Horticultural Characteristics of Selected Eggplant Cultivars

Summary

Field experiments were conducted to investigate the effect of date of planting on the growth and yield of 10 selected eggplant cultivars. Plant growth and yield were affected by date of planting. The August planting gave the highest yield (average 61.3 t/ha), while the February planting gave the least (average 20.3 t/ha). The differential response of varieties to planting date was significant. Temperature, light intensity, and excess rainfall were the primary environmental factors causing seasonal differences in growth and yield of eggplant.

Introduction

The growth duration of the eggplant crop is relatively long compared to other vegetables. Under tropical or subtropical conditions, there are abiotic and biotic stresses which considerably influence the growth and production of eggplant. This experiment aimed to: (1) observe the seasonal variation in growth, yield, and horticultural characteristics; (2) investigate these abiotic and biotic factors; and (3) identify the major constraints to eggplant production.

Materials and Methods

Ten cultivars which represented different plant and fruit types were used. Bimonthly plantings started in April 1992 and were completed in February 1993. Each planting used a randomized complete block design (RCBD) with four replications.

In each planting, plants were sown and transplanted to raised beds (1.5 m x 6 m). Each plot contained a single row of 12 plants with 50-cm spacing between plants. Before making the raised beds, 1500 kg/ha compost, 300 kg/ha ammonium sulphate, 600 kg/ha calcium superphosphate, and 200 kg/ha potassium chloride were incorporated into the soil. Mulching was done by using plastic film. Cultural practices suggested by local experiment stations were followed.

Plant height and number of leaves were measured and recorded at 10-day intervals beginning at 10 or 20 DAT and ending at 100 or 110 DAT for cultivars Pingtung Long, Farmers Long F_1,

and F-100. Data on plant height, days to maturity, fruit size, number of fruit/plant, and yield were collected and analyzed.

Results and Discussion

Plant growth. The growth and development in terms of plant height and number of leaves were measured and recorded at 10-day intervals for three cultivars: Pingtung Long, Farmers Long F_1, and F-100. The growth, in terms of height as indicated by sigmoid curves, differed remarkably among the various planting times (fig. 2). Varieties showed similar growth trends within times of planting, however. Generally, plant growth was faster and more steady in April, June, and August plantings than others. These three plantings had warm temperatures (23–28°C) during the early growing stage. On the other hand, the eggplant seemed very sensitive to temperature. Plant growth was very slow in the first 50 DAT for the October and December plantings when mean temperatures decreased to below 21°C. All the three cultivars exhibited a very similar growth curve which showed fast growth in height from 40 to 60 DAT and leveling off afterward (fig. 2).

The time of planting had a marked effect on the number of leaves. In general, the number of leaves increased slowly during the first 40 DAT, followed by a steady increase during the period between 40 DAT and 80 DAT (fig. 2) with some exceptions among the varieties and plantings. The fluctuation in number of leaves of each cultivar within the plantings was attributed to defoliation which was caused by some environmental factors such as wind, monsoon rain, and other physiological stresses.

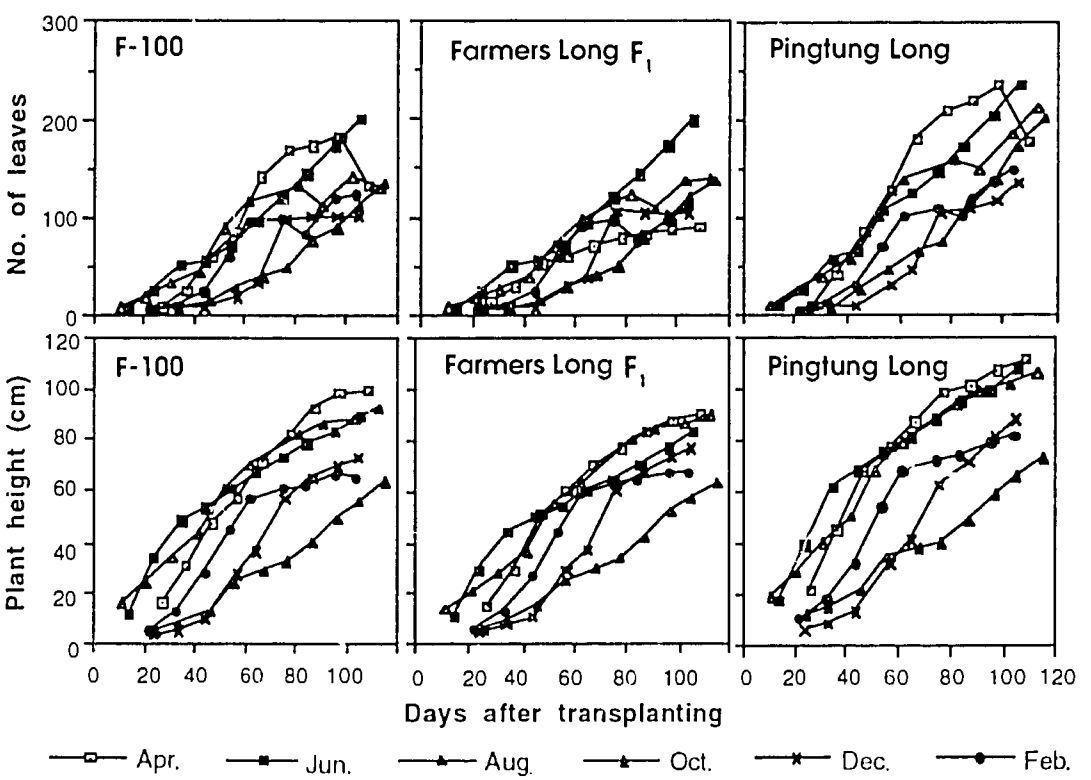

Fig. 2. The growth of eggplant cultivars F-100, Farmers Long F_1, and Pingtung Long at different planting seasons

Plant height. The final measurement of plant heights of the selected cultivars in six plantings are given in table 3. Significant differences were observed among cultivars within the plantings. Among the varieties, Black Enerma 564, F-100, and Onita F_1 were tall types, while Easter Egg F_1 and Senguro No. 2 were relatively dwarf-like. Varieties responded differently to times of planting. Maximum plant height was obtained in the April planting in all cultivars except Easter Egg F_1. The June, August, December, February, and October plantings showed decreases in height in that order irrespective of varieties. Temperatures and solar intensities during the growing periods influenced plant height of eggplant.

Table 3. Plant heights (cm) of selected eggplant cultivars as affected by the time of planting[a]

Variety	April	June	Aug.	Oct.	Dec.	Feb.	Mean
Onita F_1	116	107	124	111	96	111	111
Black Enerma 564	159	135	89	121	114	106	121
Terong Ungan Bulat	101	93	91	94	87	82	91
F-100	132	126	119	114	104	109	117
Easter Egg F_1	87	88	90	57	75	53	75
Senguro No.2	111	106	85	54	69	85	85
Ma su	127	106	98	69	92	86	96
Pinglung Long	110	100	99	76	79	80	91
Bride F_1	94	85	93	78	80	76	84
Farmers Long F_1	109	98	98	86	93	80	94
Mean	115	104	99	86	89	87	97
c.v. (%)	4	6	17	7	4	8	
LSD (0.05)	8	9	24	8	5	10	

[a]The 6 sowing dates: 24 April 1992; 24 June 1992; 19 August 1992; 20 October 1992; 21 December 1992; 19 February 1993.

Maturity. Differences in days to maturity were significant among varieties within the planting times (table 4). The average number of days to maturity ranged from 112 to 156. Among the cultivars, Easter Egg F_1 was the earliest maturing variety while Terong Ungan Bulat was the longest maturing one, regardless of plantings. Planting times had no significant effects on maturity irrespective of varieties. However, eggplant grown in cool season (October, December, and February plantings) took slightly longer to mature than those grown in warm season (April, June, and August plantings).

Fruit size and number of fruit. Fruit size, in terms of weight, varied with cultivars and planting times (table 5). F-100 had the largest teardrop-shaped fruit averaging 274 g, while Easter Egg F_1 had the smallest round fruit weighing only 72 g. Differences in fruit weights among cultivars within the plantings were significant. In most of the cultivars, the fruit weight was higher in the August planting than in other plantings. Varietal responses to different times of planting were mixed. Irrespective of cultivars, the mean fruit weights were approximately 153, 145, 139, 133, 117, and 116 g for the August, December, June, October, February, and April plantings, respectively. The plants of the April planting suffered from a flooding in July that had some adverse effects on the fruit size.

Number of fruit per plant varied with the cultivars and planting times (table 6). Among all the varieties, Bride F_1 produced consistently the highest number of fruit per plant in all plantings. Generally, there was a negative correlation between fruit size and number of fruit per plant. The larger the fruit, the less the number of fruit per plant. On the other hand, crop duration also affected the number of fruit per plant. Cultivars which produced more fruit per plant usually had long crop durations. Planting dates had a considerable effect on fruit per plant in different cultivars. The

Table 4. Days to maturity of selected eggplant cultivars as affected by the time of planting[a]

Variety	April	June	Aug.	Oct.	Dec.	Feb.	Mean
Onita F_1	138	140	126	129	113	129	129
Black Enerma 564	156	127	143	144	144	150	144
Terong Ungan Bulat	145	147	154	165	174	148	156
F-100	129	146	135	161	154	152	146
Easter Egg F_1	93	143	120	130	112	72	112
Senguro No.2	135	121	107	126	100	118	118
Ma su	145	136	146	149	143	144	144
Pingtung Long	131	136	143	153	151	161	146
Bride F_1	127	141	148	153	149	158	146
Farmers Long F_1	129	139	151	153	128	138	140
Mean	133	138	137	146	137	137	138
c.v. (%)	10	5	4	2	8	15	
LSD (0.05)	20	9	9	4	17	14	

[a]The 6 sowing dates: 24 April 1992; 24 June 1992; 19 August 1992; 20 October 1992; 21 December 1992; 19 February 1993.

Table 5. Fruit size (g) of selected eggplant cultivars as affected by the time of planting[a]

Variety	April	June	Aug.	Oct.	Dec.	Feb.	Mean
Onita F_1	107	142	158	148	186	148	148
Black Enerma 564	210	278	284	235	238	164	235
Terong Ungan Bulat	121	164	168	166	141	134	149
F-100	245	278	322	263	297	236	274
Easter Egg F_1	70	63	81	68	72	79	72
Senguro No.2	106	94	124	82	152	112	112
Ma su	77	86	92	82	84	66	81
Pingtung Long	92	112	123	116	124	98	111
Bride F_1	67	88	90	79	70 f	66	77
Farmers Long F_1	70	87	85	86	86 f	65	80
Mean	116	139	153	132	145	117	134
c.v. (%)	9.9	7.6	8.0	8.9	11.2	15.8	
LSD (0.05)	17	15	18	16	25	26	

[a]The 6 sowing dates: 24 April 1992; 24 June 1992; 19 August 1992; 20 October 1992; 21 December 1992; 19 February 1993.

Table 6. No. of fruit per plant of selected eggplant cultivars as affected by the time of planting[a]

Variety	April	June	Aug.	Oct.	Dec.	Feb.	Mean
Onita F_1	13.0	27.1	17.6	15.6	4.8	15.6	16
Black Enerma 564	19.6	19.8	20.4	15.6	9.6	8.4	16
Terong Ungan Bulat	25.6	32.2	34.0	22.2	36.4	24.3	29
F-100	21.3	25.6	23.1	22.4	14.3	12.2	20
Easter Egg F_1	38.9	73.2	58.9	29.0	42.5	12.7	42
Senguro No.2	16.7	27.4	17.4	12.3	9.1	16.6	17
Ma su	27.3	26.7	46.7	14.8	25.5	12.6	26
Pingtung Long	34.9	26.7	37.3	24.4	27.9	17.5	28
Bride F_1	49.3	54.4	68.6	47.0	51.5	33.6	51
Farmers Long F_1	57.8	44.5	66.3	37.3	36.9	15.3	43
Mean	30.4	35.7	39.0	24.1	25.9	16.9	29
c.v. (%)	11.9	18.6	13.1	18.6	20.4	29.5	
LSD (0.05)	5.26	9.7	7.4	7.1	7.1	7.4	

[a]The 6 sowing dates: 24 April 1992; 24 June 1992; 19 August 1992; 20 October 1992; 21 December 1992; 19 February 1993.

cultivars responded differentially to date of planting (table 6). Irrespective of cultivars, the plants produced remarkably more fruit per plant in warm (April, June, and August plantings) than in cool season (October, December, and February plantings). The warm temperature, high solar radiation, and adequate moisture supply during the crop season were the main factors affecting fruit number.

Yield. The marketable yields of 10 cultivars in six planting dates are given in table 7. The differences in marketable yields among varieties were significant with regard to the planting dates. Averaged over planting dates, yields varied with the cultivars. The large fruiting variety, F-100, gave a considerably higher yield (77.9 t/ha) than the others. One of the early varieties, Senguro No. 2, had the lowest yield (21.2 t/ha). Planting dates had a remarkable effect on marketable yields of different varieties. The highest yields were obtained from the August planting in all cultivars, except Onita F_1 and Senguro No. 2. Varietal responses to remaining planting dates were dissimilar. Irrespective of varieties, the highest average yield of 61.3 t/ha was produced by the August planting, while the February planting gave the lowest yield (20.3 t/ha). The yield of August planting was approximately three times more than that of February planting (table 7). The June, October, December, April, and February plantings showed decreases in yield in that order. Apparently, the low yield in February planting was attributed to the monsoon rains which occured during the fruiting period of the crop, while that in April planting was probably caused by the water stress (flooding) which occurred in July 1992.

Table 7. Yield (t/ha) of selected eggplant cultivars as affected by the time of planting[a]

Variety	April	June	Aug.	Oct.	Dec.	Feb.	Mean
Onita F_1	12.5	43.2	34.8	24.8	8.6	24.8	24.8
Black Enerma 564	45.6	68.7	71.4	45.6	28.2	14.3	45.6
Terong Ungan Bulat	34.4	62.1	71.6	45.9	63.0	37.0	52.3
F-100	56.8	83.3	93.0	73.9	49.9	32.5	77.9
Easter Egg F_1	29.7	57.7	59.3	21.7	35.3	8.2	35.3
Senguro No.2	19.7	31.7	26.9	11.9	15.7	21.2	21.2
Ma su	23.3	29.0	53.3	14.3	25.1	9.1	25.7
Pingtung Long	35.4	37.3	56.1	34.5	41.0	19.9	37.4
Briue F_1	36.3	59.2	76.8	45.7	43.1	25.4	47.6
Farmers Long F_1	45.0	46.5	70.3	39.7	36.7	10.8	41.5
Mean	33.9	51.9	61.3	35.8	34.7	20.3	40.9
c.v. (%)	17.0	13.4	10.7	20.7	17.5	24.7	
LSD (0.05)	8.3	10.1	9.5	10.9	8.8	7.1	

[a]The 6 sowing dates: 24 April 1992; 24 June 1992; 19 August 1992; 20 October 1992; 21 December 1992; 19 February 1993.

The results of this investigation revealed that eggplant can be best planted in June to August. The high yield obtained from August planting was associated with large fruit size and high number of fruit per plant. Favorable environmental factors, such as high temperature during the early growing stage, high solar radiation, sufficient moisture supply, and effective control of disease and insect pests were contributing factors to high yield during this crop season.

Constraints. As a warm-season crop, eggplant thrives best at relatively high temperatures. It is more sensitive to low temperatures than tomato or pepper. This investigation showed that both cool temperatures and low-intensity solar radiation caused slow growth of the young plants and decreased pollen viability and fruit set in flowering plants as indicated by the low number of

fruit and yields in the cool-season plantings. Although eggplant was shown to be quite tolerant to flooding, excessive water caused considerable yield reduction.

Insects are generally considered the most serious constraint in eggplant production in the tropics. Among the insects, thrips and mites were the most important ones which caused serious damage to leaves and other plant parts. The damage was more pronounced during the warm and dry season. Diseases are another major problem of eggplant production, especially in tropical Asia. However, no particularly important disease was found at AVRDC's experimental field. Foliage disease such as leaf spot commonly occurs late in the crop season.

Preliminary Screening of Resistance to Bacterial Wilt in Eggplant

Summary

Commercial cultivars of eggplant from worldwide collections were screened in a greenhouse for resistance to bacterial wilt caused by *P. solanacearum*. Among the 30 cultivars tested, M 701 F_1 and Slim Jim were highly resistant with only 3% and 7% of disease indices, respectively. Their resistance was superior to the resistant control, Terong Hijau. These resistant varieties could be of great importance in an eggplant breeding project.

Introduction

Bacterial wilt (BW) caused by *Pseudomonas solanacearum* is an important disease of eggplant worldwide. The bacteria can survive in soil in areas of mild to warm climates and can be a limiting factor in growing eggplant. Field losses of 50% have been observed in the U.S., and losses between 75% and 81% have been reported in India. The purpose of this experiment is to evaluate varietal resistance to bacterial wilt and to identify resistant sources for developing breeding lines.

Materials and Methods

Thirty commercial eggplant cultivars including the resistant and susceptible control varieties were used. Seeds were sown in 2-in. plastic pots in the greenhouse. Each entry was composed of 15 plants in a tray and arranged in RCBD with three replications. Bacterial wilt inoculum PSS 97 was prepared by the plant pathology unit. BW screening was done by soil inoculation method to supplement root cutting. When seedlings were 30 days old, each pot was drenched with 20 ml inoculum adjusted to a concentration of 10^8 bacteria cells/ml. After inoculation, soil moisture was maintained at a high level and temperature was maintained at 25-32°C in the greenhouse.

The inoculated plants were observed daily, and records were kept of the date of appearance of wilt symptom and of plant death. Disease reading, based on the scale of 0 - 5 (0 = no symptoms, 1 = one leaf wilted, 2 = two or three leaves wilted, 3 = all leaves wilted except top two or three, 4 = all leaves wilted, 5 = dead), was taken at 7-day intervals and converted to disease indices. The experiment was terminated 30 days after inoculation (DAI). Data were analyzed by ANOVA and Duncan's multiple range tests.

Results and Discussion

Wilt symptoms were found 5 DAI especially on the susceptible varieties. The inoculation technique was very effective. Most of the susceptible plants were dead within 10–14 DAI.

Under these test conditions, none of the commercial cultivars showed immunity to bacterial wilt. However, two varieties, M 701 F_1 and Slim Jim, appeared to be resistant with disease indices of 3% and 7%, respectively (table 8). The resistant control variety, Terong Hijau (TS 56B), had a disease index of 20%. Senguro No. 2 F_1, Pingtung Long, and Masumi F_1 were moderately resistant to bacterial wilt. Twenty-three varieties (82%) were considered to be susceptible including two of the moderately susceptible ones.

Table 8. The disease indices and percentage of nonsymptomatic eggplant after inoculation with (*Pseudomonas solanacearum* PSS7) for 30 days[a]

Acc. no.	Variety	Disease index[b]	Nonsymptomatic plants (%) (%)	Bacterial wilt reaction[c]
S017	Violette Lunga	88 ab	10	S
S024	Long Purple	100 a	0	S
S026	M701 F_1	3 h	97	R
S028	Millionaire F_1	46 c-f	53	MS
S030	Senguro No. 2 F_1	24 f-h	76	MR
S029	Ichiban F1	86 ab	14	S
S039	Rikvzen Naga F_1	92 a	8	S
S040	Sanshi Naga F_1	77 a-c	20	S
S117	Pingtung Long	38 d-g	62	MR
S116	Ma-su	72 a-c	28	S
S119	Farmers Long F_1	67 a-e	33	S
S003	Casper	89 ab	11	S
S014	Slim Jim	7 gh	93	R
S016	Sicilia F_1	89 ab	10	S
S021	Othello	77 a-c	20	S
S023	Queen of Sheba F_1	97 a	3	S
S025	Florida High Bush	97 a	3	S
S027	Megal F_1	97 a	3	S
S037	Black Gnome	83 ab	17	S
S038	Masumi F_1	36 e-g	63	MR
S041	Ichifugi	70 a-d	30	S
S042	Daikokuden F_1	56 b-e	40	MS
S121	Vittoria F_1	100 a	0	S
S001	Blacknite F_1	97 a	3	S
S002	Vernal F_1	100 a	0	S
S009	Onita F_1	97 a	3	S
S020	Ingfrat F_1	100 a	0	S
S022	Edna F_1	100 a	0	S
TS56B	Terong Hijau (R ck)	20 f-h	80	R
S120	Bonne (S ck)	100 a	0	S

[a]Planting dates: sowing, 15 June 1993; inoculation, 14 July 1993.

[b]Disease index % = $(\Sigma n_i \times i)/[i_{max} \times (\Sigma n_i)]$, where i = disease reading, 0 - 5, i_{max} = 5.; Means followed by the same letter are not significantly different at 5% level (DMRT).

[c]R = less than 20% plants wilted; MR = 20 to 40% plants wilted; MS = 40 to 60% plants wilted; S = more than 60% plants wilted.

M 701 F_1 is a Japanese variety from Musashino Seed Co., whereas Slim Jim is a small fruit eggplant from Fratelli Ingegnoli, Italy. Both varieties have good horticultural characters. M 701 F_1 has teardrop fruits, 19.8 cm long and 5.3 cm thick, and is dark purple in color. Slim Jim has small cylindrical dark purple fruit 13.3 cm long and 3.7 cm in diameter. The resistant control, Terong Hijau, is a germplasm collection from Indonesia. It bears small round fruit 4.2 cm long, 4.9 cm thick, and is green with white stripes. The evidence of BW resistance in these varieties will be reconfirmed. The use of these genetic materials should be beneficial in gradually improving the level of resistance of eggplant to bacterial wilt.

Mungbean Entomology

Identification of Sources of Resistance to Bean Pod Borer in Mungbean

Summary

Bean pod borer (*Maruca testulalis*) is one of the most destructive pests of mungbean and related *Vigna* species in tropical to subtropical Asia and Africa. Insect larva bores into the pods and feeds on developing seeds. AVRDC aims to breed mungbean cultivars resistant to this pest. In late 1992 and early 1993 we screened 2000 mungbean accessions for resistance to bean pod borer in Thailand where this insect is endemic. Seeds of each of the 2000 accessions were planted in single rows in individual 4 m x 0.4 m plots. Plants were grown using customary cultural practicies but no insecticide was used. At harvest we recorded the total and insect-damaged pods and calculated the percentage of damaged pods for each accession. Pods damaged ranged from 0 to 93%. The average damage was 15%. Three accessions (V 3274, V 3276, and V 3279) had damage-free pods whereas accessions V 3277, V 3281, V 3483, V 3812, V 3949, V 4300, and V 4411 had less than 2% pods with insect damage. These 10 accessions appeared promising and will again be screened for resistance in multireplicate tests in Thailand to confirm the resistance before utilizing them in our pod borer-resistance breeding program.

Introduction

Bean pod borer, *Maruca testulalis*, is a destructive pest of mungbean and related *Vigna* species in tropical to subtropical Asia and Africa. Larvae of this insect bore into the green mungbean pods and feed on developing seeds. As a result of such feeding habit, seed yield is reduced directly. AVRDC aims to breed mungbean cultivars resistant to bean pod borer. Since 1991, AVRDC's mungbean germplasm collection has been screened for resistance to bean pod borer. In late 1992 and early 1993, we screened 2000 mungbean accessions for resistance to this pest to select the least damaged ones which might have genetic resistance to bean pod borer.

Materials and Methods

The screening was done at the Field Crops Research Station, Phitsanulok, by the Chainat Field Crop Research Center, Thailand. Land was worked into 4-m-long and 0.4-m-wide plots. Seeds of each of 2000 accessions were planted as a single row in individual plots. The crop was grown using customary cultural practices with no insecticide used. At harvest we recorded the total number of mature pods as well as bean pod borer-damaged ones in each accession. Percent damaged pods was calculated by dividing the number of damaged pods by the total number of pods and multiplying the product by 100.

Results and Discussion

The insect-damaged pods among the 2000 accessions ranged from 0 to 93%. Average damage was 15%. Pods of three accessions, V 3274, V 3276, and V 3279, were free of any bean pod borer damage. Less than 2% of pods of accessions V 3277, V 3281, V 3483, V 3812, V 3949, V 4300, and V 4411 were damaged by the insect. These 10 accessions appeared to be promising. We will screen these accessions again in Thailand utilizing several replications to confirm their resistance before utilizing them in our bean pod borer-resistance breeding program.

Mungbean Physiology

Selection for Homozygous Bruchid Resistance in the Mungbean $F_3BC_2S_1$ Population with RFLP Markers

Summary

$F_3BC_2S_1$ lines of a cross between bruchid-resistant TC 1966 and susceptible breeding line VC3890A were investigated using restriction fragment length polymorphism (RFLP) analysis to select plants homozygous for bruchid resistance. Fifteen $F_3BC_2S_1$ plants, expected to have the homozygous bruchid resistance gene, were selected using two RFLP markers closely linked to both sides of the bruchid resistance gene in linkage group no. 8.

Introduction

The current mungbean RFLP linkage map has been used for recurrent selection with bruchid resistant markers in the progeny of crosses between bruchid-susceptible VC 3890A and bruchid-resistant TC 1966, a wild progenitor, *Vigna radiata* ssp. *sublobata*. This cross was one of the crosses used in the conventional backcross breeding. Previously two lines (53 and 28) in the F_3BC_2 generation were selected for having 89.4% of the recurrent parent's genome and heterozygous bruchid resistance gene from the donor parent by RFLP analysis. In this study we tried to advance the generation and select plants among the selfings of these two F_3BC_2 lines to obtain homozygous bruchid-resistant genes with a minimum of the undesirable genes from the donor parent. Agronomic characters of selected $F_3BC_2S_1$ lines and the recurrent parent, VC 3890A, were also compared.

Materials and Methods

Plant materials

Selfed lines in the F_3BC_2 generation (i.e., $F_3BC_2S_1$ lines) of bruchid-susceptible VC 3890A x bruchid-resistant TC 1966 were planted in pots and grown under greenhouse conditions. During the growing period, they were regularly inspected for morphological characteristics. At 20 days after planting, 3 g of newly emerged leaves were collected from each plant and brought to the laboratory for the extraction of genomic DNA.

Genomic DNA preparation

Sampled leaves were frozen in liquid nitrogen and ground well using mortar and pestle. Ground leaf powder was incubated with 11 ml of extraction buffer at pH 8.0 (100 mM Tris-HCl; 50 mM EDTA; 500 mM NaCl; 1.25% SDS; 30 mM $NaHSO_4$) at 65°C for 15 min. After incubation, 3.6 ml of 5 M potassium acetate was added and kept in the ice for 60 min. It was then centrifuged

at 3000 rpm for 15 min; the supernatant was collected by filtration through miracloth. An equal volume of isopropanol was added, mixed well and kept at -20°C for 60 min to precipitate the DNA. The precipitated DNA was hooked out carefully by a modified Pasteur pipette and washed with 70% ethanol then transferred to a 1.5 ml micro tube. After drying, DNA was resuspended by adding 400 µl of TE buffer and treated by 2 µl of RNase (10 mg/ml) at 37°C for 60 min.

Probes

DNA probes were provided by Dr. Nevin Dale Young of the University of Minnesota, USA. R26 and M371 probes which are closely linked to both sides of the bruchid resistance gene in linkage group no. 8 were used for detection of bruchid-resistant loci, while A315, Q43 and M287 were used to confirm the genotype with recurrent parent, VC 3890A. A randomly primed DIG labeling kit (Boehringer-Mannheim) was used for labeling the probe.

Southern analysis

Five micrograms of DNA of both parents and 58 BC_2S_1 plants were completely digested with 20 units of restriction enzymes: EcoR I for R26, Hind III for M287, and EcoR V for M371 and Q47 were digested at 37°C overnight, and Bst NI for A315 at 60°C overnight. Digested DNA was then loaded on 1% agarose gel and run for electrophoresis before being transferred to a Hybond-N nylon membrane with 20x SSC solution. Each DIG-labeled probe was hybridized with the membrane at 63°C overnight. After that, the membrane was washed twice, each for 15 min with 2x SSC, 0.1% SDS and 0.5x SSC, 0.1% SDS at 60°C before the detection of signals by the DIG-chemiluminescent detection method.

Results and Discussion

Fig. 1 shows that R26 and M371 probes, which are closely linked to both sides of the bruchid resistance gene in linkage group no. 8, provide adequate polymorphism to detect for bruchid resistance. With this analysis, data in table 1 show that among 58 $F_3BC_2S_1$ plants, R26 and M371 RFLP markers were segregated at a ratio well fitted to 1:2:1 ($c^2 = 0.3$, $P > 0.75$); crossing-over rate is 10.3% (i.e., 6 among 58 plants). Fifteen plants among 58 $F_3BC_2S_1$ plants seem to be homozygous for bruchid resistance.

The A315 probe which is situated at a distance of 12 cM from M371 locus confirmed that the chromosome segment was already homozygous with the recurrent parent, VC 3890A. The region of Q43 and M287 RFLP markers which are located on different linkage groups no. 1 and 3 are also homozygous with the recurrent (VC 3890A) chromosome segment. The results reported here show that RFLP-based selection is very reliable and effective for breeding for bruchid resistance.

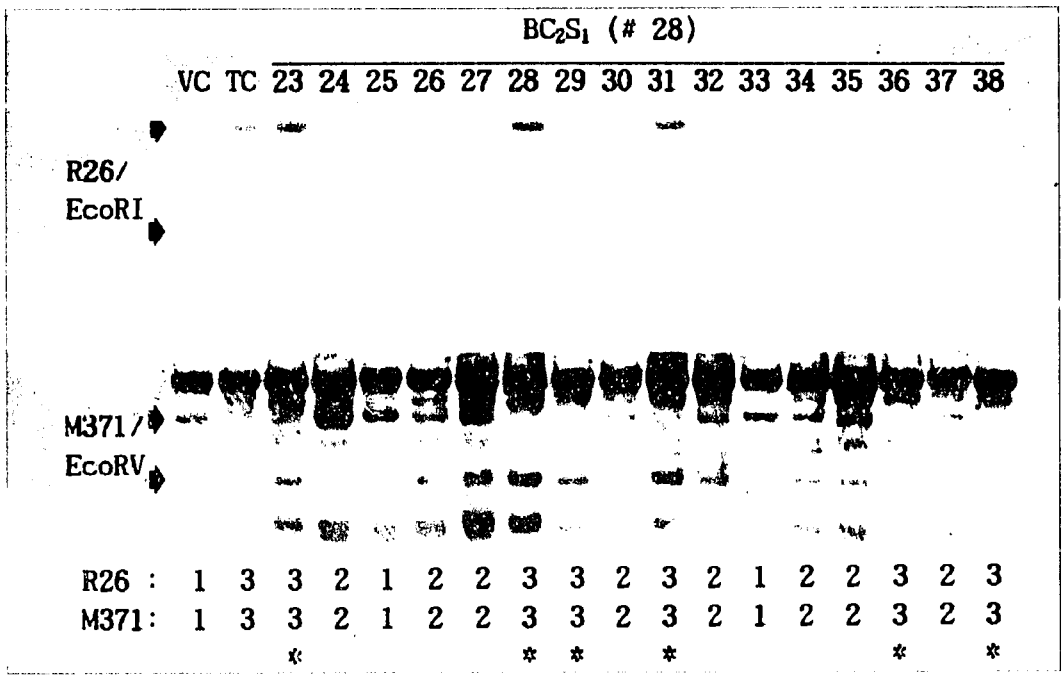

Fig. 1. RFLP analysis for the selection of homozygous bruchid-resistant mungbean plants in $F_3BC_2S_1$ (line 28) population using DIG-labeled R26 and M371 probes which are closely linked to both sides of bruchid resistance gene (B). VC: VC 3890A; TC: TC 1966 (*Vigna radiata* ssp. *sublobata*); and *: B/B

Table 1. Segregation of RFLP markers in the $F_3BC_2S_1$ population

Markers	Linkage group no.	Genotype[a]	No. of BC_2S_1 plants AA	Aa	aa	Expected ratio	X^2	*P* (df = 2)
R26[b]	8	Aa	17	26	15	1:2:1	0.30	0.75-0.90
M371[b]	8	Aa	16	26	16	1:2:1	0.31	0.75-0.90
A315[c]	8	AA	58	0	0	1:0:0	0.00	1.00
Q43	1	AA	58	0	0	1:0:0	0.00	1.00
M287	3	AA	28	0	0	1:0:0	0.00	1.00

[a] BC_2 genotype for bruchid resistance by the RFLP analysis.
[b] Markers are closely linked to the bruchid resistance gene, with only 10.3% recombination value.
[c] Marker in the distance of 12 cM from M371 locus.

Selection for Bruchid and Powdery Mildew Resistance in the Mungbean $F_3BC_2S_1$ Population with RFLP Markers

Summary

RFLP marker-assisted mungbean breeding for bruchid and powdery mildew resistance was carried out in the $F_3BC_2S_1$ generation of the VC 3890A/TC 1966 cross. One plant each from previously identified heterozygous resistant lines (12 and 23) were homozygous for two bruchid (B) resistant markers and one powdery mildew (PM) resistant marker. Some gene(s) correlated with indeterminate growth seemed to be linked to the PM resistant loci. Further confirmation with

more RFLP markers will be necessary to distinguish these two traits and effectively select for PM resistance.

Introduction

An RFLP linkage map has been previously used for selection of bruchid- and powdery mildew-resistant lines in the F_2, F_3, F_3BC_1, and F_3BC_2 generations of the VC 3890A/TC 1966 cross. In this study we tried to self and advance the F_3BC_2 generation, using RFLP markers to select plants among the selfed generation of F_3BC_2 for homozygous bruchid- and powdery mildew-resistant genes from both parents.

Materials and Methods

Selfed seeds of two bruchid- and powdery mildew-resistant lines (12 and 23) and two bruchid-resistant lines (28 and 53), previously selected from the F_3BC_2 generation by the RFLP method, were sown on 30 June and 19 July. About 3 g of newly emerged leaves of these plants were harvested, ground in liquid nitrogen, and stored in -80°C before DNA extraction. DNA extraction and Southern blot analysis were conducted as previously described. With two parents as controls, bruchid- and powdery mildew-related markers were scored for selection.

Results and Discussion

For bruchid resistance, M371 and R26 probes, which are 20 cM apart, were used for scoring. Among 74 progenies of line 12, nine and eight plants each were homozygous for TC 1966 at M371 and R26, and five plants homozygous for both loci. Among 40 progenies of line 23, eight, nine and eight plants each were homozygous for TC 1966 at M371, R26, and both loci. Cross-over rate between these two loci was extremely high (25%) in line 12, compared to less than 20% in other lines.

For powdery mildew resistance, Q43 and A132 are two linked markers. Due to shortage of A132 probe, M241 was scored as a reference. Five plants in line 12 and nine in line 23 are homozygous for Q43 locus. Only one plant in each line was homozygous for Q43, M371, and R26 loci, but no plant was homozygous for all four loci. On the Bst NI-digested membrane, hybridization with M241 showed two polymorphism (a, b). On the other hand, only one polymorphism (c) appeared on the RI-digested membrane when probing with M241. Polymorphism b was highly correlated with polymorphism c ($r = 0.49$, $P < 0.01$). Among three polymorphisms created by M241, polymorphism b is highly correlated with Q43 ($r = 0.26$, $P < 0.01$). The inconsistent scoring result between Q43 and M241 loci could be due to the long distance (i.e., 47 cM) between the two loci. Since M241 is far from the PM resistance gene, further confirmation with A132 would still be necessary.

Progenies from bruchid- and PM-resistant lines (12 and 23) tended to be taller than those lines (28 and 53) with bruchid resistance only (table 2). Table 2 also shows that line 53 is most closely related to the recurrent parent, VC 3890A, in agronomic traits. Line 53 is also more uniform than lines 12 and 23, the genotype of which is about 80% different from that of the donor parent (about 80% from the heterozygous genotype of the donor parent), TC 1966. Since the wild donor parent (TC 1966), with an average height of 180 cm carries indeterminate growth character, the results indicate that some plant height or indeterminate related gene(s) are located at the same chromosome and closely linked to Q43. The correlation analysis also indicates that plant height is related to the Q43 scoring ($r = 0.43$, $P < 0.01$). Since indeterminate growth is an unfavorable character, further investigation on markers near the PM resistance gene would still be necessary to identify these two traits independently.

Table 2. Comparison of five agronomic traits of four F_3BC_2 lines and their parents[a]

Line no.	Recurrent genotype (%)	Peduncle no./plant	Pod no./ plant	Seed no./ pod	100-seed wt (g)	Plant ht (cm)
Line 12 (Br+PM)	83.7					
Mean		4.6	22.9	6.7	6.4	96.8
SD		2.0	10.9	1.1	0.7	28.4
c.v.%		43.8	47.5	17.0	11.4	29.3
Line 23 (Br+PM)	82.8					
Mean		4.1	22.3	6.4	6.3	88.8
SD		1.3	11.9	1.4	0.9	22.1
c.v.%		31.8	53.3	20.9	14.1	24.9
Line 28 (Br)	89.4					
Mean		3.4	12.7	6.4	6.4	64.2
SD		0.5	3.6	0.9	0.4	9.0
c.v.%		14.5	28.1	13.3	6.5	14.0
Line 53 (Br)	89.4					
Mean		10.0	23.6	6.2	6.7	74.6
SD		2.5	8.2	0.7	0.5	8.1
c.v.(%)		25.1	34.7	11.9	7.8	10.9
VC 3890A	100.0		20.0	6.8	6.8	74.2
TC 1966	0.0		9.0	7.0	1.6	180.6

Identification of Bruchid-Resistant Plants with Two Molecular Markers

Summary

The mungbean RFLP map for bruchid resistance gene was constructed based on a specific cross, VC 3890A x TC 1966. This experiment was carried out to test its applicability in identifying bruchid resistance in progeny derived from different parentages. Parents and F_1 progenies of the cross between BC_3F_8 (TC 1966 x VC 1178A) and Korean cultivar Jeonnam 2 were analyzed for this gene with morphological and RFLP markers. Some genomic changes took place in the resistance gene region during the course of three backcrossings and eight selfings. But interim results suggest that R26 and A315, located 10 and 30 cM, respectively, from the resistance gene, could be used as probes to select bruchid-resistant plants in different cross combinations involving TC 1966.

On the other hand, the segregation data indicate that hypocotyl color probably is controlled by more than one gene. Further analysis is needed to identify F_2 generations to confirm the introgression of bruchid resistance gene.

Introduction

The mungbean RFLP genetic map, consisting of more than 200 RFLP and RAPD markers, has been constructed and is in the process of saturation. The RFLP map for bruchid resistance was essentially based on the segregation of markers in the F_2 population of a cross of VC 3890A x TC 1966. This study aimed to investigate the applicability of this map in determining the bruchid resistance of the progeny of a cross of BC_3F_8 (of TC 1966 x VC 1178A) and Korean variety Jeonnam 2. The study also tested against segregation of morphological markers such as hypocotyl color and seed coat luster.

Materials and Methods

Plant materials

A bruchid resistance gene was incorporated from TC 1966 to VC 1178A through a conventional backcross breeding method. Its progeny, BC_3F_8, was crossed with a Korean variety, Jeonnam 2. F_1 plants of this cross were grown in the greenhouse and used for RFLP analysis. Analysis involving F_2 plants is still in progress. BC_3F_8 (TC 1966 x VC 1178A) has green hypocotyl and shiny seed coat; Jeonnam 2 has green hypocotyl and dull seed coat. These two morphological characteristics were inspected in F_1 and F_2 generations.

DNA extraction, restriction digestion, and blotting

DNA isolation and Southern transfer were conducted as previously described. DNA of both parents were digested by eight restriction enzymes: EcoR I, EcoR V, BstNI, Hind III, DraI, Hae III, BamHI, and Sau3AI. Each DIG-labeled RFLP probe was hybridized against Southern blots containing digested DNA. Detected polymorphic markers were used for selecting true F_1 hybrid plants among F_1 expected plants and will be used for analysis of segregation in F_2 population.

Results and Discussion

Twenty polymorphic markers were detected from 32 RFLP clones of which the map position had been constructed. Detected polymorphic markers were used for selection of true F_1 hybrid and will be used for the analysis of F_2 generation.

Among 20 F_1 plants of the cross of BC_3F_8 (TC 1966 x VC 1178A) and Jeonnam 2, four were found to be selfed (fig. 2). Plant numbers 5 to 7 in fig. 2 were likely self-crossed because they had the same RFLP score and hypocotyl color as Jeonnam 2. These F_1 plants also had dull seed coat like Jeonnam 2.

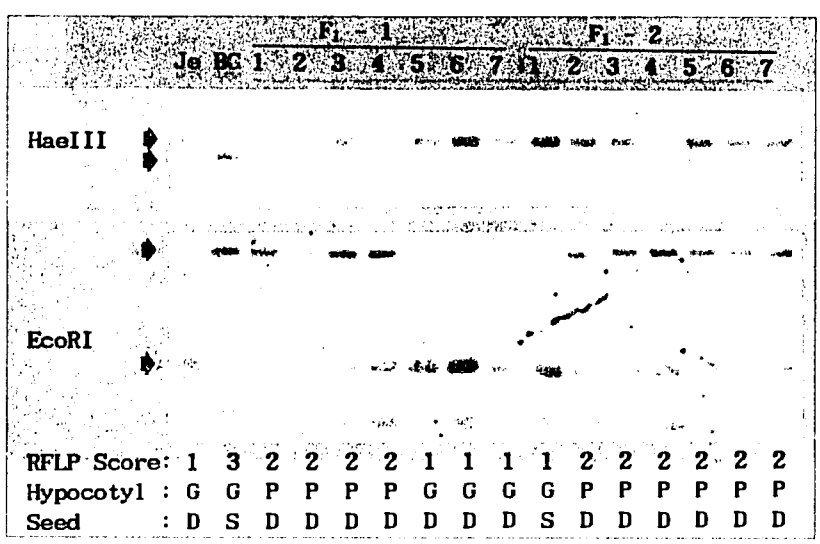

Fig. 2. RFLP analysis of F_1 plants derived from the cross of BC_3F_8 (TC 1966 x VC 1178A) and Jeonnam 2. DNA of F_1 plants were digested by Hae III and EcoR I and hybridized with DIG-labeled R26 probe. Je: Jeonnam 2; BC: BC_3F_8 (TC 1966 x VC 1178A); F_1 - 1: Jeonnam 2 x BC_3F_8: F_1 - 2: BC_3F_8 x Jeonnam 2; Hypocotyl: P (purple), G (green); Seed surface: D (dull), S (shiny)

Literature suggests that hypocotyl color is determined by a single dominant gene which is linked to seed-coat structure gene with 15.0% of crossing-over rate, and that purple hypocotyl is dominant to green hypocotyl. Fig. 2 shows that both parents had green hypocotyl but the F_1 plants had purple hypocotyl. Table 3 shows that the F_2 population segregated with a ratio against the single-gene theory (3:1) but was prone to two-gene theory (9:7 or 1:1). Likely this character is controlled by two closely linked genes.

Table 3. Segregation of hypocotyl color in F_2 population of the cross between BC_3F_8 x Jeonnam 2

Entry	Hypocotyl color	No. of F_2 plants[a] Purple	Green	Expected ratio	X^2	P (df = 1)
BC_3F_8	Green					
Jeonnam 2	Green					
F_1	Purple	32	46	3:1[a]	48.0	<0.001
(BC_3F_8 x				9:7[b]	7.38	0.01-0.05
Jeonnam 2)				1:1[c]	2.51	0.10-0.20
F_1	Purple	37	33	3:1[a]	19.81	<0.001
(Jeonnam 2				9:7[b]	0.32	0.50-0.70
x BC_3F_8)				1:1[c]	0.23	0.50-0.70

[a]Conventional theory for hypocotyl color in mungbean.
[b]The ratio for characters controlled by two independent genes.
[c]The ratio for characters controlled by two closely linked genes.

With R26 clone (i.e., 10 cM from the bruchid resistance gene) as a probe, fig. 3 shows that individuals in the BC_3F_8 have a distinct band at 5.6 Kb. However, bulked DNA from 50 individual plants show the other distinct band at 3.1 Kb, which is unique to Jeonnam 2, and not presented in the individuals of BC_3F_8 parents.

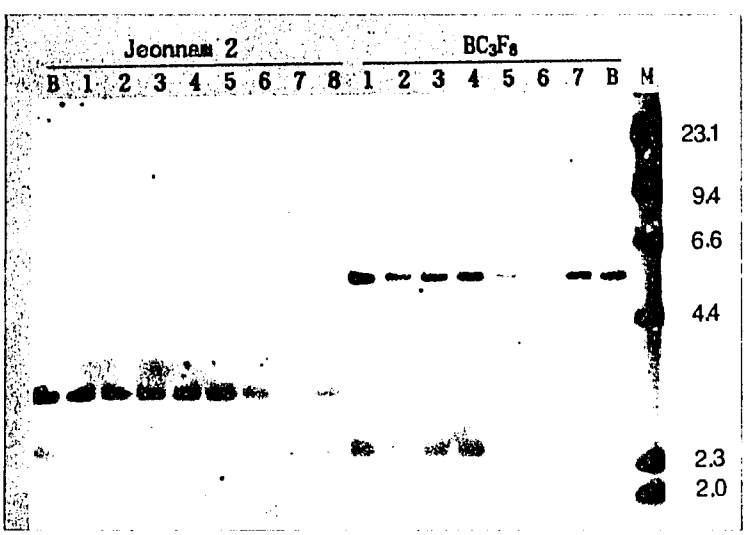

Fig. 3. Purity test of Jeonnam 2 and BC_3F_8 (TC 1966 x VC 1178A) by RFLP analysis with R26 as a probe. DNA of each plant and bulked DNA from 50 plants were digested by EcoR I and hybridized with DIG-labeled R26 probe. B: bulked DNA from 50 individual plants. M: I Hind III marker

The introgression of the bruchid resistance gene into the F_1 plants of BC_3F_8 (of TC 1966 x VC 1178A) x Jeonnam 2 is confirmed by the RFLP analysis. Fig. 4 shows the TC 1966-specific EcoR I-derived, R26-hybridized band (5.6 Kb) presented in the BC_3F_8 (of TC 1966 x VC 1178A) population and in F_1 (of BC_3F_8 x Jeonnam 2) but not in other ancestries (i.e., VC 1178A and Jeonnam 2) and nonrelated lines; all of these have 3.1 Kb band. This band is likely a deletion or insertion of a certain DNA fragment in the region. This TC 1966-specific band (5.6 Kb), which could be hybridized with R26 clone, is useful for detecting bruchid resistance gene in distant generations involving TC 1966 as a parent.

Using A315 clone (i.e., 30 cM from the bruchid resistance gene at the opposite side of the R26 locus) as a probe also proves the incorporation of genome from a bruchid-resistant parent into BC_3F_8 and F_1 (fig. 5). However, fig. 5 also indicates that TC 1966-specific BstNI-digested band (7.0 Kb) was changed in BC_3F_8 and F_1 plants to 6.2 Kb. Both bands were not presented in other ancestries and breeding lines. Apparently, deletion of about 0.8 Kb or base pair substitution for EcoR I recognition site took place in this region. This suggests that genomic changes took place during the course of three backcrossings and eight selfings of TC 1966 x VC 1178A. This study is still in progress to confirm the bruchid resistance in the F_2 generation.

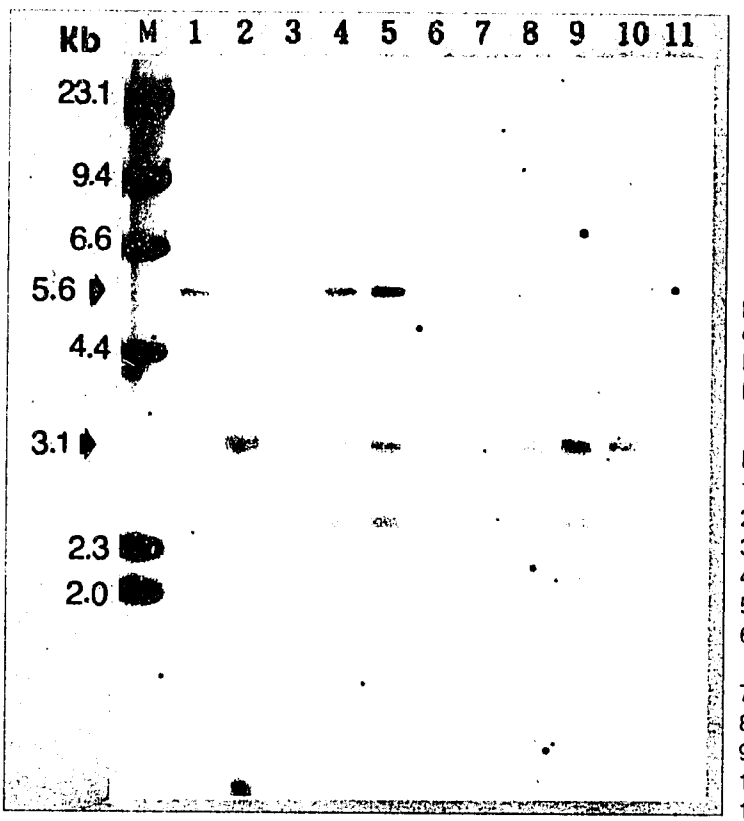

Fig 4.
Pedigree of Jeonnam 2 and BC_3F_8 (TC 1966 x VC 1178A) by RFLP analysis with R26 as a probe. DNA of each entry was digested by EcoR I and hybridized with DIG-labeled R26

M: I Hind III marker
1: TC 1966
2: VC 1178A
3: BC_3F_8 (TC 1966 x VC 1178A)
4: F_1 - 1 (BC_3F_8 x Jeonnam 2)
5: F_1 - 2 (Jeonnam 2 x BC_3F_8)
6: Jeonnam 2 (V 2984 x VC 1089B)
7: V 2984
8: VC 1089B
9: VC 3890A
10: VC 1973A
11: V 5926

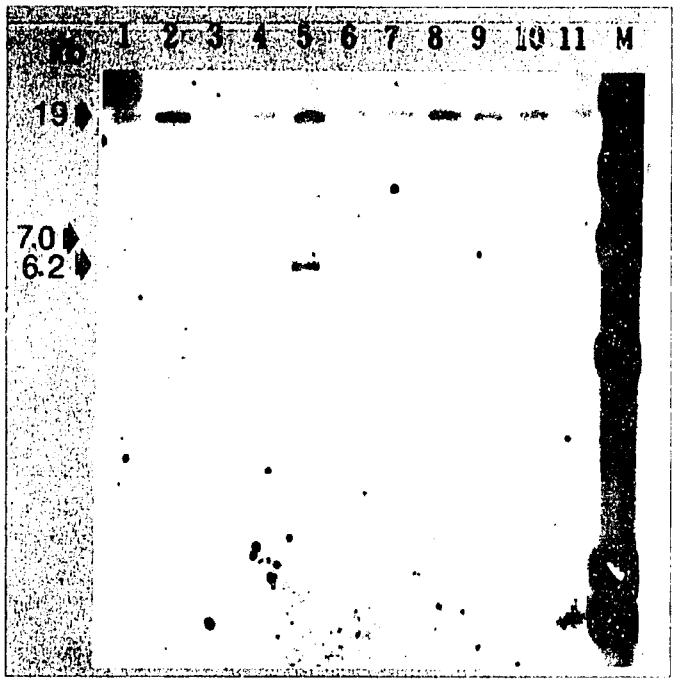

Fig 5.
Pedigree of Jeonnam 2 and BC_3F_8 (TC 1966 x VC 1178A) by RFLP analysis with A315 as a probe. DNA of each entry was digested by BstN1 and hybridized with DIG-labeled A315

M: I Hind III marker

1: TC 1966
2: VC 1178A
3: BC_3F_8 (TC 1966 x VC 1178A)
4: F_1 - 1 (BC_3F_8 x Jeonnam 2)
5: F_1 - 2 (Jeonnam 2 x BC_3F_8)
6: Jeonnam 2 (V 2984 x VC 1089B)
7: V 2984
8: VC 1089B
9: VC 3890A
10: VC 1973A
11: V 5926

Pepper Breeding

Seed Production, Observation, and Evaluation Trials of New and Advanced Germplasm

Summary

Seed production in isolation under screened cages or tunnels was conducted for 187 breeding lines. The materials consisted of 20 lines from disease screening, 30 sweet peppers from Sri Lanka, 16 Szechwan pureline selections, 30 INTHOPE no. 3 entries and 91 new accessions or seed stocks for maintenance. An advanced yield trial was conducted on 22 breeding lines of fresh market sweet peppers from Sri Lanka carrying resistance to bacterial wilt and tolerance to CVMV and CMV. Average yield after 11 harvests was 31 t/ha. Five lines were most promising. Observational trials on Hungarian fresh market peppers were conducted in search of useful breeding materials. A fall-winter observational trial, at two planting densities, was conducted in 1992-93. Despite heavy infestations of mites and thrips on some varieties the marketable yields were within expectations for cool season performance. In the 1992-93 cool-dry season an advanced yield trial was conducted on 16 selected and 3 check lines from Taiwanese Szechwan landraces. Ten selections had early marketable yields comparable to the hybrid check, whereas, three selections had sum marketable yields comparable to the hybrid. Breeder's seed of these lines is available for global testing.

Introduction

Seed production, observational and evaluation trials are ongoing activities in the pepper breeding project. These activities are essential for maintaining breeding lines and identifying new breeding materials. Sweet peppers from Sri Lanka carrying resistance to bacterial wilt and tolerance to CVMV and CMV were evaluated and advanced from F_4 to F_6 at AVRDC. Some lines should be promising to improve sweet peppers for the tropics. Cooperation in pepper breeding began with the Hungarian Vegetable Crops Research Institute in 1992. Among other activities observation trials on Hungarian fresh market peppers are being conducted at AVRDC in search of useful breeding materials. Last year a spring-summer evaluation was conducted. The fall-winter trial (1992-93) is reported here. Another evaluation trial was conducted on 16 Szechwan selections and 3 check lines during the 1992-93 cool-dry season. The Szechwan selections are smooth elongated fruit types of moderately low pungency. They are most stable for cool season production under intensive management.

Materials and Methods

Seed production

Seed production in isolation under screened cages or tunnels was conducted for 187 pure breeding lines. The materials consisted of 20 lines from disease screening, 30 sweet peppers from

Sri Lanka, 16 Szechwan purelines, 30 INTHOPE no. 3 entries, and 91 new accessions or seed stocks for maintenance.

Observation and evaluation trials

Sweet peppers from Sri Lanka. Twenty-two F_5 sweet pepper lines and one parent check were evaluated in three replications in a randomized complete block design. Lines were sown on 1 October 1992 and transplanted on 5 November 1992. Each experimental unit comprised of 20 plants in a two-row, 1.5-m-wide bed; spacing between plants was 0.5 m between rows and 0.45 m between plants in the row. Plant population density was 29,630 plants/ha. Management practices consisted of fertilizer applications of actual N-P_2O_5-K_2O at 147-106-133 kg/ha, Borax at 10 kg/ha, and 1.3 t/ha of an organic fertilizer amendment. All fertilizer was incorporated pretransplant. Beds were mulched with silvery plastic. Fruits were harvested at the green mature stage beginning on 24 December 1992 until 4 March 1993 (11 harvests). Crop duration in the field was 17 wk (119 days). Mean temperatures (maximum and minimum) and humidity, and total precipitation were 23.4°C, 15.6°C, 80.7% and 49 mm, respectively, for the period. Yield performance, fruit characteristics and quality traits were evaluated. Organoleptic evaluations were conducted by a volunteer panel.

Fresh market sweet and hot peppers from Hungary. Six hot pepper varieties, including four hybrids, and eight sweet pepper varieties, including two hybrids, were chosen for cool season evaluation. Two hybrid check varieties, 'Blue Star' and 'Gypsy', were also tested. The Hungarian varieties were selected based on their superior performance out of 31 varieties tested in the previous summer. The experiment was sown on 30 October 1992 and transplanted on 8 December 1993. Each variety was sown at two plant densities, 29,630 plants/ha vs. 53,333 plants/ha on 1.5-m beds without replication. There were 14 plants per plot, 10 of which were harvested. Crop management was the same for the experiment described earlier.Harvest began on 17 February until 7 April 1993 (8 harvests). Sweet peppers were harvested in the green mature stage, whereas, hot peppers were harvested at red maturity. Total crop duration posttransplanting was 120 days (3.9 mo). Mean temperatures (maximum and minimum) and humidity, and total precipitation were 23.6°C, 15.9°C, 81% and 35.5 mm, respectively. Yield performance and quality traits were evaluated.

Hot pepper Szechwan pureline selections. Sixteen Szechwan selections, two original landrace populations, and one hybrid variety, Hot Beauty (Known You Seed Co.), were sown on 7 September 1992 and transplanted on 8 October 1992 in an advanced yield trial. The experimental design was a randomized complete block with four replications. The experimental unit was 26 of 30 plants spaced 0.45 m between plants and 0.5 m between rows on a two-row, 1.5 m x 6.75 m bed. Fertilizer was incorporated into the beds once at actual N-P_2O_5-K_2O of 147-106-133 kg/ha, Borax 10 kg/ha and 1.3 t/ha of an organic fertilizer amendment. Beds were covered with silver plastic mulch. Furrow irrigation was employed. Plots were harvested eight times at the red mature fruit stage, beginning on 13 January until 4 March 1993. Total crop duration posttransplanting was 146 days (4.7 mo). Mean temperatures (maximum and minimum) and humidity, and total precipitation were 24.5°C, 16.4°C, 81.1%, and 40 mm, respectively, for the crop duration. Data were collected for determining fresh and dry weight yields, harvest index, and fruit dimensions. Quality traits were evaluated by the Analytical Laboratory using NIRS and anthracnose disease was evaluated by the Plant Pathology Unit based on the percentage of fruits

showing symptoms of latent infection after incubation. Plant and fruit types were observed for uniformity.

Results and Discussion

Sweet peppers from Sri Lanka. Mean fresh marketable fruit weight for all harvests was 30.97 ± 5.8 t/ha. The mean of the parent line CA 8 was 15.5 t/ha. Cull fruits accounted for less than 4% of the total yields. On a dry weight basis lines had 7.5% dry matter, 26.8% total sugars, and 6.1% lipids, and vitamin C at 98.7 mg/100 g (fresh weight) on the average. Most lines had tapered fruit shape. Color ranged from waxy-yellow to green. Based on earliness, growth characteristics, yield and fruit quality, five lines were highlighted. A detailed report is published in the Training Reports 1993. Twenty F_6 lines, the parent check, and three commercial hybrids are being evaluated from production in the 1993 hot-rainy season.

Fresh market sweet and hot peppers from Hungary. Despite heavy infestations of mites and thrips on some varieties the marketable yields were within expectations for cool season performance. Of the hot peppers, the hybrids Rapidus, Rapires, Novator, and Novares had high and comparable marketable yields between 20-25 t/ha. Of the sweet peppers, the hybrids Blue Star (local check), Savo, Block and the open-pollinated variety Hosszu Taltos had high and comparable yields between 19-26 t/ha. Fruits per plant were significantly less at the higher planting density for the sweet peppers, and individual fruit weights were significantly less for both the hot and sweet peppers at the higher plant density (t, a = 0.05) (table 1). Yield differences, however, were not significant indicating that the higher plant density compensated for a reduction in certain yield components. Cull fruits averaged 21% of the total fruit production. Quality traits averaged 6.7% dry matter, 28% sugars, 5% lipid (all based on dry weight) and vitamin C at 120 mg/100 g (fresh weight). The varieties Feeske, Novator F_1, Rapidus F_1, Novares F_1 and Rapires F_1 had the highest vitamin C content (180-206 mg/100 g). Performance of the lines was considerably better in this cool season evaluation than in the spring-summer trial of 1992 (see AVRDC 1992 Progress Report). More detailed variety information is available upon request.

Table 1. Mean performance of Hungarian fresh market peppers at two planting densities, AVRDC, cool season 1992-93

Fruit type		Planting density	Marketable Fruit per plant	Marketable Yield (t/ha)	Marketable Single fruit wt (g)
Hot (6 varieties)		29,630	12.5	15.1	43.1
		53,333	9.4	18.2	36.7
	Student's t ($t_{critical}$=2.228)		2.2	1.8	3.7
Sweet (10 varieties)		29,630	8.4	14.3	59.9
		53,333	6.0	15.5	48.9
	Student's t ($t_{critical}$=2.101)		4.8	1.2	4.2

Hot pepper Szechwan pureline selections. The major production constraints were mite and thrips injury, fruit worms, and virus. Mean marketable yields were 7.1 t/ha (fresh) and 1.0 t/ha (dry), slightly lower than for the 1991-92 trial (AVRDC 1992 Progress Report). Ten selections had early marketable yields comparable to the hybrid check, whereas, three selections had sum marketable yields comparable to the hybrid (table 2). Cull fruit averaged 23% by number and 15% by weight. The hybrid had the highest harvest index of 43% whereas the mean harvest index was 28%. On the other hand, the hybrid had the most cull fruits (37%). One selection, Szechwan 9-19-1-1-BK_4 had exceptionally long elegant fruits, which averaged 15 cm in length and a fruit:length ratio of 12.9. The Szechwan 1 landrace had a competitive yield but was nonuniform for fruit type. The Szechwan 10 landrace had fair uniformity but low yield. Quality traits (on dry weight) averaged 14.7% dry matter, 1.37 mg/g DM capsaicin, 23% sugars, 8.7% lipids, 8302 color value (note: Hungarian paprika standard = 20,274 color value) and vitamin C (fresh weight) 119 mg/100 g (table 3). Anthracnose incidence was relatively low with a mean latent infection of 5.8%. Four lines, including the hybrid check, had higher anthracnose incidence ranging from 14 to 21%. Breeders' seed of seventh and eighth generation selections from Taiwanese Szechwan landraces is available for global testing.

Collection, Evaluation, Multiplication, and Distribution of INTHOPE Entries

Summary

The International Hot Pepper Trial Network (INTHOPE) has fostered the systematic evaluation and distribution of tropical hot peppers. At present, evaluation has been standardized for independent disease screening against 10 pathogens, NIRS analysis for six quality traits, abridged characterization for 20 descriptors, and 24 field performance variables including maturity, yield components, harvest index and fruit characteristics. Subsequent to cool-season seed production, the INTHOPE no. 3 set of 16 out of 30 entries tested was distributed via 34 seed shipments covering 64 test sites among 23 counties. Field performance of the 30 entries was evaluated twice in the 1992 hot-rainy season and twice in the 1992-93 cool-dry season. Treatments that were added to the summer season evaluation tested the effect of sowing date/plant density (confounded effects) on field performance. Yields were considerably higher from the 16 June 1992 sowing (44,444 plants/ha) compared to the 1 May 1992 sowing (66,667 plants/ha). Combined yields for the two plantings were low and averaged 35.5 total fruits per plant, 1.6 t/ha and 2.8 t/ha marketable and total yields, respectively. In the cool season, the effects of silver plastic vs. rice-straw mulch were compared. Early yields were enhanced by the plastic-mulch treatment; however, final yields were significantly higher for the straw mulch treatment. Overall, the cool-dry season performance averaged twice the hot-humid season evaluation.

Introduction

The International Hot Pepper Trial Network (INTHOPE) has fostered the systematic evaluation and distribution of tropical hot peppers. The INTHOPE no. 3 set was evaluated at AVRDC in 1992-93 and 16 of 30 tested lines were distributed in 1993 to 34 participants, representing 64 test sites among 23 countries. Field performance of 30 entries was evaluated twice in the 1992 hot-rainy season and twice in the 1992-93 cool-dry season. The first rainy-season trial was reported briefly last year. Disease screening results for resistance to 10 pathogens were completed and are reported in the Pepper Pathology Section.

Table 2. Mean comparisons of field performance of Szechwan pureline selections, AVRDC, cool season, 1992-93

Pedigree	N[a]	SMFP		EM		SM FW		SM DW		TCN		T CW		HI	
			rank	(t/ha)	rank	(t/ha)	rank	(t/ha)	rank	(%)	rank	(%)	rank	(%)	rank
Szechwan 1-4-1-Bk	4	29.4	12	1.8	8	6.5	12	0.9	12	31.2	2	20.8	2	28.4	10
Szechwan 1-4-1-Bk3	4	37.8	5	1.9	7	7.7	6	1.1	7	25.2	7	17.9	4	31.9	4.5
Szechwan 1-10-Bk4	4	40.5	4	2.3	3	8.9	3	1.3	3	20.9	14.5	14.2	13	33.8	2
Szechwan 9-19-2-Bk4	4	41.4	3	1.9	6	7.5	7	1.2	4	23.1	9.5	14.4	12	31.9	4.5
Szechwan 10-9-5-Bk4	4	25.0	16	2.1	4	6.7	11	0.9	11	27.7	3	19.0	3	**25.3**	13
Szechwan 1-3-1-Bk4	4	24.9	17	0.8	18	5.1	19	**0.8**	16	25.7	5	17.8	5	**21.8**	18
Szechwan 1-10-3-Bk4	4	50.1	2	2.3	2	9.3	2	1.4	2	13.5	19	8.3	19	32.4	3
Szechwan 9-10-1-1-Bk4	4	25.1	15	0.8	19	5.3	17	0.8	18	21.1	13	12.3	15	17.6	19
Szechwan 9-10-1-2-Bk4	4	25.3	14	0.9	17	5.9	16	0.9	14	15.7	16	10.6	16	24.9	14
Szechwan 9-19-1-1-Bk4	4	29.9	10	1.8	9	6.0	14	0.9	13	23.1	9.5	14.9	8	28.9	9
Szechwan 9-19-1-1-Bk4	4	29.5	11	1.3	15	6.4	13	0.9	15	25.6	6	17.2	7	24.1	15
Szechwan 10-9-1-1-Bk4	4	24.5	18	1.3	14	5.3	18	0.8	19	23.7	8	14.8	9	22.6	16
Szechwan 10-9-5-2-Bk4	4	29.3	13	1.8	11	7.3	8	1.0	9	26.7	4	17.7	6	26.9	11
Szechwan 10-9-6-1-Bk4	4	35.0	6	2.0	5	7.2	9	1.0	8	23.0	11	14.6	10	30.0	7
Szechwan 10-9-6-2-Bk4	4	34.5	7	1.6	13	8.7	4	1.1	6	21.2	12	14.5	11	31.3	6
Szechwan VC	4	30.7	8.5	1.8	10	7.1	10	1.0	10	14.1	18	9.4	18	25.9	12
Szechwan 1 (ck)	4	30.7	8.5	1.7	12	8.4	5	1.2	5	20.9	14.5	13.6	14	29.4	8
Szechwan 10 (ck)	4	23.7	19	1.2	16	5.9	15	0.8	17	15.4	17	9.8	17	22.5	17
Hot Beauty (F_1)	4	55.2	1	2.4	1	9.6	1	1.6	1	36.8	1	31.5	1	43.1	1
Mean		32.8		1.7		7.1		1.0		22.9		15.4		28.2	
c.v. (%)		15.1		27.3		14.9		14.7		21.9		25.1		12.5	
Fisher's Protected LSD, $P \leq 0.05$, a = 0.05; N = 4		7.0		0.64		1.50		0.22		7.1		5.5		5.0	
Fisher's Protected LSD, $P \leq 0.05$, a = 0.05, N = 3 vs. N = 3								0.236						5.4	
Fisher's Protected LSD, $P \leq 0.05$, a=0.05, N=3 vs. N=4														5.7	

[a]No. of replications sampled, experimental design: RCB with 26 plants per experimental unit.

Note: data in bold indicates a missing replication; S = sum (all harvests); E = early ; M = marketable; FW = fresh weight; DW = dry weight; T = total (marketable + culls); FP = fruits per plant; t/ha = tonnes per hectare; CN = cull number; CW = cull weight; HI = harvest index

Table 2. continued.

Name or pedigree	N[a]	IMFW		FL		FWD		FLWR		WTH	
		(g)	rank	(cm)	rank	(cm)	rank		rank	(cm)	rank
Szechwan 1-4-1-Bk	4	7.5	8	12.4	11	1.2	12	10.1	10	0.22	2.5
Szechwan 1-4-1-Bk3	4	6.8	16	12.2	15.5	1.1	16	11	7	0.21	6.5
Szechwan 1-10-Bk4	4	7.4	9	12.9	4	1.3	7	10.4	9	0.21	6.5
Szechwan 9-19-2-Bk4	4	6.2	18	12.5	8.5	1.1	16	11.2	4.5	0.17	17
Szechwan 10-9-5-Bk4	4	9.1	2	11.9	18	1.5	1	8.1	19	0.2	11
Szechwan 1-3-1-Bk4	4	6.9	14	12.7	6	1	19.5	12.6	3	0.17	17
Szechwan 1-10-3-Bk4	4	6.3	17	12.4	11	1.1	16	11.1	6	0.21	6.5
Szechwan 9-10-1-1-Bk4	4	7.1	12	12.9	4	1	19.5	12.7	2	0.17	17
Szechwan 9-10-1-2-Bk4	4	7.8	7	12.2	15.5	1.3	7	10	11.5	0.2	11
Szechwan 9-19-1-1-Bk4	4	6.8	16	13.8	2	1.2	12	11.2	4.5	0.2	11
Szechwan 9-19-1-1-Bk4	4	7.3	10	15	1	1.2	12	12.9	1	0.18	15
Szechwan 10-9-1-1-Bk4	4	7.2	11	12.6	7	1.2	12	10.5	8	0.19	13.5
Szechwan 10-9-5-2-Bk4	4	8.5	5	12.2	15.5	1.4	3	8.9	18	0.21	6.5
Szechwan 10-9-6-1-Bk4	4	7	13	12.9	4	1.3	7	10	11.5	0.21	6.5
Szechwan 10-9-6-2-Bk4	4	8.6	3.5	12.5	8.5	1.3	7	9.7	13.5	0.22	2.5
Szechwan VC	4	8	6	12.4	11	1.4	3	9	17	0.19	13.5
Szechwan 1 (ck)	4	9.4	1	12.3	13	1.4	3	9.1	16	0.23	1
Szechwan 10 (ck)	4	8.6	3.5	12.2	15.5	1.3	7	9.2	15	0.21	6.5
Hot Beauty (F_1)	4	5.9	19	11.3	19	1.2	12	9.7	13.5	0.14	19
Mean			7.5		12.6		1.2		10.4		0.19
c.v. (%)			7.9		5.1		7.7		5.1		9.2
Fisher's Protected LSD, a = 0.05; N = 4	0.8		0.9		0.1		0.8		0.03		

[a]no. of replications sampled, experimental design: RCB with 26 plants per experimental unit.
IMFW = individual marketable fruit weight; FL = fruit length; FWD = fruit width; FLWR = fruit length:width ratio; WTH = fruit wall thickness (subsamples = 10)

Table 3. Quality trait comparisions for hot pepper Szechwan pureline selections, AVRDC, cool season 1992-93

Pedigree	N[a]	Dry matter (DM) (%)	Capsaicin (mg/g DM)	Sugars (%)	Lipid (%)	Color value (x100)	Vitamin C (fresh wt) (mg/100 g)
Szechwan 1-4-1-Bk	4	14.3	1.0	23.9	8.6	78.2	163.5
Szechwan 1-4-1-Bk3	(4)	14.5	1.2	23.8	8.6	75.1	**130.6**
Szechwan 1-10-Bk4	4	15.1	1.1	24.3	8.7	98.6	169.8
Szechwan 9-19-2-Bk4	4	16.4	2.9	19.9	10.0	79.6	94.2
Szechwan 10-9-5-Bk4	4	13.9	0.3	25.2	8.7	86.7	101.7
Szechwan 1-3-1-Bk4	**3**	**15.5**	**0.6**	**21.8**	**9.1**	**87.5**	**179.9**
Szechwan 1-10-3-Bk4	4	14.8	3.1	23.6	8.4	87.0	122.4
Szechwan 9-10-1-1-Bk4	4	15.2	3.8	23.9	8.5	82.5	93.9
Szechwan 9-10-1-2-Bk4	4	15.3	2.2	22.5	8.9	75.3	144.9
Szechwan 9-19-1-1-Bk4	4	15.2	0.4	22.7	9.2	80.1	170.5
Szechwan 9-19-1-1-Bk4	4	13.9	2.5	24.0	8.3	73.3	132.8
Szechwan 10-9-1-1-Bk4	4	14.8	0.6	23.6	8.8	93.1	91.8
Szechwan 10-9-5-2-Bk4	4	13.4	0.4	24.0	8.2	83.1	82.3
Szechwan 10-9-6-1-Bk4	4	14.4	1.3	23.8	9.0	86.2	87.5
Szechwan 10-9-6-2-Bk4	4	13.1	2.1	23.9	7.7	85.9	92.7
Szechwan VC	4	13.7	0.6	20.4	8.3	74.2	78.8
Szechwan 1 (ck)	4	14.6	0.7	22.8	8.9	84.2	135.2
Szechwan 10 (ck)	4	13.7	0.2	25.8	8.2	90.3	89.9
Hot Beauty (F_1)	4	16.9	0.9	21.0	10.0	77.6	121.3
Mean		14.7	1.37	23.2	8.7	83.0	119.2
c.v (%)		3.8	39.7	3.8	5.3	7.9	15.1
Fisher's Protected LSD, $P \leq 0.05$, a=0.05		0.78	0.77	1.26	0.66	9.33	25.41
Fisher's Protected LSD, $P \leq 0.05$ a = 0.05, N = 3 vs. N = 4		0.84	0.83	1.36	0.71	10.08	27.44

[a]No. of replications sampled, experimental design: RCB, 26 plants per experimental unit in bulk for quality analysis.

Note: all values based on dry weight except for vitamin C; data in bold indicates a missing replication.

Materials and Methods

1992 hot-rainy season. The experimental design was a randomized complete block with three replications and a factorial analysis of treatment 1 = 30 varieties and treatment 2 = two sowing dates confounded in two planting densities (1 May 1992 at 66,667 plants/ha and 16 June 1992 at 44,444 plants/ha). Replications were nested in sowing date for the analysis of variance. The May and June sowings were transplanted on 4 June 1992 and 21 July 1992, respectively, with each variety on a 2-row bed. Beds were 1.0 m apart. Plant spacing for the June and July transplants was 0.30 m (between rows) x 0.30 m (between plants), and 0.30 m (between rows) x 0.45 m (between plants), respectively. The experimental unit was 26 plants bordered by end-row pairs. Beds were mulched with rice straw. Fertilizer was applied by a basal incorporation of N-P_2O_5-K_2O at 60-120-120 kg/ha, 10 kg/ha Borax, and an organic fertilizer amendment of 1.3 t/ha. Side-dressing between plants was done four times with N-P_2O_5-K_2O at 40-10-20 kg/ha. Conditions were rainfed with supplemental furrow irrigation five and six times (including transplanting) for the May and June plantings, respectively. From the May sowing fruits were harvested 11 times beginning 29 July until 7 October 1992. Total crop duration posttransplanting was 125 days (4.1 mo). Mean temperatures (maximum and minimum) and humidity, and total precipitation were

31.3°C, 25.5°C, 88.1% and 1410.5 mm, respectively. From the June sowing fruits were harvested 12 times beginning 21 October 1992 until 6 January 1993. Total crop duration posttransplanting was 169 days (5.5 mo). Mean temperatures (maximum and minimum) and humidity, and total precipitation were 28.4°C, 21.4°C, 84.4% and 635 mm, respectively.

1992-93 cool-dry season. The experimental design was a randomized complete block with three replications and a factorial analysis of treatment 1 = 30 varieties and treatment 2 = silver plastic vs. straw mulch. Replications were nested within mulch treatments for the analysis of variance. Sowing and transplanting were done on 1 September and 6 October 1992, respectively. Plant population density was 29,630 plants/ha arranged with each variety on a two-row bed with 0.5 m between rows and 1.5 m between beds. Plant spacing within the row was 0.45 m. The experimental unit was 26 plants bordered by end-row pairs. Fertilizer management was the same as described elsewhere in this report for plastic vs. straw-mulched plots. Irrigation was by surface furrow. The plastic-mulched plots were harvested 13 times and the straw-mulched plots 16 times over a 15-wk period from 24 December 1992 until 9 April 1993. Total crop duration posttransplanting was 183-185 days (16 mo). Mean temperatures (maximum and minimum) and humidity, and total precipitation were 24.6°C, 16.8°C, 81.7% and 78.5 mm, respectively. Data were collected for quality traits, anthracnose incidence, yield components, harvest index and fruit dimensions.

Results and Discussion

1992 hot-rainy season. As briefly mentioned in last year's report, the production constraints during this season were mite and thrips injury, virus, bacterial spot, anthracnose incidence, and flooding. Combined yields for the two plantings averaged 35.5 total fruits per plant and 1.6 t/ha and 2.8 t/ha marketable and total weights, respectively. Although the effect of sowing date was confounded with plant density, the combination of earlier sowing with high plant density resulted in significantly lower yields than the later sowing with the lower plant density (table 4).

Table 4. Effect of sowing date/plant density on mean yield components of INTHOPE no. 3 entries, AVRDC, 1992

	Sowing date / plant density (/ha)	
Yield components	1 May / 66,667	16 June / 44,444
Total fruits per plant	25.5	45.6
Marketable t/ha[a]	0.8	2.4
Marketable t/ha[b]	0.4	0.8
Total t/ha[a]	2.5	3.2
Cull number (%)	75.1	37.2
Cull weight (%)[a]	69.8	28.2
Biological yield (t/ha)[b]	4.2	2.8
Harvest index (%)	20.1	35.3

[a]Fresh weight basis; [b]dry weight basis; (all differences significant at 5%).

Variety by sowing date interaction effects were significant for the variables days to flowering, total fresh weight yield (marketable + culls), dry weight yield, percent cull number, percent cull weight, harvest index, individual fruit weight, fruit length, and fruit width. Mean comparisons for quality traits from the June sowing are indicated in table 5. Lines with dry matter (DM) above 25% meet the standard criteria for dried spice production. Capsaicin content of most entries was moderate to mild. The most pungent entries in this evaluation were C 01664, Perennial HDV, and PBC 370. The mean response (based on dry weight) of all entries was 22.0% DM, 2.2 mg/g DM capsaicin, 12.8% sugars, 14.4 % lipid, color value 8981 and 189.4 mg/100 g (fresh weight) vitamin C.

1992-93 cool dry season. The most significant finding of the cool season INTHOPE no. 3 trial was that the silver plastic mulch treatment enhanced early yields, and the total marketable and biological yields were significantly higher from the rice-straw mulch treatment (table 6). This result can partly be explained by higher pest damage resulting from army worms, mites, and fruit worms on the plastic-mulched plots. Virus incidence and powdery mildew were other constraints to overall production.

Genotype by mulch treatment interactions were significant ($P \leq 0.05$) for days to flowering, early and sum marketable fruits per plant, early and sum total fruits per plant, sum marketable t/ha, early total t/ha, total % cull number, sum marketable and total fruit dry weight, harvest index, and individual marketable fruit weight. The significance of these interactions suggests that multilocational testing is needed to distinguish lines with wide vs. specific adaptability. Fruit shape dimensions were not significantly affected by genotype by mulch treatment interactions.

Combined over mulch treatments, there were also significant differences among entries (tables 7 and 8). The entries with the highest marketable fruit number were Perennial HDV, PBC 370, C 01664, Tiwari II, and Pant C-1. The entries with the highest marketable yields were Tiwari II, PBC 473, Pant C-1, PBC 371, Rotan, Chili Hybrid-1, Luang, Perennial HDV, and PBC 370. Compared to the summer season evaluation, mean performance of the cool season trial was approximately twofold for fruit number and fresh and dry weight yields. Quality traits were significantly ($P \leq 0.01$) influenced by mulch treatments for capsaicin content but not for other quality traits. Mean capsaicin content was higher for the straw mulch treatment (2.47 mg/g DM) compared to the plastic mulch treatment (1.58 mg/g DM); however, most of the INTHOPE no. 3 entries had moderate to low capsaicin levels in general. Quality performance did not vary considerably between the hot-humid and cooler-dry season experiments. Entries with dry matter above 25% were Perennial HDV, PBC 370, Tiwari II, Pant C-1, and G-3. All of these lines were from India except PBC 370 (Thailand). Entries with the highest sugar content (above 25%) were Ca 87067, Yuak, and PI 441561. Average sugar content was 15.3%. Entries with the highest lipid content (above 17%) were Perennial HDV and PBC 370. Average lipid content was 13.1%. Our readings on lipid content are indirect measures of potential oleoresin recovery. Color value averaged 8796. Detailed comparisons of INTHOPE no. 3 entries are available upon request and are being compiled in a small bulletin for distribution to all INTHOPE participants.

Table 5. INTHOPE no. 3 comparison of quality traits for 30 entries, AVRDC, hot-rainy season 1992

Name	Dry matter			Capsaicin			Sugars			Lipid			Color value			Vitamin C		
	(%)	N[a]	rank	(mg/g DM)	N	rank	(%)	N	rank	(%)	N	rank	(*100)	N	rank	(fresh wt) (mg/100 g)	N	rank
Perennial HDV	32.8	3	1	3.6	3	4	1.8	2	21	19.8	2	2	65.9	3	22	259.2	2	4
PSP-11	22.8	3	12	2.2	3	10	10.4	2	14	17.0	2	6	98.5	3	7	167.5	1	14
Cayenne Cajun 1	14.6	2	22	1.5	2	18	26.4	2	1	9.5	2	21	113.5	2	2	126.4	2	17
Cayenne Cajun 2	14.8	2	21	0.5	2	21	20.7	2	4	11.2	2	18	92.9	2	11	108.5	2	18
PBC 370	31.3	3	3	3.8	3	2	0.8	1	22	23.1	1	1	72.2	3	20	ne		ne
PBC 371	24.2	3	7	2.9	3	6	9.5	1	16	18.5	1	3	90.0	3	14	256.7	1	5
PBC 454	23.8	3	10	1.2	3	19	10.1	2	15	16.3	2	7	81.1	3	17	254.6	2	7
MI-1	23.6	3	11	2.6	3	8	10.9	3	12	14.5	3	12	77.5	3	19	224.7	3	8
Tiwari II	27.5	3	4	2.6	3	7	5.7	1	20	16.1	1	8	77.8	3	18	255.3	1	6
Pant C-1 (ck)	25.9	3	5	3.6	3	3	7.8	2	18	14.9	2	10	90.2	3	13	267.2	2	1
Ca 87067	15.4	1	20	0.3	1	23	22.6	1	3	11.6	1	16	126.1	1	1	149.9	1	16
IR	18.4	3	16	2.2	3	11	14.3	1	8	11.2	1	19	100.7	3	5	263.1	1	3
Szechwan 8 (ck)	16.9	3	18	1.7	3	17	19.6	3	5	9.7	3	20	110.0	3	3	169.4	3	13
Luang	17.5	3	17	1.9	3	12	12.6	3	9	17.0	3	5	37.1	3	23	95.4	2	19
Mun	20.0	3	15	1.7	3	15.5	14.9	3	7	12.1	3	15	95.3	3	9	197.1	3	10
Yuak	12.6	3	23	0.5	3	20	25.0	3	2	8.5	3	22	89.4	3	15	73.5	3	21
G-3	25.1	1	6	1.8	1	14	8.4	1	17	13.3	1	14	71.1	1	21	204.9	1	9
Nabeul II	16.2	1	19	0.4	1	22	18.5	1	6	11.4	1	17	96.9	1	8	191.1	1	12
Chili Hybrid-1	21.4	3	13	3.3	3	5	12.4	3	10	16.0	3	9	98.5	3	6	196.7	3	11
KA 6-5	23.9	3	9	1.8	3	10	7.0	2	19	14.6	2	11	88.0	3	16	87.3	2	20
PBC 473	20.3	3	14	2.2	3	9	11.7	2	11	13.5	2	13	93.2	3	10	163.3	2	15
Rotan	24.0	2	8	1.7	2	15.5	ne		ne	ne		ne	90.5	2	12	ne		ne
C 01664	32.1	2	2	5.6	2	1	10.5	2	13	18.3	2	4	109.2	2	4	266.0	2	2
Mean (all samples)	22.0			2.2			12.8			14.4			89.8			189.4		
Mean (N≥2)	22.5			2.4			13.8			14.0			87.6			177.0		
c.v. (%)	5.60			35.81			19.59			10.17			15.77			20.01		
Fisher's Protected LSD, a = 0.05; N = 3	2.10			1.42			4.64			2.43			23.04			61.01		
Fisher's Protected LSD, a = 0.05, N = 2 vs N = 3	2.35			1.58			5.18			2.72			25.76			68.21		
Fisher's Protected LSD, a = 0.05, N = 2	2.57			1.73			5.68			2.98			28.22			74.72		

[a]No. of replications sampled, experimental design: RCB with 26 plants per experimental unit in bulk for chemical analyses.
Note: statistical analyses conducted only on entries for N≥2; ne = not evaluated.

Table 6. Mulch treatment comparisons on the mean performance of 30 INTHOPE no. 3 entries, AVRDC, 1992-93 cool-dry season

Mulch	Fruit per plant		Fresh weight		Dry weight	
	EM	SM	EM	SM	SM	BY
			(t/ha)			
Silver plastic	4.3	29.8	0.8	2.8	0.8	1.6
Rice straw	2.6	68.9	0.4	4.0	1.3	2.3
Fisher's Protected LSD (P = 0.05; a = 0.05)	0.4	6.2	0.1	0.3	0.1	0.2

Note: E = early (harvest interval 1-4); S = sum (all harvests); M = marketable ; BY = biological yield.

Hybridization and Selection of New Genotypes with Combined Disease Resistance, Quality, and Regional Adaptation

Seven activities were conducted for germplasm enhancement of pepper genotypes during the 1992-93 growing seasons:

(1) Sweet and hot pepper crossing blocks to improve CVMV-resistant/CMV-tolerant F_3 selections for horticultural type,
(2) Screening and generation advance (F_3:F_4) of sweet peppers carrying *Bs2* or *Bs3* genes for resistance to bacterial spot,
(3) Screening and generation advance (F_3:F_4) of sweet and hot peppers for resistance to *Phytophthora capsici*,
(4) Generation advance and establishment of four cycle-zero populations for mass selection improvement for heat tolerance and disease resistance,
(5) Early generation testing for heat tolerance of F_2 pedigree-derived F_3 lines carrying tolerance to local virus strains, anthracnose, and powdery mildew,
(6) First generation backcross of CVMV-resistant F_2 selections to 22 recurrent parents, and
(7) New crosses for hot and sweet pepper improvement.

Seed Distribution

In 1993, the pepper breeding unit distributed 34 seed shipments for INTHOPE no. 3 representing 64 test sites among 23 countries. Five and six additional sets of INTHOPE no. 1 and no. 2, respectively were distributed. Other seed shipments of various breeding lines and populations totaled to 57 shipments among 32 countries.

Table 7. INTHOPE no. 3 mean comparisons for field performance of 30 entries, AVRDC, cool season 1992-93

Name	Origin/Donor	N[a]	SMFP	rank	EM (t/ha)	rank	SM FW (t/ha)	rank	SM DW (t/ha)	rank	T CN (%)	rank	HI (%)	rank
Perennial HDV	France/INRA	6	192.1	1	0.2	23	5.1	8	1.6	4	5.4	30	61.8	11
PSP-11	India	6	89.2	8	0.2	20	3.4	17	0.8	13	20.0	25	55.8	15
Cayenne Cajun 1	USA/LSU	5	0.9	29.5	0.0	29	0.4	29	ne		48.3	6	ne	
Cayenne Cajun 2	USA/LSU	4	4.8	26	0 5	11	1.6	23	0.1	24	45.8	8	24.7	25
CNPH 703	India/Brazil-CNPH	6	8.0	22	0.3	18	0.4	28	ne		60.7	3	ne	
PBC 365	Italy/mfm	6	44.1	12	0.6	9	1.8	22	0.3	21.5	31.8	16	33.7	24
PBC 370	Thailand/AVRDC	6	191.4	2	0.1	27	5.0	9	2.2	1	7.3	29	71.3	3
PBC 371	Thailand/AVRDC	6	92.3	6	0.5	12	5.5	4	1.3	5	12.3	26	68.9	6
PBC 454	India/AVRDC	6	36.5	15	1.4	5	3.2	18	0.9	12	32.1	15	67.0	8
MI-1	Sri Lanka/RARC-MI	6	61.5	10	0.2	24	4.0	14	0.9	11	38.9	9	66.5	9
Tiwari II	India/Malaysia	6	116.4	4	0.9	6	7.1	1	1.9	2	8.1	28	76.6	1
Mexico	Mexico/Malaysia	6	0.9	29.5	0.1	30	0.1	30	ne		64.3	2	ne	
Serrano Tampiqueno	Mexico/Malaysia	6	3.5	27	0.3	14.5	0.5	26	0.1	26	46.7	7	17.9	26
Serrano Huasteco	Mexico/Malaysia	6	5.6	24	0.2	21	0.5	27	ne		38.7	11	ne	
Pant C-1 (ck)	India/IARI	6	107.6	5	0.4	13	6.0	3	1.6	3	23.1	23	74.5	2
Ca 87067	USA/TAES	6	9.5	20	2.3	1	4.6	11	0.6	17	29.9	19	55.4	16
I R	Indonesia/LEHRI	6	14.7	18	1.7	3	4.3	12	0.7	16	54.9	5	61.3	12
Szechwan 8 (ck)	Taiwan/AVRDC	6	16.5	17	0.9	8	3.9	15	0.6	18	31.5	17	49.3	19
Luang	Thailand/Kasetsart	6	41.6	14	0.1	26	5.2	7	0.7	15	21.0	24	53.8	17
Mun	Thailand/Kasetsart	6	23.2	16	0.3	16	3.8	16	0.8	14	35.2	12	58.3	13
Yuak	Thailand/Kasetsart	6	5.9	23	0.2	22	2.3	21	0.3	23	58.0	4	42.9	22
PI 441561	Brazil/AVRDC	6	5.4	25	0.9	7	3.1	19	0.5	20	28.8	20	48.4	20
G-3	India/NBPGR	6	12.3	19	0.3	19	1.0	24	0.4	21.5	38.8	10	45.4	21
Bako Local	Ethiopia/Sri Lanka	6	1.9	28	0.3	17	0.6	25	0.1	25	79.1	1	38.2	23
Nabeul II	Tunisia/MES	6	9.2	21	2.3	2	4.0	13	0.6	19	33.0	13	51.4	18
Chili Hybrid-1	India/PAU	6	42.2	13	1.6	4	5.2	6	1.0	10	25.2	22	62.5	10
KA 6-5	Sri Lanka/RARC-KA	6	64.6	9	0.6	10	4.7	10	1.1	8	30.2	18	69.7	5
PBC 473	Indonesia/AVRDC	6	58.1	11	0.3	14.5	7.0	2	1.1	7	32.9	14	68.1	7
Rotan	Indonesia/AVRDC	6	91.9	7	0.1	25	5.4	5	1.2	6	27.7	21	70.5	4
C 01664	Denmark/AVRDC	6	129.8	3	0.0	28	2.5	20	1.0	9	12.2	27	57.6	14
Mean			49.4		0.6		3.4		1.0		34.1		61.8	
c.v. (%)			42.7		59.2		28.5		22.2		28.3		11.6	
Fisher's Protected LSD, $P \leq 0.05$; a=0.05; N=6		24.1		0.40		1.11		0.26		11.0		8.3		
Fisher's Protected LSD, $P \leq 0.05$; a = 0.05; N = 6 vs. 5								0.27				8.7		

[a]No. of replications sampled, experimental design: RCB-factorial, 26 plants per experiment unit; three replications nested in two mulch treatments.
If $N \leq 4$ then entry (both treatments) was excluded from ANOVA and mean comparisons.
Ne: not evaluated; na: not analyzed, normal distribution rejected; S = sum of all harvests; FP = fruits per plant; E = early; M = marketable; FW = fresh weight; DW = dry weight; T = total; CN = cull number; CW = cull weight; H I = harvest index.

Table 8. INTHOPE no. 3 mean comparisons for fruit characteristics of 30 entries, AVRDC, cool season 1992-93

Name	N[a]	IMFW	rank	N	FL	rank	FWD	rank	FLWR	rank	WTH	rank
Perennial HDV	6	0.9	29	6	3.5	29	0.8	28.5	4.2	25	0.3	29.5
PSP-11	6	1.4	26.5	6	6.3	21	1.0	23.5	6.3	17	0.7	20.5
Cayenne Cajun 1	5	15.5	4	5	11.7	6	1.8	6	6.4	15.5	2.1	1
Cayenne Cajun 2	4	14.1	6	6	12.7	4	2.0	4.5	6.6	12.5	1.2	7.5
CNPH 703	6	1.8	25	6	7.0	17.5	0.8	28.5	8.5	7	0.5	26.5
PBC 365	6	1.4	26.5	6	3.5	29	1.1	21	3.1	29	0.8	16.5
PBC 370	6	0.9	29	6	3.5	29	0.8	28.5	4.7	23	0.3	29.5
PBC 371	6	2.1	22.5	6	5.9	23	1.2	18.5	4.9	21	0.7	20.5
PBC 454	6	3.2	16	6	8.4	14	1.4	13.5	6.4	15.5	0.7	20.5
MI-1	6	2.5	20	6	10.3	11	1.2	18.5	10.0	2	0.7	20.5
Tiwari II	6	2.1	22.5	6	7.0	17.5	1.0	23.5	7.2	9.5	0.6	24
Mexico	6	5.7	11	6	5.2	25	1.6	8	3.4	28	1.2	7.5
Serrano Tampiqueno	6	4.8	13	6	5.8	24	1.4	13.5	4.2	24	1.4	3
Serrano Huasteco	6	2.9	17	6	5.0	26	1.3	15.5	4.0	26	1.2	7.5
Pant C-1 (ck)	6	1.9	24	6	6.7	20	1.0	23.5	7.2	9.5	0.6	24
Ca 87067	6	16.4	3	6	18.0	1	2.0	4.5	9.2	6	1.2	7.5
I R	6	9.6	8	6	14.4	2	1.5	11.5	9.4	4.5	1.1	11.5
Szechwan 8 (ck)	6	7.8	9	6	11.7	6	1.3	15.5	9.5	3	1.2	7.5
Luang	6	5.0	12	6	6.7	19	1.6	8	4.8	22	0.9	13.5
Mun	6	5.8	10	6	9.4	12	1.5	11.5	6.5	14	0.8	16.5
Yuak	6	14.5	5	6	6.2	22	3.0	1.5	2.1	30	1.2	7.5
PI 441561	6	18.7	1	6	13.2	3	2.3	3	6.0	18	1.4	3
G-3	6	2.6	19	6	7.7	15	1.0	23.5	8.1	8	0.6	24
Bako Local	6	10.7	7	6	11.0	9	1.6	8	6.8	11	1.1	11.5
Nabeul II	6	17.5	2	6	11.7	6	3.0	1.5	3.9	27	1.4	3
Chili Hybrid-1	6	4.2	15	6	8.8	13	1.6	10	5.8	19	0.9	13.5
KA 6-5	6	2.7	18	6	7.6	16	1.2	18.5	6.6	12.6	0.8	16.5
PBC473	6	4.4	14	6	10.9	10	1.2	18.5	9.4	4.5	0.8	16.5
Rotan	6	2.2	21	6	11.6	8	0.9	26	16.4	1	0.5	26.5
C 01664	6	0.9	29	6	4.0	27	0.8	28.5	5.2	20	0.4	28
Mean		6.1			8.5		1.4		6.6		0.9	
c.v. (%)		23.3			13.1		14.3		22.6		44.4	
Fisher's Protected LSD, $P \leq 0.05$; $a = 0.05$; $N = 6$		1.6			1.3	0.2		1.7		na		
Fisher's Protected LSD, $P \leq 0.05$; $a = 0.05$; $N = 6$ vs. $N = 5$			1.3		0.2		1.7		na			

[a]No. of replications sampled, experimental design: RCB-factorial, 26 plants per experimental unit; three replications nested in two mulch treatments; If $N \leq 4$ then entry (both treatments) was excluded from ANOVA and mean comparisons; ne: not evaluated; na: not analyzed (normal distribution rejected); IMFW = individual marketable fruit weight; FL = fruit length; FWD = fruit width; FLWR = fruit length: width ratio, WTH = fruit wall thickness.

Pepper Pathology

Evaluation of Resistance of Pepper to *Pseudomonas solanacearum*

Summary

A total of 108 accessions of pepper have been screened for resistance to bacterial wilt. Forty-two accessions which had shown 80-100% plant survival in previous tests were regrown to verify the resistance using a soil drenching with root-severing method, wilting, vascular discoloration, ELISA, and selective medium. From five batches of screening 50% of the accessions gave similar results, whereas, the other 50% were inconsistent. In addition to whole plant wilting, disease symptoms such as stem lesions, wilting of lower leaves, and vascular discoloration were observed. Based on these symptoms, a possible disease rating system for screening of bacterial wilt in pepper was explored. The number of plants which scored positive in vascular discoloration and ELISA tests were highly correlated. Among the 108 accessions tested, MC 4, Cili Langkap, and PI.-38475 appear to have a high level of tolerance to infection by *Pseudomonas solanacearum*.

Introduction

Bacterial wilt, caused by *Pseudomonas solanacearum*, is an important disease of pepper under certain tropical conditions. Yield loss up to 100% have been reported in certain areas of India. The development of resistant varieties thus offers an effective means to control this disease. AVRDC has conducted an intensive resistance screening program. A total of 108 accessions of pepper have been screened. Of this, 26 have been retested. Inconsistent results in the resistance screening of some of the accessions led to another retest. Forty-two accessions which had shown 80-100% plant survival in previous tests were grown to verify the resistance using a soil drenching with root-severing method. Wilting, vascular discoloration, ELISA and a selective medium were used to characterize resistance.

Materials and Methods

Inoculation

Seeds of 42 accessions were sown in flats with susceptible and resistant checks. Seedlings were inoculated with bacterial strain PSS71 at 28 days after emergence (DAE) using soil drenching with the root-severing method. Roots were injured with a knife by cutting the soil 1.5 cm away from the stem and a 1200-ml bacterial suspension (10^8 cfu/ml) poured into each flat. After inoculation, plants were kept in a heated glasshouse, the temperature of which was maintained around 28°C. The experiment followed the randomized complete block design with three replications. Each accession had five plants per replication. Plants with all the leaves wilted were considered wilted; disease scoring was done up to 28 days after inoculation (DAI).

Enzyme-linked immunosorbent assay (ELISA)

At the end of 28 DAI, accessions with 93-100% plant survival was subjected to an indirect ELISA test. All plants in these accessions were cut at the base of the stem and any discoloration of the vascular tissues was noted. Plants that were discolored were scored as positive. Then, 3-cm cuttings were taken from the base of each of the plant, weighed, and macerated separately with extraction buffer pH9.6. For each 1 g of tissue, 1 ml of buffer was added. A volume of 100 µl of each extract was added to each well and incubated at 37°C for 1 h. The sap was flicked out from the plate and wells were washed three times with PBS-T for at least 5 min. Then, 200 µl blocking buffer was added to each well and incubated at 37°C for another hour. Washing was done following the procedure explained earlier. Subsequently, 100 µl of specific antibody (IgGR303) diluted 1:2000 in blocking buffer was added to each well and incubated for 1 h at 37°C. Washing using PBS-T was repeated and 100 µl of the second goat anti-rabbit, antibody-alkaline phosphatase (GAR-AP) conjugate diluted 1:3000 in blocking buffer was added to each well. These were then incubated for 1 h at 37°C and washed with PBS-T again. A volume of 100 µl of peroxidase substrate solution was added to each well and left for 5-20 min until reaction was completed. Change in color was observed and the samples were scored as positive and negative. IgGR303 antibody was kindly supplied by Dr. John Elphinstone of the Natural Resources Institute, U.K.

Selective media

The remaining plant stems from the above tests were used. A stem piece weighing about 1 g was cut from the base of each remaining stem, washed with tap water, and dried. Each piece was then surface sterilized with 70% alcohol and put separately into glass tubes containing 5 ml sterile water. Samples were incubated at 18°C for 16 h and the suspensions were streaked out on triphenyl tetrazolium chloride (TTC) medium plates. After incubating at 30°C for 2 days, samples with plates showing typical *P. solanacearum* colonies were scored as positive.

Results and Discussion

Percentage of wilt for each accession is presented in comparison with the results of previous screening tests in table 1. In five batches of screening, 50% of the accessions gave similar results; the other 50% were inconsistent. Some of the accessions which gave 0-20% wilt in previous screening tests showed a high level of susceptibility (80-100%). Inconsistent results for some of the accessions may be attributed to factors such as environmental changes in the glasshouse, growth differences of the plants, failure to diagnose the symptoms other than the whole plant wilting, and genotypic differences within the accession. Although the plants were kept in a heated glasshouse, fluctuating day and night temperatures and relative humidities were observed. These differences may have influenced the degree of susceptibility of the accessions.

The infection rate, calculated using area under the disease progress curve (AUDPC) and the logit transformation for each of the accession, is given in table 2. The high AUDPC and slope values were related to the highly susceptible accessions as determined by final percentage of wilt. A total of 14 accessions showed 93-100% plant survival in this screening. Aside from whole plant wilting in these accessions, disease symptoms such as lesion development along the stem, and wilting of one or two leaves at the lower nodes were observed. Size of the lesions varied between 1-12 cm and in some cases plants broke at the place where the lesions developed. Most of the unwilted plants showed vascular discoloration at the stem base and were positive to ELISA test. The number of plants scored positive for vascular discoloration, and those positive for ELISA test were highly correlated ($r = 0.86$, $P = 0.0001$), whereas, plants scored positive using the selective medium were not correlated with the positive scores of vascular discoloration or ELISA. One

Table 1. Bacterial wilt evaluation for 45 accessions of peppers inoculated[a] in five screening tests

Name or Pedigree	Origin	Date of inoculation (D-M-Y)				
		11-2-93	27-10-92	13-7-92	7-7-92	31-12-91
		----------Wilt (%)----------				
Orias Kossarvu	Hungary	100	-	0	-	-
Kun Ja	Korea	93	-	0	-	-
Tiwari II	India	80	20	-	-	-
California Wonder (S ck)	USA	80	68	87	9	80
KA-2	Sri Lanka	80	-	7	-	-
Huay Sithon	Thailand/KKU	67	-	-	27	20
Cheong Yang	Korea	60	-	0	-	-
UL-2190	Nigeria/IAR	53	-	0	-	-
CO1621	Hungary	53	-	13	-	-
Num	Thailand/Kasetsart	53	-	20	-	-
KKU Cluster	Thailand/KKU	53	-	-	0	33
Unknown 41	Thailand	40	-	13	-	-
Huaruar	Thailand/KKU	40	-	-	7	47
Var. U-Kimba	Nigeria/IAR	33	-	20	-	-
Jawahar 218	India/PAU	33	-	-	7	27
Lv. 1092	Indonesia/LEHRI	33	-	-	0	60
G-3	India	27	7	-	-	-
PBC199	Thailand	27	-	0	-	-
U-Kashinburgu	Nigeria/IAR	27	-	0	-	-
Keriting	Indonesia/LEHRI	27	-	-	7	13
Lv. 2323	Indonesia/LEHRI	27	-	-	0	7
Perennial HDV	France/INRA	20	0	-	-	-
PBC370	Thailand	20	20	-	-	-
PL-2289	Nigeria/IAR	20	-	0	-	-
Szechwan 8**	Taiwan/AVRDC	20	-	15	-	-
Lv. 2319	Indonesia/LEHRI	20	-	-	0	27
P. Sakaraho*	Nigeria/IAR	20	-	-	0	33
PL-2289	Nigeria/IAR	20	-	-	0	40
Szechwan 8**	Taiwan/AVRDC	13	20	-	-	-
Var. P. Sakaraho*	Nigeria/IAR	13	-	0	-	-
MI-2	Sri Lanka/RARC MI	13	-	0	-	27
Cipanas	Indonesia/LEHRI	13	-	-	0.	7
R1-26(17)	Malaysia/MARDI	7	-	0	-	-
King Gum Go Chu	Korea	7	-	0	-	-
PBC385	Malaysia	7	-	13	-	-
MC 5	Malaysia/MARDI	7	-	-	13	24
Szechwan 10	Taiwan/AVRDC	7	-	-	0.0	33
MC 4 (R ck)	Malaysia/MARDI	0	0	0	0	0
IR	Indonesia/LEHRI	0	0	-	-	-
PSP-11	India	0	7	-	-	-
PBC473	Indonesia	0	7	-	-	-
Lv. 1583	Indonesia/LEHRI	0	-	0	-	-
PBC384	Malaysia	0	-	0	-	-
Cili Langkap	Malaysia/MARDI	0	-	7	-	-
PL-38475	Nigeria/IAR	0	-	7	-	-
Lv. 1583	Indonesia/LEHRI	0	-	-	0	27

[a]Soil drenching with root-severing method.
- Not evaluated.
*&** same accessions with different seed lots.

Table 2. Percentage of wilt and the rate of infection estimated from the regression of the logit transformation of AUDPC on 25 days after inoculation for 45 accessions of pepper

Name	Origin/Donor	% Wilt[b]	AUDPC[c]	Regression coefficient[d]
Orias Kossarvu	Hungary	100	86.8	0.160
Kun Ja	Korea	93	74.8	0.148
Tiwari II	India	80	66.3	0.103
California Wonder (S ck)	USA	80	60.0	0.119
KA-2	Sri Lanka	80	57.0	0.092
Huay Sithon	Thailand/KKU	67	57.7	0.041
Cheong Yang	Korea	60	45.5	0.100
UL-2190	Nigeria/IAR	53	48.8	0.010
CO1621	Hungary	53	41.3	0.047
Num	Thailand/Kasetsart	53	38.8	0.071
KKU Cluster	Thailand/KKU	53	35.2	0.018
Unknown 41	Thailand	40	33.5	0.026
Huaruar	Thailand/KKU	40	39.2	0.024
Var. U-Kimba	Nigeria/IAR	33	29.2	0.017
Jawahar 218	India/PAU	33	25.0	0.024
Lv. 1092	Indonesia/LEHRI	33	23.5	0.020
G-3	India	27	23.2	0.013
PBC199	Thailand	27	21.5	0.016
U-Kashinburgu	Nigeria/IAR	27	20.7	0.018
Kenting	Indonesia/LEHRI	27	20.2	0.015
Lv. 2323	Indonesia/LEHRI	27	18.7	0.014
Perennial HDV	France/INRA	20	24.7	0.005
PBC370	Thailand	20	17.2	0.013
PL-2289	Nigeria/IAR	20	15.5	0.013
Szechwan 8	Taiwan/AVRDC	20	13.8	0.013
Lv. 2319	Indonesia/LEHRI	20	13.2	0.009
P. Sakaraho	Nigeria/IAR	20	10.5	0.016
PL-2289	Nigeria/IAR	20	8.3	0.010
Szechwan 8	Taiwan/AVRDC	13	11.5	0.004
Var. P. Sakaraho	Nigeria/IAR	13	11.2	0.006
MI-2	Sri Lanka/RARC MI	13	9.5	0.009
Cipanas	Indonesia/LEHRI	13	9.5	0.007
R1-26(17)	Malaysia/MARDI	7	6.0	0.002
King Gum Go Chu	Korea	7	6.0	0.002
PBC385	Malaysia	7	6.0	0.002
MC 5	Malaysia/MARDI	7	5.2	0.004
Szechwan 10	Taiwan/AVRDC	7	1.2	0.003
MC 4 (R ck)	Malaysia/MARDI	0	0.0	0.000
IR	Indonesia/LEHRI	0	0.0	0.000
PSP-11	India	0	0.0	0.000
PBC473	Indonesia	0	0.0	0.000
Lv. 1583	Indonesia/LEHRI	0	0.0	0.000
PBC384	Malaysia	0	0.0	0.000
Cili Langkap	Malaysia/MARDI	0	0.0	0.000
PL-38475	Nigeria/IAR	0	0.0	0.000
Lv. 1583	Indonesia/LEHRI	0	0.0	0.000
HSD[a]				0.127

[a]Tukey Kramer HSD (a = 0.05).
[b]Soil drenching with root-severing method.
[c]Area under disease progress curve.
[d]Regression coefficient ln(1/1-x) on days after inoculation.

reason for this poor correlation may have been that the same stem section was not used for both ELISA and the selective-medium assays. Bacterial population may not be the same below and above 3 cm from the base of the stem.

The accessions MC 4, Cili Langkap, and PL-38475 showed 0% wilt. In these accessions, 33% of the plants were positive to the ELISA test and for vascular discoloration (table 3). The accession PSP-11 was immune to the disease in this testing. None of the plants in this accession wilted or contained bacteria inside the plants. Due to the slow germination rate, the seedlings of this accession were very small and had two expanded true leaves at the time of inoculation, whereas, the other accessions had 6-11 leaves. In pepper, it appears that wounding either roots or stem is necessary to differentiate levels of resistance to bacterial wilt (see AVRDC 1991 Progress Report). These small seedlings may not have had a sufficiently grown root system at the time of inoculation for which the roots could be wounded by cutting the soil surface in between two rows of plants. Therefore, in screening a large number of accessions, it is important to have uniform germination to minimize physiological growth differences within and among accessions. Prior knowledge about the growth rate of different accessions could also help improve screening efficiency. Accessions with similar growth rates could be sown in the same flats and inoculated at the proper growth stage rather than at a specific day after sowing. For routine screening of resistance to bacterial wilt in pepper, susceptibility is mainly based on whole plant wilting. In some accessions, other symptoms, e.g., stem lesions, wilting of lower leaves, and vascular discoloration were observed. Ignoring such symptoms in disease scoring may overlook some mechanisms of tolerance or otherwise misclassify susceptible plants.

In this screening, six accessions were free from wilt symptoms, but most of the plants of these accessions gave a positive reaction to the ELISA test and showed vascular discoloration at the stem base. The incorporation of a bacteria detection method by ELISA may increase the efficiency of selection of resistant genotypes. However, the high correlation shown between the percent infected plants diagnosed by ELISA and vascular discoloration shows that the latter can be equally effective in detecting bacterial wilt resistance in pepper plants.

Table 3. Percentage of disease incidence obtained using five methods of evaluation for resistance to *Pseudomonas solanacearum* in 14 accessions of pepper[a]

Name or pedigree	Origin	Wilt	VDSB	ELISA	SIM	Stem lesion
IR	Indonesia/LEHRI	0	80	87	47	20
PSP-11	India	0	0	0	0	0
PBC473	Indonesia	0	27	60	33	7
Cili Langkap	Malaysia/MARDI	0	33	33	33	7
Lv. 1583	Indonesia/LEHRI	0	73	73	67	7
PBC384	Malaysia	0	67	80	20	0
PL-38475	Nigeria/IAR	0	33	33	57	0
Lv. 1583	Indonesia/LEHRI	0	60	60	47	7
MC 4	Malaysia/MARDI	0	33	33	50	13
R1-26(17)	Malaysia/MARDI	7	87	73	40	0
King Gum Go Chu	Korea	7	60	53	33	7
PBC385	Malaysia	7	60.	60	40	0
MC 5	Malaysia/MARDI	7	67	53	40	7
Szechwan 10	Taiwan/AVRDC	7	93	93	13	33

[a]Evaluation based on the means of three replications and five plants per replication after inoculation by soil drenching with root wounding.
VDSB- vascular discoloration at stem base.
ELISA- enzyme-linked immunosorbent assay, positive reaction.
SIM- selective medium, positive reaction.

The results obtained upon screening of the different accessions up to 28 DAI indicated that there were four possible types of response in pepper to *P. solanacearum*: (1) whole plant wilting; (2) lesions on the stem with or without few wilted leaves at the lower nodes and vascular discoloration at stem; (3) neither wilting nor stem lesion but vascular discoloration at stem base; (4) no wilting, no vascular discoloration and no detectable amount of bacteria by ELISA test. Among the 108 accessions tested, MC 4, Cili Langkap, and PI-38475 had the highest level of resistance to bacterial wilt based on the four methods of evaluation used. Further studies are needed to determine if a more detailed disease rating would adequately characterize resistance and whether symptoms other than wilting are associated with disease incidence or plant survival under field conditions.

Screening for Virus Resistance in Peppers

Summary

Viruses, particularly those transmitted by aphids, are the major constraint to successful production of peppers in tropical Asia. Weekly or more frequent preventive insecticide sprays are common. AVRDC, with its goal of sustainable agricultural production, has made it a priority to develop virus-resistant lines/populations. Many sources of resistance to potato virus Y (PVY) and the tobamoviruses tobacco mosaic virus (TMV) and tomato mosaic virus (ToMV) have been identified in previous years. Similarly, a few lines with chili veinal mottle virus (CVMV) resistance have also been found. This year's focus was on cucumber mosaic virus (CMV), pepper mild mottle virus (PMMV), and peanut bud necrosis virus (PBNV), a tospovirus similar to tomato spotted wilt virus (TSWV). Resistance to CMV has not been found so far. A different screening method was, therefore, used this year that would enable us to detect tolerant lines. Several lines with tolerance to CMV were identified with this method. Seed of tolerant lines have been collected and will undergo more thorough screening.

Additional sources of resistance to CVMV and PVY were found in PBC and VC lines and GRSU accessions. Two lines were identified with PMMV resistance. We also found that lines which are resistant to the tomato spotted wilt type strain are not necessarily resistant to peanut bud necrosis virus, a related but distinct tospovirus which infects pepper and tomato in Asia.

Introduction

One hundred percent virus infection in farmers' pepper fields is not uncommon in tropical Asia. Knowing that most viruses are transmitted by insects, farmers routinely apply insecticides weekly or more frequently. This practice is not only costly but also harmful to the farmer and the consumer. AVRDC has, therefore, made it one of its priorities to develop lines or populations with resistance to the most important viruses (CMV, CVMV, PVY, TMV/ToMV, and PMMV; in order of importance). Intensive screening of the germplasm collection for virus resistance had been initiated several years ago. Many sources of resistance to PVY, ToMV, and TMV and a few sources of resistance to CVMV have been identified in the past and are already being used by AVRDC breeders. However, no stable resistance against CMV, one of the most damaging viruses of peppers, has been identified. Similarly, only two sources of resistance to PMMV have been found in wild species. The search for tolerance/resistance to CMV and resistance to PMMV has been given priority in 1993. Some attention has also been given to tospovirus resistance, since this virus is considered potentially dangerous in pepper plantings.

Materials and Methods

Comparison of two inoculation methods for CMV

Two inoculation methods were tested: inoculation at the cotyledon stage, and inoculation of the third leaf of plants decapitated just below the fifth fully developed leaf. Inoculations were done first with Peet's strain and 2 days thereafter with strain NT9 at 1:10 in 0.01 M PO_4 buffer pH7.2. At 2 and 5 wk after inoculation, the uninoculated leaves were tested by DAS ELISA as follows: cotyledon inoculation — the third and sixth leaf tested; third leaf inoculation — the two new shoots were tested by ELISA. The following lines were tested: 97 PBC lines (067, 074, 075, 081, 092, 097, 105, 110, 136, 137, 140, 142A, 146, 148, 151, 155, 157, 158, 158-5, 172, 174, 178, 180, 185, 186, 193, 199, 204, 206, 207, 209, 241, 272, 289, 310A, 323A, 329, 362, 365, 370, 371, 373, 376, 377, 380, 381, 384, 385, 389, 398, 401, 403, 404, 405, 407, 408, 409, 411, 412, 413, 415, 416-2, 417, 426, 427, 450, 452, 454, 457A, 461, 462, 462A, 463, 469, 470, 471, 485, 518, 535, 537, 546, 548, 549, 552, 595, 596, 597, 598, 687, 688, 690, 691, 692, 693, 694, 695, 711), 2 GRSU accessions (C00605 and C01777); 5 Thai local varieties (Bangchang, Pichit 08, Pichit 014, Khenoo Ubon, and Chau Makau); and 10 VC lines (16a, 33a, 40a, 41a, 38a, 39a, 215, 218, 221, and 195).

Screening for TSWV resistance

One *Capsicum chinense* line, PI 159236, which has been reported resistant to isolates from the USA and to certain isolates from Brazil was tested. *C. annuum* (Yolo Wonder) served as the susceptible check. Twenty plants were mechanically inoculated at the second-leaf stage with peanut bud necrosis virus (formerly called watermelon or tomato strain of TSWV). The virus was propagated in *N. benthamiana*. A homogenate of 1:10 in phosphate buffer containing 0.01 M Na_2SO_3 (pH7.0) served as the inoculum. Symptoms were recorded at 20-30 DAI. At the same time, an indirect dot ELISA on NC membranes of the uninoculated leaves was conducted.

Routine resistance screening

The following PBC lines were screened for resistance to CMV, PVY, CVMV, and PMMV: PBC 92, 97, 110, 140, 142A, 172, 178, 180, 186, 193, 206, 272, 310, 323, 323A, 349, 370, 427, 457, 470, 471, 545, 549, 569, 690, 691, 692, 693, 694, 695, 710, 711, 787, and LV 2411. In addition, the following VC lines: VC 38a, 39a, 195, 196, 197, 198, 199, 200 and GRSU accessions C0474, 1175, 1315, 162-1, 1622, 1694, 1862A, 2741B, 3289A, 3763, 3764, 3765, 3773, 4070, 4071, 4072, 4073, 4150, 4198, 4356, 4712, 5045, and 5472 were screened. The following INTHOPE no. 3 entries were screened for resistance to PMMV, PVY, CVMV, CMV, ToMV, and TMV: PBC 07 ', 137, 142A, 365, 370, 371, 417, 450, 452, 454, 461, 463, 473, 474, 485, 495, 518, 519, 521, 523, 524, 535, 548, 552, 595, 596, 597, 651, C01664, and C04352.

The following INTHOPE no. 4 lines were screened for resistance to CMV, CVMV, PVY, TMV, ToMV, and PMMV: PBC 074, 142A, 455, 456, 464, 483, 522, 534, 539, 558, 580, 581, 582, 592, 600, 612, 613, 615, 621, 622, 632, 643, 729, 730, 731, and 830.

Results and Discussion

Comparison of two inoculation methods for CMV

Most PBC lines reacted similarly in both inoculation methods, namely, 100% infection with strong mosaic. However, six lines (PBC 136, 186, 310A, 546, 549, and 688) showed considerably

less infection when inoculated at the third-leaf stage. Some lines (PBC 075, 370, 371, 463, 518, 537, and 548) also produced fewer infected plants when inoculated at the cotyledon-leaf stage. One of the VC lines (VC 16a) was identified with 0% infection when inoculated at the third-leaf stage, compared with 17% infection at the cotyledon stage. Similarly, 2% of plants of line VC 41a became infected at the third-leaf stage, compared to 23% at the cotyledon stage. Line VC 33a had 47% infected plants when inoculated at the third-leaf stage and 96% infected plants when inoculated at the cotyledon stage. Two of the GRSU accessions (C 0480 and C 0563) contained a high percentage of resistant individuals when inoculated by both methods. Among the Thai lines, Kheenoo Ubon had 30% infection when inoculated at the third-leaf stage compared to 71% at the cotyledon stage. Line Chau Makau had 50% resistant plants by both inoculation methods. Resistant plants were transplanted to the field and subjected to natural infection. Seed was collected from individual plants that were still resistant after 5 mo in the field. Since all other lines were 100% infected, the above results indicate that tolerance may be present in some of the lines listed above. Plants of these seeds will be tested again in the greenhouse by careful monitoring of virus entry, virus movement within the plants, and virus titer.

Routine resistance screening

INTHOPE entries. Eleven entries of INTHOPE no. 3 were found resistant to PVY (PBC 365, 370, 450, 452, 454, 495, 521, 524, 535, 596, and C01664) and some entries had a high percentage (> 30%) of PVY-resistant individuals (PBC 371, 417, 485, and 519). Five entries were resistant to CVMV (PBC 371, 495, 518, 523, and C01664) and several had a high percentage (> 60%) of CVMV-resistant individuals (PBC 137, 142A, 365, 450, 452, 454, 461, 474, 519, 524, 548, and 596). Lines PBC 137, 365, 417, and C04352, were resistant to ToMV and TMV; line PBC 473 was resistant to ToMV.

Among the INTHOPE no. 4 entries, 1 (PBC 522) was resistant to CVMV; 11 were resistant to PVY (PBC 483, 534, 580, 581, 582, 592, 622, 729, 730, 731, and 830), and 1 (PBC 621) resistant to TMV and ToMV.

PBC lines. Nine PBC lines were resistant to CVMV (PBC 092, 180, 349, 370, 545, 549, 569, 691, and 787), and three had a high percentage (> 60%) of resistant plants (PBC 457A, 690, and 695). Five lines (PBC 349, 458, 545, 710, and 787), were resistant to PVY and one (PBC 323) was resistant to PMMV.

VC lines. Two of the VC lines (VC 198 and 199) were resistant to both ToMV and TMV. Two lines (VC 38 and VC 195) were resistant to PVY and CVMV, and one line (VC 200) had > 60% CVMV-resistant plants.

GRSU accessions. Two of the GRSU accessions (C 00503 and C 01315) were resistant to CVMV, and one line (C04712) was resistant to PMMV.

Screening for TSWV

C. chinense 159236 proved susceptible to the Asian PBNV. Seventy-five percent of the plants of this line became systemically infected with pronounced chlorotic rings. Presence of virus in such tissue could be confirmed by indirect ELISA. The susceptible line Yolo Wonder had 83% infected plants (systemic chlorotic rings and etching) in which virus could also be detected by indirect ELISA. This indicates that lines resistant to the type strain of TSWV which seems to

predominate in the Western Hemisphere are not necessarily resistant to the tospovirus PBNV which infects pepper (and other crops) in Asia.

Conclusions

A number of additional sources of CVMV resistance were found which are probably of different genetic background than the ones previously identified. Screening for further resistance sources to CVMV may no longer be necessary. We will focus on tolerance to CMV now that we have identified several lines with suspected CMV tolerance. The investigation of the resistance mechanism involved will be our priority. The search for additional sources of PMMV will also continue, since only few and wild types with resistance have been found so far. Some attention also needs to be given to identification of sources of resistance to PBNV since none have been identified yet.

Further Studies on Pepper Mild Mottle Virus, Chili Veinal Mottle Virus, and Cucumber Mosaic Virus

Summary

Chili veinal mottle virus and cucumber mosaic virus are the most important viruses on pepper in Taiwan as well as in other Asian countries. The reasons for the high incidence in farmers' fields are not well understood. Another virus, pepper mild mottle virus, is causing severe damage on pepper fruit in southern Europe. The virus has been detected on a number of seedlots produced by commercial companies in Taiwan. Seed detection methods and virus elimination from infected seed, therefore, need to be developed.

No evidence for seed or soil transmission of either CMV or CVMV was found. The aphid species *A. gossypii* which is abundant in farmers' pepper fields was shown to effectively transmit both CMV and CVMV.

PMMV was present on 80% of the seedcoats and in all the embryos of seed collected from PMMV-inoculated plants. However, only 20% of seedcoat-borne PMMV was infectious compared to all the embryo-borne PMMV, as shown by local lesion assay on *N. glutinosa*. Similarly, only 10% of the hot pepper plants and 37% of the sweet pepper plants grown from ELISA-positive seed showed any visible symptoms of PMMV infection. When tested by ELISA, however, 100% of the plants showed presence of PMMV in the roots, compared to around 50% in aboveground plant parts. The reason as to why this virus does not produce the characteristic fruit mottling and deformation symptoms here in Taiwan, as observed in southern Europe where the same virus is devastating, is not clear.

None of the seed treatments tested, which are used against other tobamoviruses, were found effective in eliminating seedborne PMMV.

Introduction

Chili veinal mottle virus and cucumber mosaic are the most important viruses in Taiwan as well as in many other Asian countries. Detailed epidemiological studies which would help explain the high incidence of these two viruses in farmers' fields have not yet been conducted. Pepper mild mottle virus, which causes serious damage on field grown peppers in other parts of the world such as Europe, has only been found sporadically in Taiwan. The role of seed

transmission in the epidemiology of this virus in Taiwan is not well understood. Preliminary experiments were, therefore, conducted to clarify some of the abovementioned problems.

Materials and Methods

Detection of PMMV on seeds

Seed was collected from hot pepper plants (cv. Passion) mechanically inoculated with PMMV at the second-leaf stage. Sixty seed batches of 30 seeds each were used for the detection of virus by inoculation to *N. glutinosa*, a local lesion host of PMMV and by ELISA. The buffer in which seeds were shaken, as well as the seeds themselves, were used for the tests.

Movement of PMMV from seed into plants

Seed was taken from PMMV-inoculated hot and sweet pepper (cv. Passion) pepper (cv. Yolo Wonder) 6 mo after harvest. Forty seeds were sown in Vermiculite*. Plantlets were transplanted at the third-leaf stage into autoclaved soil in 10-cm clay pots, making sure that the plants did not touch each other. An ELISA test was conducted on leaves 106 days after transplanting (DAT) and on roots and fruit at 165 DAT. At the same time, root, fruit, and stem tissues (from the top and middle sections) of 10 ELISA-positive plants were inoculated on *N. glutinosa*.

Effect of seed treatments on elimination of PMMV

Seed was collected from plants mechanically inoculated with PMMV at the second-leaf stage. Three treatments, described in detail in the AVRDC 1992 Progress Report, were tested: HCl (5.3%) for 4 h; NaOH (2%) for 10 min; Na_3PO_4 (10%) for 2 h; 76°C dry heat for 3 days. For each treatment, batches of 30 seeds were used with four replications. An ELISA test was conducted on each seed batch after seeds were shaken overnight in extraction buffer. Both the buffer in which the seeds were shaken as well as the seeds themselves were tested.

Survey for PMMV in Taiwan and characterization of PMMV isolates

Three hundred and sixty-six leaf samples were collected from pepper-growing areas in southern and central Taiwan (Tainan, Pingtung, Chiayi, and Puli). They were tested by DAS-ELISA for the presence of PMMV using a PMMV-specific polyclonal antiserum prepared at AVRDC.

PMMV was isolated from these samples via systemic infection of *Capsicum frutescens*, followed by four single local lesion transfers on *Nicotiana tabacum* Xanthi NC. Pathotype identification was on a set of five differential hosts, including *L. esculentum* (Bonnie Best), *C. annuum* (Tisana), *C. baccatum* PI 260549, *C. chacoense* PI 260429, and *C. chinense* PI 159236.

Soil transmission of CMV and CVMV

Twelve soil samples of 5 kg each (top 30 cm soil) were collected randomly from AVRDC fields and used to grow hot peppers with a high incidence of both CMV and CVMV. The soil samples were divided into two parts: 1 kg was mixed 1:2 with 0.1 M phosphate buffer, pH7.0, and shaken overnight. An ELISA test was conducted in triplicate on the buffer solution in which

the soil samples was shaken. The buffer samples were also used to inoculate *N. glutinosa*. The other 4 kg was distributed into 84 small plastic pots (8-cm diam) into which two seeds each of the hot pepper cv. Hot Beauty were sown. At the second- and fifth-leaf stages, all plants were tested by DAS-ELISA for the presence of CMV and CVMV.

Seed transmission of CVMV

Seeds were collected from hot pepper plants known to be infected with CVMV. Twenty-four batches originating from 24 different hot pepper lines, each containing 40 seeds, were ground in 0.1 M PO_4 buffer and tested by DAS-ELISA. Three other batches, each consisting of 150 seeds, were grown in autoclaved soil in 8-cm plastic pots. The emerging plantlets were tested at the second- and fifth-leaf stages by DAS-ELISA for the presence of CVMV.

Insect transmission of CVMV and CMV

Three hundred aphids (*A. gossypii*) were collected from field-grown pepper plants infected with both CMV and CVMV. The aphids were released inside a screen cage into which 100 hot pepper seedlings cv. Hot Beauty had been planted. After 1 wk the insects were killed with insecticide. At 3 and 56 days thereafter the plants were tested by ELISA for the presence of CMV and CVMV.

Results and Discussion

Detection of PMMV on seeds

Eighty-three percent of the buffer samples in which PMMV-infected seed were shaken and 100% of the crushed seed gave a positive ELISA reaction, indicating that most PMMV is present inside the seed embryo. However, when tested on *N. glutinosa*, only 20% of the buffer samples produced local lesions. On the other hand, all of the ground seed samples produced local lesions. Thus, only a small percentage of the seedcoat-borne PMMV appears to be infectious. On the contrary, all PMMV carried inside the seed was infective. Therefore, for effective seed health testing, ELISA tests should be supplemented by mechanical inoculations to determine whether virus detected by ELISA is indeed infectious. A positive ELISA test of seed does not necessarily imply that plants emerging from such seed will become infected.

Table 4. Movement of PMMV into plants from infected seed

Host	Plants showing symptoms (%)	Positive ELISA reaction (%)		
		Leaves	Root	Fruit
Hot pepper	10 (mid mosaic)	7	97	47
Sweet pepper	37 (mid mosaic)	53	100	60

Movement of PMMV from seed into plants

Only 10% of the hot pepper and 37% of the sweet pepper plants showed visible symptoms when grown from seedlots of PMMV-inoculated plants (table 4). However, ELISA tests detected virus in 97% of the roots of hot pepper and 100% of roots of sweet pepper plants. Virus was present in 53% of the leaves and 60% of the fruit of sweet pepper plants compared to 7% of the leaves and 47% of the fruit of hot pepper plants.

Infectious PMMV (producing local lesion on *N. glutinosa*) was only detected in 44% of the roots and 56% of the fruit and stems of the ELISA-positive hot pepper plants chosen for infectivity testing. Similarly, infectious PMMV was only detected in 63% of the roots, 25% of the fruit, and 38% of the stems of the ELISA-positive sweet pepper plants. It appears that most of the virus from the infected seed had moved into the roots, and only some into leaves, stems, and fruits. The reason as to why infectious PMMV was found only in some of the ELISA-positive tissue is not clear yet.

The PMMV isolate used for these experiments is the same pathotype, namely, P1.2, which is known to cause considerable damage to sweet pepper crops in southern Europe. However, severe fruit deformation and mottle, common in southern Europe, were not observed in any of the fruit produced from plants grown from infected seed in our experiments. This may be due to differences in environmental conditions, particularly temperature. This will be subjected to further investigation. When conducting surveys for PMMV, samples should be taken from roots rather than from aboveground plant parts since roots appear to be nearly always 100% infected.

Effect of seed treatments on elimination of PMMV

The 3-day heat treatment was found to completely eliminate PMMV from seedcoats. However, the same treatment only eliminated virus carried in the endosperm in one of the four seedlots. None of the other treatments was effective in eliminating virus from the seedcoats nor the endosperm. All seedlots tested were found to be still 100% contaminated after any of the other treatments. These results indicate that PMMV, unlike ToMV, is very difficult to eliminate from pepper seed (particularly in case of embryo contamination) using conventional treatment methods. Therefore, different methods need to be developed to effectively eliminate PMMV from seedcoats as well as embryos.

Survey for PMMV in Taiwan and characterization of PMMV isolates

Only seven of the 36 plant samples tested by ELISA were found to be positive. The finding of only a few plants infected with PMMV was unexpected in view of the high percentage of PMMV-infected pepper seedlots of local seed companies (see AVRDC 1992 Progress Report). One reason for this may be that most PMMV is usually present in the root tissue and very little in aboveground tissue, as shown above.

Three pure PMMV isolates were obtained. All produced mosaic on *C. annuum* (Tisana) and *C. baccatum* PI 260549, and necrotic local lesions on *C. chacoense* PI 260429 and *C. chinense* PI 159236. All three isolates are, therefore, of pathotype 1.2, the same pathotype found in previous surveys. This pathotype is also very common in Europe.

Soil transmission of CMV and CVMV

None of the 12 soil samples collected from pepper fields with high incidence of CMV and CVMV gave a positive reaction in ELISA with CMV or CVMV. Similarly, when soil samples shaken overnight in buffer were used in inoculated *N. glutinosa*, no systemic infection with mosaic (typical for CMV) or chlorotic spots (typical for CVMV) were observed. Furthermore, none of the 100 hot pepper seedlings planted in soil collected from the same fields showed any virus symptoms, nor was the presence of CMV or CVMV detected by ELISA. These two sets of results suggest that soilborne infection with either one of these two viruses is either absent or may not play a major role in AVRDC fields.

Seed transmission of CVMV

CVMV was not detected by ELISA in any of the 24 batches of 40 seeds tested. Furthermore, none of the 143 seedlings grown out from seed of CVMV-infected plants became infected with CVMV, as shown by the absence of visible symptoms and negative ELISA tests.

Insect transmission of CVMV and CMV

A. gossypii was found to transmit both CMV and CVMV. More plants (55%) showed CVMV symptoms than CMV symptoms (23%) at 39 days after the plants were exposed to infected insects. This may indicate that CVMV is more effectively transmitted by *A. gossypii* than CMV. However, at 61 days 93% of the plants exposed to insects became infected with CMV, compared to only 63% infected with CVMV.

Conclusions

Apparently, there is no transmission of CMV and CVMV through seed and soil. Therefore, initial infection must be through aphid-transmission from neighboring crops or weed hosts. *Aphis gossypii*, a common aphid species in Taiwan, is an efficient vector for both viruses.

Seed of PMMV-infected plants carry the virus on the seedcoat and inside the embryo as shown by ELISA. However, ELISA does not distinguish whether the virus is merely present or also infective. Therefore, infectivity tests on *N. glutinosa* are needed to determine whether virus detected by ELISA is also infectious. Such tests showed that all virus carried inside the embryo is infectious compared to only a small percentage of virus carried on the seedcoat of emerging plantlets. Only a small percentage of plants emerging from infected seed actually become infected and show visible symptoms. Most virus will move into the roots upon seed germination and not all will be infectious. Therefore, when conducting surveys for PMMV root tissue or fruit should be used as sample and not the leaves. All PMMV isolated so far are pathotype P1.2, the same pathotype which causes severe symptoms on sweet pepper in southern Europe. The reason as to why this virus, which is devastating to pepper crops in southern Europe, hardly produces any visible symptoms on leaves or fruit is not clear.

Artificial Barriers to Reduce Aphid and Virus Incidence

Summary

Previous experiments conducted at AVRDC and elsewhere have shown that the planting of corn as barrier crops significantly reduced virus incidence in peppers. However, per-plant-yields were significantly lower, because of the shading effect of the corn. This method of virus control has, therefore, not become very popular among farmers. Also, for more convenient management, farmers prefer a monocrop of peppers to one of peppers and corn. An experiment was, thus, conducted to test a reusable inert mechanical barrier such as a net that might deter aphids from landing on the pepper plants and would not give a strong shading effect. A 1-m-high clear nylon net barrier around a 7.5 x 10-m plot was found effective in reducing virus incidence in hot pepper plants by about 50%. Throughout the growing season, almost the same aphid populations were found on plants of these plots as on those not surrounded by mechanical barriers but receiving

weekly insecticide applications. One reason for this is probably the presence of the ladybugs in the unsprayed plots surrounded by nets. Although yields of the first three harvests were significantly lower in plots surrounded by nets, overall yields were the same. Thus, the use of a nylon net barrier without insecticide application is effective in reducing virus incidence under southern Taiwan conditions, and maintaining the same overall yields as in farmers' fields where insecticides are applied weekly.

Introduction

Past experiments conducted at AVRDC and elsewhere have shown that planting corn as a barrier crop can significantly reduce virus incidence in pepper fields. However, because of the shading effect, yields have generally been lower than when peppers were grown without corn as barrier crops. Also, high populations of aphids were usually found on the corn crop, which could move to the neighboring pepper plants when the corn crop was disturbed or harvested earlier. Therefore, a mechanical barrier without these disadvantage and which might be equally effective in reducing virus but without any adverse effect on yield was tried.

Materials and Methods

The hot pepper variety Hot Beauty was used in this study. Two treatments were compared: treatment 1: plots surrounded on all four sides with a 1-m-high, 32-mesh translucent nylon screen and no insecticide application; and treatment 2: farmers' practice, which consisted of weekly spraying with the insecticide Tamaron of plots not surrounded by a net. There were three replications. Each plot was 7.5 x 10 m and consisted of five beds with double rows of 22 plants per row. Plant-to-plant distance was 45 cm and between-plant distance was 50 cm. Distance between treatments was 7.5 m to prevent interplot treatment interference. Beds of both treatments were covered with a locally produced plastic foil (silvery side up). Seed was sown on 15 September in an insect-proof screenhouse and transplanted to the field on 22 October. One day before transplanting, plants of all treatments received one application of Pirimor, an insecticide effective against aphids and Kelthane, a miticide.

At regular intervals, aphid counts were conducted on each plant using a scale of 1-3, with 1= 0 aphids/plant, 2= 1-20 aphids/plant and 3= >20 aphids/per plant. The counts were taken the day before insecticide was applied on treatment 2. Similarly, the number of ladybugs/plant were counted on 5, 12, and 19 March. Virus incidence (CMV) was measured on all plants/plot (except the end-of-the-row plants). One leaf from the top, middle, and bottom of each plant was collected, pooled, and used for the ELISA test. Five ELISA tests were conducted on 1 November (10 DAT), 17 November (26 DAT), 23 December (62 DAT), and 16 February (117 DAT).

The climatic environment (temperatures, wind speed, wind direction) during the course of the experiment is given in fig. 1.

Results and Discussion

Aphid and ladybug counts. Aphid counts in unsprayed plots surrounded by border nets and in sprayed plots generally did not significantly differ from each other (table 5). High aphid counts were noticed on 28 October; 13, 20, and 27 November; 4 and 11 December; and 12 and 19 February. The aphid population was extremely low from 18 December to 4 February and from 5 to 17 March. These low aphid counts did not always coincide, as anticipated, with extremely low temperatures and high winds. However, some of the low counts, namely, on 18 and 24 December; 20 and 29 January; and 5 February were correlated with low temperatures and high winds.

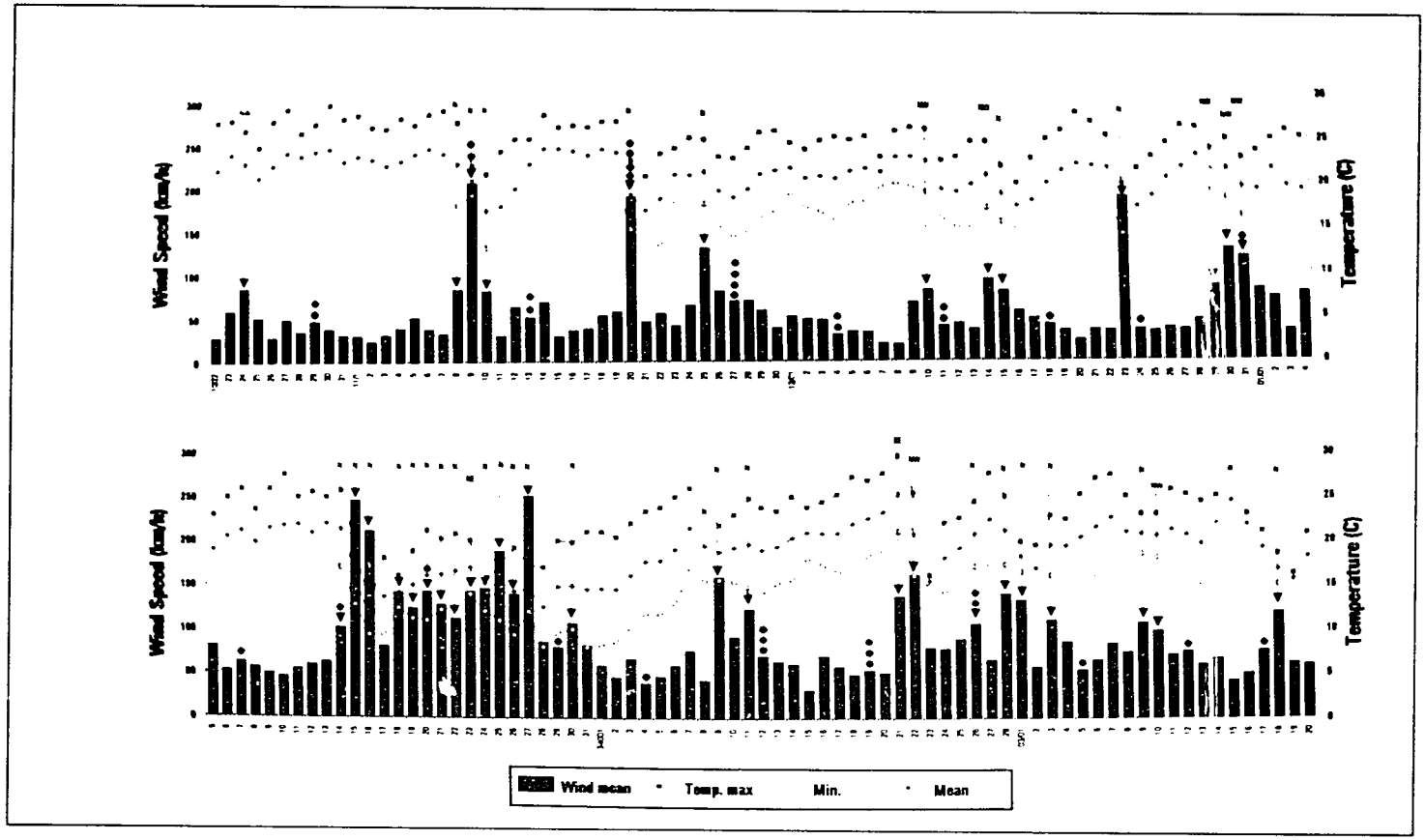

Fig. 1. Climatic data for the growing period of hot pepper

**** High aphid counts on the plants (>50% of the plants have aphids and > 10% of these plants have populations of more than 20 aphids).

* Low aphid populations on the plants (most plants have no aphids, 10% of the plants have aphids populations of 20 fewer than).

Table 5. Comparative aphid counts on pepper plants in plots surrounded by nets and plots not surrounded by nets

Aphid count[a]	No. of plants													
	Oct. 29		Nov. 9		Nov. 13		Nov. 20		Nov. 27		Dec. 4		Dec. 11	
	N[b]	NN[c]	N	NN	N	NN	N	NN	N	NN	N	NN	N	NN
0 aphids	138 a[d]	142 a	202 a	164 a	187 a	148 a	165 a	97 b	160 a	111 b	190 a	187 a	199 a	180 a
< 20 aphids	80 a	78 a	18 a	55 a	31 a	52 a	38 a	67 a	48 b	107 a	27 a	32 a	21 a	40 a
> 20 aphids	1	0	0	1	2 b	20 a	17	56 b	12 a	2 a	3 a	1 a	0	0
	Dec 18		Dec. 24		Dec. 31		Jan. 7		Jan. 14		Jan. 20		Jan. 29	
	N	N	N	NN	N	NN	N	NN	N	NN	N	NN	N	NN
0 aphids	213 a	217 a	220 a	218 a	219 a	217 a	220 a	216 a	219 a	215 a	217 a	209 b	217 a	209 b
< 20 aphids	7 a	3 a	0 a	2 a	1 a	3 a	0 a	4 a	1 a	5 a	3 b	11 a	3 b	11 a
> 20 aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb. 4		Feb. 12		Feb. 19		Feb. 26		Mar. 5		Mar. 12		Mar. 17	
	N	NN	N	NN	N	NN	N	NN	N	NN	N	NN	N	NN
0 aphids	217 a	209 b	145 a	171 a	68 a	168 a	196 a	190 a	217 a	218 a	218 a	218 a	216 a	220 a
< 20 aphids	3 b	11 a	75 a	49 a	152 a	52 a	23 a	30 a	3 a	2 a	2 a	2 a	4 a	0 a
> 20 aphids	0	0	0	0	0	0	1	0	0	0	0	0	0	0

[a]Number of aphids per plant; measured on all plants of each plot except those at the end of the rows.
[b]N = net, no insecticide sprays on the plants.
[c]NN = no net, weekly insecticide sprays on the plants.
[d]Data are means of three replications. For each date, means within rows followed by the same letter are not significantly different at the 5% level (DMRT).

On 5, 12, and 19 March an average of 5.6, 3.6, and 1.9 ladybugs, respectively, were observed on plants in plots surrounded by the border net and not receiving any insecticides. However, no ladybugs were found in the plots receiving weekly insecticides. Regular insecticide spraying thus completely eliminates ladybugs, the natural enemies of the aphids. It is very possible that the presence of ladybugs in the unsprayed plots is the reason why the aphid population in these plots was not higher than in sprayed plots.

Virus incidence. Virus incidence was unexpectedly low in both treatments (fig. 2). However, it was clear that virus incidence in plots surrounded by the border net was lower than in plots not surrounded by the net. Aphids are generally passive long-distance fliers but are carried by the wind. A mechanical barrier in the form of a 1-m-high net is apparently effective in reducing, but not totally preventing aphids from alighting on the pepper crop.

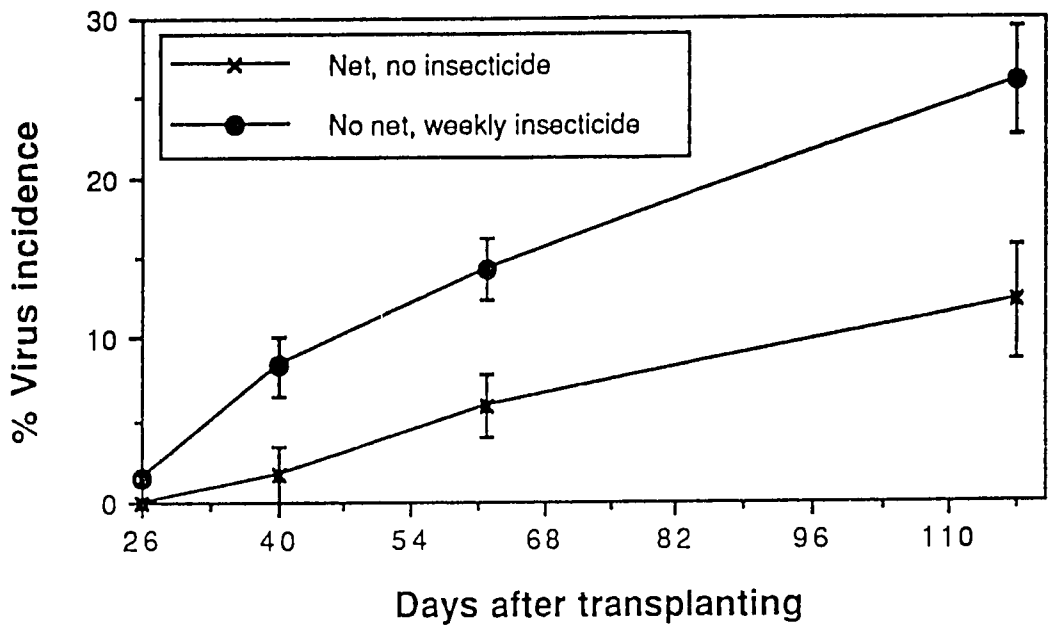

Fig. 2. CMV incidence in plots surrounded by net barriers receiving no insecticides and plots not surrounded by nets receiving weekly insecticide sprays

Yield. Plots surrounded by nets and receiving no insecticide treatments had significantly lower yields (in terms of total fruit weight, fruit number, and average fruit weight) in the first three harvests than plots not surrounded by nets and receiving insecticides (table 6). However, in the following six harvests yields (in terms of total fruit weight and total fruit) of plots surrounded by nets were significantly higher. When comparing all harvests (harvests 1-9), there was no significant difference in total yields between the two treatments, although total fruit number was higher and average fruit weight was lower in plots surrounded by the nets. Therefore, if high yields in the first three harvests and large overall fruit size are not absolutely desired by the farmer, he can achieve similar overall yields without using insecticide, provided he surrounds his plots with a mechanical barrier such as a screen net.

Table 6. Yield parameters of hot peppers grown on plots surrounded by 1-m-high clear plastic mesh screens with no insecticide applications

Treatment	Harvests 1-3			Harvests 4-9			Harvests 1-9		
	Total fruit wt (kg)	Total fruit no.	Avg. fruit wt (g)	Total fruit wt (kg)	Total fruit no.	Avg. fruit wt (g)	Total fruit wt (kg)	Total fruit no.	Avg. fruit wt (g)
Net, no insecticide	3.1 b[a]	493 b	6.3 b	18.7 a	5,675 a	3.3 a	21.8 a	6,217 a	3.5 b
No net, weekly insecticide	5.6 a	741 a	7.5 a	14.4 b	3,896 b	3.7 a	20.0 a	4,635 b	4.3 a

[a]Data are means of three replications. Means within columns followed by the same letter are not significantly different at the 5% level (DMRT).

Conclusions

In the absence of insecticide sprays, a 1-m-high clear nylon net barrier was found to reduce virus incidence by 50% in 7.5 x 10-m plots. Total yields of such plots were not significantly different from those of plots not surrounded by the net but receiving weekly insecticide. Thus, under southern Taiwan conditions this method may show promise in reducing virus incidence during the winter months. Since winds generally come from the north during that time of the year, a single barrier on the north of the plot might be sufficient to reduce virus incidence. Since such a net can be reused, it presents a cheaper and environment friendly control method.

Evaluation of Pepper Entries in INTHOPE no. 3 for their Reactions to Anthracnose

Summary

Pepper accessions in INTHOPE no.3 were evaluated for their reactions to anthracnose based on the incidence of postharvest fruit rot developing from latent field infections. Entries with the lowest percentage of infected pods and presumably the most resistant to anthracnose were PBC 651 (2.2%), PBC 495 (5.0%), PBC 417 (6.8%), C0 4352 (8.3%), PBC 552 (8.3%), and PBC 370 (8.8%). The percentage of pods developing anthracnose ranged among entries from 2.2 to 37.9%. These results were compared with the size of lesions that developed on fruit of the same entries following laboratory inoculations with *Colletotrichum capsici* and *C. gloeosporioides*. Average lesion size (scale of 0-4) for the various entries following inoculation ranged from 1.7 to 3.2 for *C. capsici* and 2.6 to 4.0 for *C. gloeosporioides*. The percentage of field-infected pods was not significantly correlated with the lesion size on pods of the same entries caused by either pathogen in laboratory inoculations. These results suggest that the current laboratory inoculation method is not reliable for evaluating anthracnose resistance in pepper.

Introduction

Anthracnose fruit rot is one of the most important diseases of pepper grown in the hot-humid tropics. The disease frequently causes severe yield loss when pepper is grown during the rainy season. *Colletotrichum capsici* and *C. gloeosporioides* are generally reported as the two major causal agents of anthracnose. *C. gloeosporioides* is predominant in Taiwan. Resistant lines have been reported, but most are not suitable types for cultivation. This study was conducted to evaluate 30 pepper entries included in the third International Hot Pepper Trial Network (INTHOPE no. 3) for their reactions to anthracnose under field conditions, and to compare a laboratory evaluation method with the field results.

Materials and Methods

Pepper fruit from each entry in INTHOPE no. 3 were evaluated for their reactions to anthracnose. Two methods were used for evaluation, i.e., (1) incubation of fruit harvested from a naturally infected field to determine the incidence of pods developing symptoms from latent infections, and (2) inoculation of pods with conidia of *C. gloeosporioides* and *C. capsici* independently, using a pin-puncture method and rating disease response based on lesion size.

Disease incidence from latent infections

Asymptomatic mature red fruit from three separate field plantings of INTHOPE no. 3 at AVRDC were observed for postharvest development of anthracnose. Fruit samples were taken from harvests made on 10 December 1992 (planting PP92SU05B), 8 January 1993 (planting PP92F-14A), and 8 January 1993 (planting PP92F-14B). Three 20-pod fruit samples of each pepper entry from each of the three plantings were evaluated. Pods were rinsed in tap water, blotted dry with paper towels, and immersed in a 1% sodium hypochlorite solution for 2 min followed by rinsing in distilled water. The pods were immediately transferred onto a wire screen in a plastic bag and incubated at room temperature for 2 wk. Anthracnose diagnosis was confirmed by microscopic observations of conidial morphology from representative lesions. The

numbers of pods with anthracnose were counted after the 2-wk incubation. The incidence of pods developing postharvest anthracnose was determined for each INTHOPE entry by averaging the results from the three 20-pod samples from each planting and taking the mean of the results from the three plantings.

Disease response of inoculated fruit

Asymptomatic pods were surface sterilized and incubated in the same way as described earlier. Three replications of 10 pods each from the 30 INTHOPE no. 3 pepper lines were inoculated and evaluated for their responses to *C. gloeosporioides* and *C. capsici*, separately. The experiment was conducted twice using fruit harvested on 15 January 1993 from planting PP92F-14A and 8 January 1993 from planting PP92F-14B. Each pod was inoculated by making a cluster of four needle punctures near the center of the pod and placing 0.2 ml of a conidial suspension (*C. gloeosporioides* or *C. capsici*) on the wounded area. Disease severity ratings were made 2 wk after inoculation using a 0-4 rating scale: 0 = no lesion; 1 = lesion < 0.5 cm; 2 = lesion 0.5-1.0 cm; 3 = lesion 1.1 - 2.0 cm; and 4 = lesion > 2.0 cm.

Results and Discussion

There were 30 accessions in INTHOPE no. 3, but only 27 were evaluated for disease development from latent infections because insufficient fruit of accessions PBC 450, PBC 463, and PBC 519 were available for sampling. The average incidence of diseased pods developing as a result of latent infection over all entries was 33.1%, 12.2%, and 12.4%, respectively, for plantings PP92SU05B, PP92F-14A, and PP92F-14B. Although both *C. capsici* and *C. gloeosporioides* were observed as incitants of anthracnose in all three plantings, *C. gloeosporioides* was the predominant pathogen. The mean incidence of diseased pods for each entry from the three field plantings shows a wide range of reactions to anthracnose among the pepper entries (table 7). The percentage of pods developing anthracnose during the 2-wk incubation period ranged among entries from 2.2 to 37.9%. Entries with the lowest percentage of infected pods and presumably the most resistant to anthracnose were PBC 651 (2.2%), PBC 495 (5.0%), PBC 417 (6.8%), C 04352 (8.3%), PBC 552 (8.3%), and PBC 370 (8.8%). There is some reservation about including C 04352 and PBC 552 in this group, because fruit of these entries was not available for evaluation from the PP92SU05B planting which had the highest overall incidence of anthracnose.

Fruit of all pepper entries developed lesions following inoculation with spores of either *C. capsici* or *C. gloeosporioides*. The average lesion size on a scale of 0-4 (0 = no lesion and 4 = lesion > 2.0 cm diam) 2 wk after inoculation was 2.4 for *C. capsici* and 3.5 for *C. gloeosporioides* over all entries. The average lesion size for the various entries ranged from 1.7 to 3.2 for *C. capsici* and 2.6 to 4.0 for *C. gloeosporioides* (table 7). There was no correlation (r = .075) between the individual responses of the 30 pepper accessions to the two pathogens, suggesting any resistance mechanism is likely to be expressed independently.

The percentage of pods developing anthracnose from latent field infections for each of the pepper accessions was compared to the disease response, measured by lesion size, of the same accessions following wound inoculation by the two pathogens. There was no significant correlation between the incidence of field infection and lesion size induced by *C. capsici* (r = .416) nor *C. gloeosporioides* (r = -.178). Assuming that the incidence of pods developing anthracnose from latent field infections is a valid means of evaluating resistance, these results suggest that the pin-puncture inoculation method is not reliable for evaluating anthracnose resistance in pepper.

Table 7. Anthracnose reactions of INTHOPE no. 3 pepper lines

		Field	Laboratory inoculation	
		Infected pods	Lesion size[b]	
Entry	Name	percentage[a]	*C. capsici*	*C. gloeosporioides*
PBC 651	Chili Hybrid-1	2.2	1.7	4.0
PBC 495	Perennial HDV	5.0	2.3	3.3
PBC 417	Ca 87067	6.8	2.2	3.3
C 04352	PI441561	8.3	2.0	3.4
PBC 552	Nabeul II	8.3	2.1	3.4
PBC 370	PBC 370	8.8	1.7	3.4
PBC 452	Cayenne Cajun 2	12.1	3.2	3.9
PBC 595	Yuak	12.2	2.1	3.6
PBC 074	Szechwan 8	12.2	2.6	3.5
PBC 371	PBC371	12.8	2.8	3.8
PBC 521	Tiwari II	12.9	2.4	3.7
PBC 142	Pant C-1	14.1	2.6	3.7
PBC 454	PBC454	17.1	2.0	3.6
PBC 518	PSP-11	17.7	1.7	3.2
C 01664	C 01664	18.7	3.2	3.6
PBC 548	G-3	20.1	2.6	3.2
PBC 137	CNPH 703	21.9	2.5	3.4
PBC 461	KA 6-5	23.2	2.3	3.2
PBC 535	IR	23.3	2.6	2.9
PBC 597	Mun	27.0	2.6	3.8
PBC 524	Serrano Huasteco	27.1	2.8	3.8
PBC 473	PBC 473	28.2	2.7	3.5
PBC 596	Luang	28.7	2.5	3.8
PBC 485	MI-1	29.7	2.7	3.4
PBC 474	Rotan	30.2	3.0	3.7
PBC 523	Serrano Tampiqueno	31.9	1.8	4.0
PBC 365	PBC 365	37.9	3.0	2.6
PBC 463	Bako Local[c]	-	3.6	3.4
PBC 450	Cayenne Cajun 1[c]	-	3.5	3.7
PBC 519	Mexico[c]	-	2.4	4.0
Mean		18.4	2.4	3.5
LSD		(0.05) 19.7	(0.01) 1.2	(0.01) 0.7

Correlation coefficients:

Percentage infected pods with *C. capsici* lesion size: r = 0.416.

Percentage infected pods with *C. gloeosporioides* lesion size: r = -0.178.

C. capsici with *C. gloeosporioides* lesion size: r = 0.075.

[a]Percentage of apparently healthy pods at harvest that developed anthracnose lesions from latent infections during a 2-week postharvest incubation. Values shown are based on observations of up to 180 pods per entry, i.e., three 20-pod samples from each of three separate plantings.

[b]Lesion size was scored on a 0 to 4 scale following wound inoculation of pods; 0 = no lesion; 2 = lesion diam < 0.5 cm; 2 = lesion 0.5-1.0 cm; 3 = lesion 1.1-2.0 cm; and 4 = lesion > 2.0 cm. Values presented are the means of two experiments, each replicated three times. Sample size was 10 fruit per replication.

[c]Insufficient fruit available for evaluations; these entries are not included in the rank order.

Conclusions and Recommendations

We have previously observed that differences among pepper lines exist in their levels of susceptibility to anthracnose based on disease incidence in the field and laboratory inoculations. Even though results are somewhat inconsistent in various trials and among evaluation methods for disease response, the pepper breeder has begun to incorporate some of the more resistant sources into the breeding program at AVRDC. Future pathology studies will concentrate on pepper lines observed in previous studies to have resistance to anthracnose. Several isolates of *C. gloeosporioides* and *C. capsici* will be tested for their reactions on these pepper lines to determine whether distinct pathotypes exist among isolates of the two fungal species. Additional studies will be conducted to refine the laboratory inoculation methodology.

Evaluation of Pepper Entries in INTHOPE no. 3 for their Reactions to *Phytophthora capsici*

Summary

Thirty entries in INTHOPE no. 3 were evaluated at the seedling stage in a greenhouse study for their reactions to *Phytophthora capsici*. The disease reaction of each entry was determined based on the percentage of surviving plants 14 DAI (300 ml of a 10^4 zoospores/ml suspension applied to the soil surface of each planter flat 30 DAS). Useful levels of resistance were observed in four entries: PBC 370, PBC 371, PBC 495, and PBC 535 in which more than 60% of the plants survived.

Introduction

Phytophthora blight of pepper caused by *Phytophthora capsici* is a serious disease of pepper in both tropical and temperate climates. The disease occurs in both rainfed and irrigated dry land pepper crops. The fungus is soilborne and causes root rot, stem blight, foliar blight, and fruit rot of pepper. Thirty entries in INTHOPE no. 3 were evaluated in this study for their reactions to *P. capsici*.

Materials and Methods

Seeds of the pepper lines to be tested were sown in a steam-sterilized soil mix, four lines per soil flat (32 x 48 cm), and thinned after emergence to 20 plants per line. Each line was replicated four times with each replication planted in a different flat and arranged in a randomized complete block design on a greenhouse bench. In addition to the 30 INTHOPE no. 3 lines being tested, highly resistant (PI 201234) and highly susceptible (Queen Star) pepper lines were included as controls.

To prepare inoculum, isolate Pc-4 of *P. capsici* was grown on V-8 juice agar in petri plates for 1 wk. Each plate colony along with the agar medium was cut into four equal sections and each section moved aseptically to a sterile petri plate and diced into approximately 5 mm^2 pieces. Sufficient sterile distilled water was poured into each plate to bring the level even with the upper surface of the agar blocks and the plates were incubated with continuous lighting at 28°C for 24 h for sporangial development. The plates were then transferred to an incubator at 4±1°C for 45 min to trigger zoospore formation and release. Water containing zoospores was decanted from the plates and adjusted to 10^4 zoospores/ml.

Plants were inoculated by drenching the soil surface of each flat with 300 ml of the 10^4 zoospores/ml suspension 30 days after seeds were sown. The disease reaction of each entry was

evaluated based on the percentage of surviving plants 14 DAI. Disease reaction categories were based on the system described in the AVRDC 1989 Progress Report: highly resistant = 80-100% survival, moderately resistant = 50-79% survival, moderately susceptible = 30-49% survival, and highly susceptible = 0-29% survival.

Results and Discussion

Useful levels of resistance were found in four of 30 entries tested (table 8). One line, PBC 370, was rated as highly resistant based on survival of 87.5% of the seedlings following inoculation. Three lines, PBC 495, PBC 371, and PBC 535, were rated as moderately resistant with survival rates of 75.0%, 63.8%, and 61.8%, respectively. This study is a portion of a larger effort at AVRDC to evaluate peppers for their reactions to Phytophthora blight and to identify sources of resistance to *P. capsici* in *Capsicum* spp. for use in development of resistant pepper lines and cultivars.

Table 8. Percentage survival of pepper plants among entries in INTHOPE no. 3 14 days after inoculation with *Phytophthora capsici*

Entry	Name/Source	Survival (%)
PBC 370	(Thailand)	87.5[a]
PBC 495	Perennial HDV	75.0
PBC 371	(Thailand)	63.8
PBC 535	IR	61.8
PBC 074	Szechwan 8	44.5
C 01664	(Denmark)	30.0
PBC 474	Rotan	26.8
PBC 473	(Indonesia)	22.5
PBC 461	KA-6-5	16.5
PBC 142A	Pant C-1	13.8
PBC 597	Mun	12.5
PBC 548	G-3	10.8
PBC 596	Luang	8.8
PBC 137	CNPH 703	6.3
PBC 365	(Italy)	5.0
PBC 454	(India)	2.5
PBC 651	Chile Hybrid 1	2.5
C 04352	PI 441561	1.3
PBC 463	Bako Local	1.3
PBC 518	PSP-11	1.3
PBC 417	Ca 87067	0
PBC 450	Cajun1	0
PBC 452	Cajun2	0
PBC 485	MI-1	0
PBC 519	Mexico	0
PBC 521	Tiwari II	0
PBC 523	Serrano Tampiqueno	0
PBC 524	Serrano Huasteco	0
PBC 552	Nabeul II	0
PBC 595	Yuak	0
PI 201234[b]		100
Queen Star[c]		0
LSD (0.05)		12.9

[a]Values based on 20 plants in each of four replications. [b]Highly resistant control.
[c]Highly susceptible control.

Soybean Breeding

Development of Soybean Rust-Tolerant Lines

Summary

Soybean rust caused by *Phakopsora pachyrhizi* results in yield losses of up to 95%. Extensive research at AVRDC and elsewhere has shown that single-gene resistance is not dependable due to multiple virulent genes in the pathogen. Soybean rust tolerance and partial resistance appear to be the solution to the problem. Breeding has made considerable progress in making selections for rust tolerance. Utilizing the advanced yield trial data from spring and autumn a rust tolerance index (RTI) similar to a stress tolerance index (STI) was developed. The STI is able to discriminate effectively the high-yielding, rust-tolerant selections in environments with and without rust.

Introduction

The yield loss due to soybean rust caused by *Phakopsora pachyrhizi* has been reported to be 5-95%. Four independent single dominant genes conferring resistance to four specific races of the soybean rust pathogen have been identified (Hartwig 1986[1]). However, they were ineffective against other virulent races of the pathogen. Although rate reducing resistance has been identified the difficulties associated with the identification and quantification made us change the strategy and select genotypes tolerant to *P. pachyrhizi* instead. Tolerance to *P. pachyrhizi* infection was defined as the yielding ability of soybean genotypes grown under severe rust stress relative to those grown under no or minimum rust stress. The objective of this research is to select genotypes with high yield potential with genes for partial resistance and tolerant to soybean rust to minimize the use of fungicides resulting in reduced production cost and yield increase. There is also a need to develop a reliable selection criteria for identifying both high yield and rust tolerance.

In 1992 a stress tolerance index (STI) was found to be a better predictor of soybean rust tolerance and high yield potential. STI is estimated as: $(Yp * Ys)/(\bar{Y}p)^2$ where Yp = the yield under no-rust environment or potential yield; Ys = yield under environment with rust; and $\bar{Y}p$ = mean yield potential. The rust intensity (SI) was determined using one minus the ratio between the mean yield in rust environment and mean potential yield $1-(Ys/\bar{Y}p)$.

Materials and Methods

Two advanced yield trials (AYT 1 and 2) were conducted in autumn 1992 and spring 1993. The planting dates and the number of entries evaluated are given in table 1.

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[1]Hartwig, E.E. 1986. Inheritance of a fourth major gene conferring resistance to soybean rust. Crop Science 26(6):1135-1136.

Table 1. Planting dates and number of entries for AYT and IYT in 1991 - 1993

Experiment	No. of entries plus (checks)	Dates of planting
AYT 1	12 (2)	11 February 1992
AYT 1	12 (2)	16 July 1992
AYT 1	12 (2)	30 September 1992
AYT 2	11 (3)	25 February 1992
AYT 2	11 (3)	1 October 1992
IYT 1	51 (3)	27 February 1992
IYT 1	51 (3)	16 July 1992
IYT 1	51 (3)	2 October 1992
IYT 2	39 (3)	27 February 1992
IYT 2	39 (3)	16 July 1992
IYT 2	39 (3)	2 October 1992
AYT 1	11 (3)	23 February 1993
AYT 2	11 (3)	24 February 1993

A split plot design with fungicide and no fungicide as main plot and genotypes as subplots, with four replications was used. Entries were planted in 6-m-long, six-row plots. The harvest plot size was 5 x 2 m (four middle rows).

Fungicide-treated plots were allowed to have only natural disease infection (if any). The plots without fungicide were inoculated with soybean rust pathogen inoculum prepared by the plant pathology group. Data on percent soybean rust infection, grain yield, and 100-seed weight were collected and subjected to pooled analysis of variance to determine the source of variation for various components. In analyzing the data, the genotypes, treatments and seasons were all fixed while the replication was considered random.

The rust tolerant index (RTI) (AVRDC 1991[2]) was calculated as follows:

$$RTI = \frac{\text{Yield (Ys) or 100-seed weight (100 SWs) w/o fungicide}}{\text{Yield (Yp) or 100-seed weight (100 SWp) with fungicide}} \times 100$$

$$= \frac{\text{Ys or 100SWs}}{\text{Yp or 100SWp}} \times 100$$

A combined analysis of 1992 spring and autumn planting was conducted and an estimate of component of variance was also determined.

Recently a statistical procedure was developed and reported for identifying genotypes with high yield and stress tolerance potential (Fernandez 1993[3]). The stress can be either drought or excess moisture. The stress tolerance index (STI) is estimated as: $(Yp * Ys)/(\bar{Y}p)^2$ where Yp = the yield under no stress environment or potential yield; Ys = yield under stress environment, $\bar{Y}p$ = mean potential yield. The larger the value of STI in a stress environment, the higher was its stress tolerance and yield potential. Since soybean rust disease is also a stress condition for the plant, this procedure was used to determine rust tolerance and yield potential. The relationship between RTI and STI was also investigated. The rust intensity was determined from the ratio between the mean yield in a rust environment and mean potential yield 1-(Ys/Yp).

[2]AVRDC. 1991. AVRDC 1990 Progress Report. Shanhua, Tainan, Taiwan.

[3]Fernandez, G.C.J. 1993. Effective selection criteria for assessing stress tolerance. In: Kuo, C.G. (ed.) "Adaptation of Food Crops to Temperature and Water Stress: proceedings of an international symposium". Taiwan. 13-18 August 1992. p. 257-270, AVRDC, Tainan, Taiwan.

Results and Discussion

Yield trial, 1992. The maximum rust severity was 78% which is almost similar to 1991. The RTI varied from 31 to 96 for yield and 69 to 98 for 100-seed weight. Percent rust lesion in the plot with fungicide was 6-15% in AYT 1 while in AYT 2 it was 5-11%. Selections GC 84051-9-1 and GC 84058-18-4 had an RTI of more than 90% for both yield and 100-seed weight. Five selections (GC 84051-32-1, GC 86017-170-1N, GC 86049-35-2-1-1-8-1N, GC 84051-9-1, and GC 84058-18-4) had an STI of more than 0.80. In general, the results appear to be similar to 1991.

Combined analysis of the AYT data for spring and autumn 1992 showed that the differences between genotypes (G), seasons (S), and treatments (T) were highly significant for both grain yield and 100-seed weight, which is an important yield component influenced by soybean rust. Among the first order interactions, GxS, VxT, SxT for yield and 100-seed weight were highly significant in both AYT 1 and AYT 2 (table 2).

Table 2. Pooled analysis of AYT trial data in spring and autumn, 1992

Source of variance	Yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
AYT 1								
Between genotypes (G)	13	0.1713	5.83	0.0001	13	0.914	57.58	0.0001
Between seasons (S)	1	3.8923	132.58	0.0001	1	0.4847	30.53	0.0001
GxS	13	0.2206	7.52	0.0001	13	0.131	8.25	0.0001
R (S)	6	0.2688	9.16	0.0001	6	0.0826	5.2	0.0001
Between treatment (T)	1	116.3142	3961.88	0.0001	1	31.7555	2000.42	0.0001
VxT	13	0.7128	24.28	0.0001	13	0.175	11.02	0.0001
SxT	1	33.8888	1154.32	0.0001	1	4.2957	270.61	0.0001
TxR (S)	6	0.0146	0.5	0.8092	6	0.0355	2.24	0.0422
SxVxT	13	0.0423	1.44	0.1459	13	0.0357	2.25	0.0098
Error	156	0.0294			156	0.0159		
AYT 2								
Between genotypes (G)	13	0.9855	31.97	0.0001	13	3.2666	483.42	0.0001
Between seasons (S)	1	41.0406	1331.23	0.0001	1	0.1986	29.39	0.0001
GxS	13	0.3368	10.92	0.0001	13	0.0326	4.83	0.0001
R (S)	6	0.2257	7.32	0.0001	6	0.0139	2.05	0.0617
Between treatment (T)	1	40.7282	1321.1	0.0001	1	7.1894	1063.93	0.0001
VxT	13	0.8761	28.42	0.0001	13	0.1422	21.04	0.0001
SxT	1	3.8	123.26	0.0001	1	0.0754	11.16	0.0010
TxR (S)	6	0.2773	9.0	0.0001	6	0.0155	2.29	0.0380
SxVxT	13	0.1632	5.29	0.0001	13	0.0177	2.62	0.0026
Error	156	0.0308			156	0.6757		

DF = degrees of freedom; MS = Mean square; F = F test; Pr=Probability

A critical review of the soybean rust tolerance screening results in the past three years suggested that σ^2F was the major component of variance for yield in spring and autumn. However, in 1991, the σ^2S was the major component variance. But 1992 data for both AYT 2 were similar to the past three years except 1991 (table 3). The severity of soybean rust in both spring and autumn is almost similar in the treatment without fungicide (AVRDC 1993[4]).

[4]AVRDC. 1993. AVRDC 1992 Progress Report. Shanhua, Tainan, Taiwan.

Table 3. Estimates of the components of variance for yield in AYT, spring and autumn, 1992

Component of variance	Estimate (%)
AYT 1	
σ^2G	0.49 (0.0001)[a]
σ^2S	1.89 (0.0001)
σ^2F	56.79 (0.0001)
σ^2GS	1.31 (0.0001)
σ^2GF	4.67 (0.0001)
σ^2SF	33.07 (0.0001)
σ^2SFG	0.18 (0.1459)
σ^2	1.60
AYT 2	
σ^2G	5.61 (0.0001)[a]
σ^2S	34.40 (0.0001)
σ^2F	34.14 (0.0001)
σ^2GS	3.59 (0.0001)
σ^2GF	9.93 (0.0001)
σ^2SF	6.32 (0.0001)
σ^2SFG	3.11 (0.0001)
σ^2	2.90

[a]Probability level.

The relationship between RTI and yield; STI and yield; RTI and STI and SI are given in table 4. For AYT 1 and 2 in autumn 1992 the relationship between RTI and yield and STI and yield were highly significant. However, RTI and STI were significant for AYT 1 in 1992 but not for AYT 2. Soybean rust intensity was higher for AYT 1 compared to AYT 2.

Table 4. Correlation coefficient between RTI or STI and yield-without-fungicide and RTI and STI in different seasons and different years

Year/season/trial	Correlation between			
	RTI and yield	STI and yield	RTI and STI	SI
1992 autumn AYT 1	0.95***	0.94***	0.79***	0.34
1992 autumn AYT 2	0.77**	0.86***	0.35 NS	0.29
1993 spring AYT 1	0.65*	0.89***	0.25 NS	0.30
1993 spring AYT 2	0.87***	0.87***	0.52 NS	0.38

Stress intensity = (1-[Ys/Yp]).
*,**,***Significant at 5%, 1%, and 0.1% level, respectively.

Three-D plots with soybean rust severity (Ys X-axis), yield with fungicide (potential yield Yp, y axis), and STI (Z-axis) for AYT 1 and AYT 2 in autumn are presented in fig. 1 and 2. The X-Y plane is divided into four segments as reported by Fernandez (1993) by drawing intersecting lines through Ys and Yp. The four resulting groups are marked A, B, C, and D. Group A genotypes in AYT 1 (GC 87019-4-10-4, AGS 129, and SRE-D-14B) expressed uniform superiority in environments with and without rust; in AYT 2 genotypes GC 86049-35-2-1-1-8-1 N and GC 84051-32-1 belonged to Group A. Group B genotypes performed favorably only in the environment without rust; Group C genotypes yielded relatively high only in a rust environment; and Group D genotypes performed poorly in environments with and without rust.

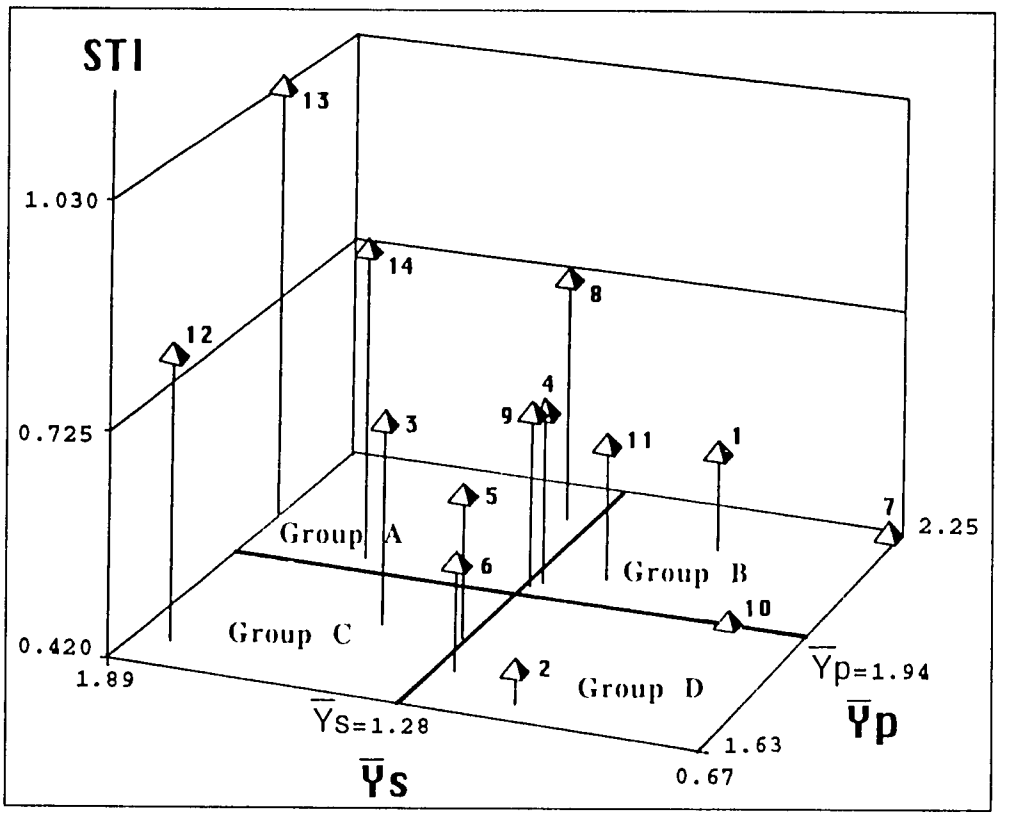

Fig. 1. The 3-D plot among STI, Yp, and Ys under moderate conditions (SI = 0.34), AYT 1, autumn 1992

Group			
A	B	C	D
(8)[a] GC 87019-4-1B-4	(1) GC 87018-20S-B-1	(3) SS 86054-23-2	(2) SS 86013-7-4
(13) AGS 129	(4) GC 87016-12S-B-2	(5) GC 87012-10-B-5	(6) GC 87016-11-B-2
(14) SRE-D-14B	(7) 87017-40-B-1	(12) GC 86004-9	(10) GC 87021-26-B-1
	(9) GC 87021-13-B-2		
	(11) SS 84009-6-5		
	(10) GC 87021-26-B-1		

[a]Numbers in parentheses are code numbers.

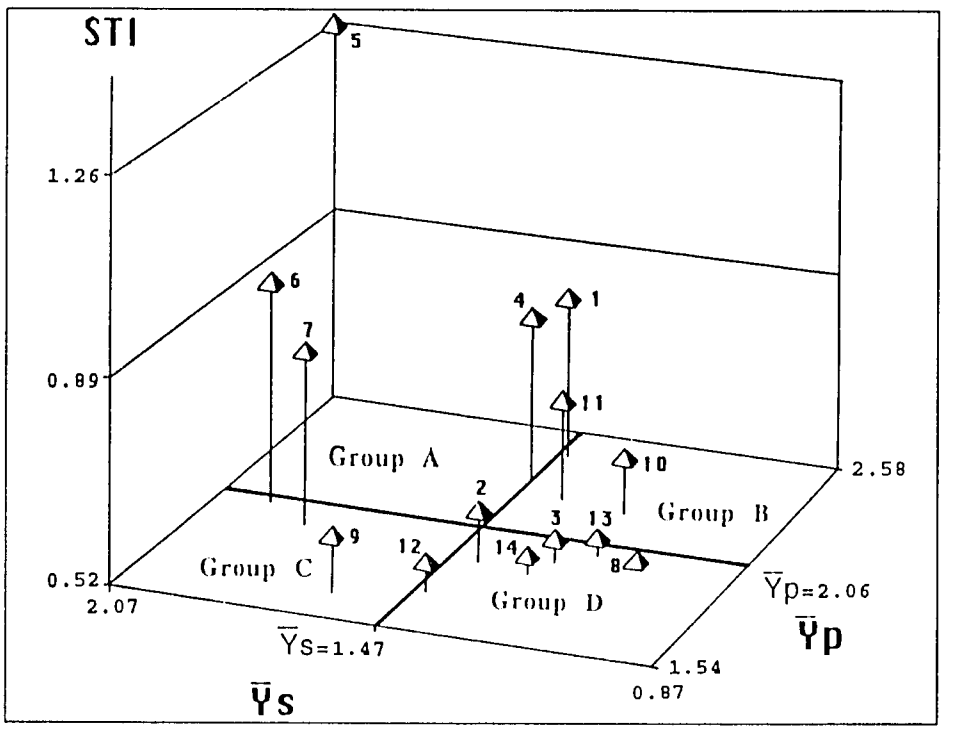

Fig. 2. **The 3-D plot among STI, Yp, and Ys under moderate conditions (SI = 0.29), AYT 2, autumn 1992**

Group			
A	B	C	D
(4)[a] GC 86049-35-2-1-1-8-1N	(1) GC 86017-170-1N	(6) GC 84051-9-1	(2) GC 84058-21-4
(5) GC 84051-32-1	(10) GC 84040-16-1	(7) GC 84058-18-4	(3) GC 84058-21-2
	(11) GC 84040-7-1	(9) GC 86018-427-3	(8) GC 84040-27-1
			(12) AGS 129
			(13) AGS 302
			(14) SRE-D-14B

[a]Numbers in parentheses are code numbers.

Yield trial, 1993. The maximum soybean rust severity was rather low compared to most years (only 59%). Seven entries (GC 00002-100, GC 00138-29, GC 60020-8-7-7-18, SRE-B-15C, SRE-C-56A, SRE-D-14B, and AGS 302) in AYT 1 and one entry (GC 84058-18-4) in AYT 2 had an STI of more than 0.80 for yield. The relationship between RTI and yield was highly significant only for AYT 2, whereas STI and yield were highly significant for both AYT 1 and AYT 2. Rust intensity (SI) was more for AYT 2 than for AYT 1. No relationship was observed between RTI and STI (table 3).

The three-D plots can be seen in fig. 3 and 4. A total of seven genotypes in AYT 1 and AYT 2 belonged to Group A which expressed uniform superiority in treatments with and without rust.

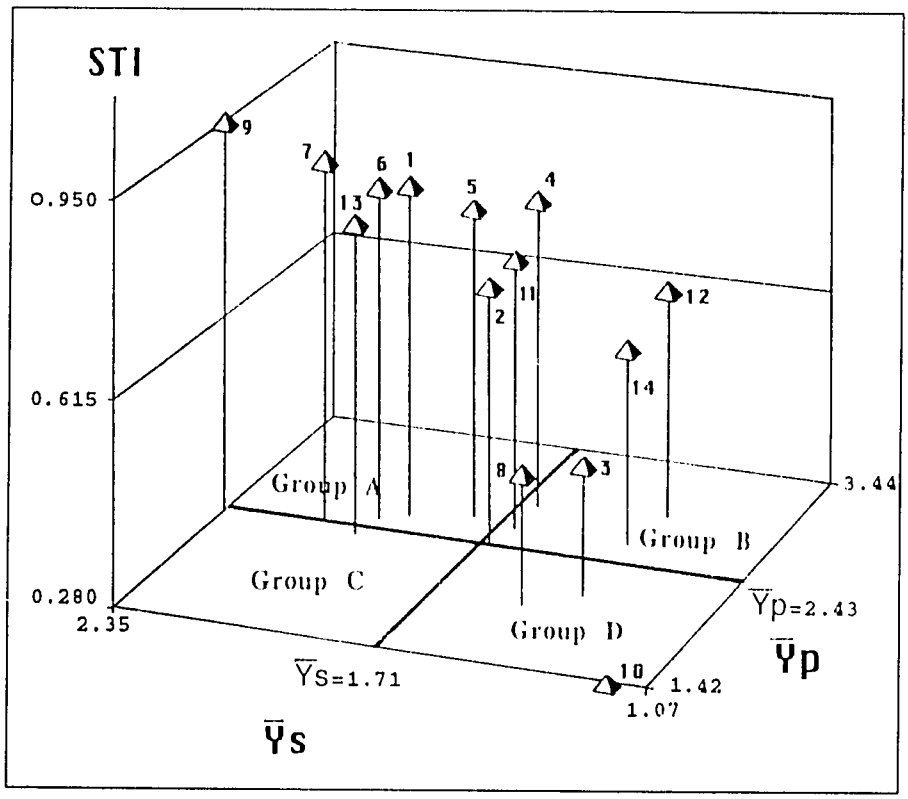

Fig. 3. The 3-D plot among STI, Yp, and Ys under moderate conditions (SI = 0.30), AYT 2, spring 1993

Group			
A	B	C	D
(4)[a] GC 60020-8-7-7-18	(2) GC 82146-43-9-9	(9) SRE-D-14B	(3) G 9947-21-9
(5) GC00138-29	(4) GC 00002-100	(13) AGS 302	(8) SRE-D-14A
(6) SRE-B-15C	(11)269		
(7) SRE-C-56A	(12) AGS 129		
	(14) OCB		

[a]Numbers in parentheses are code numbers.

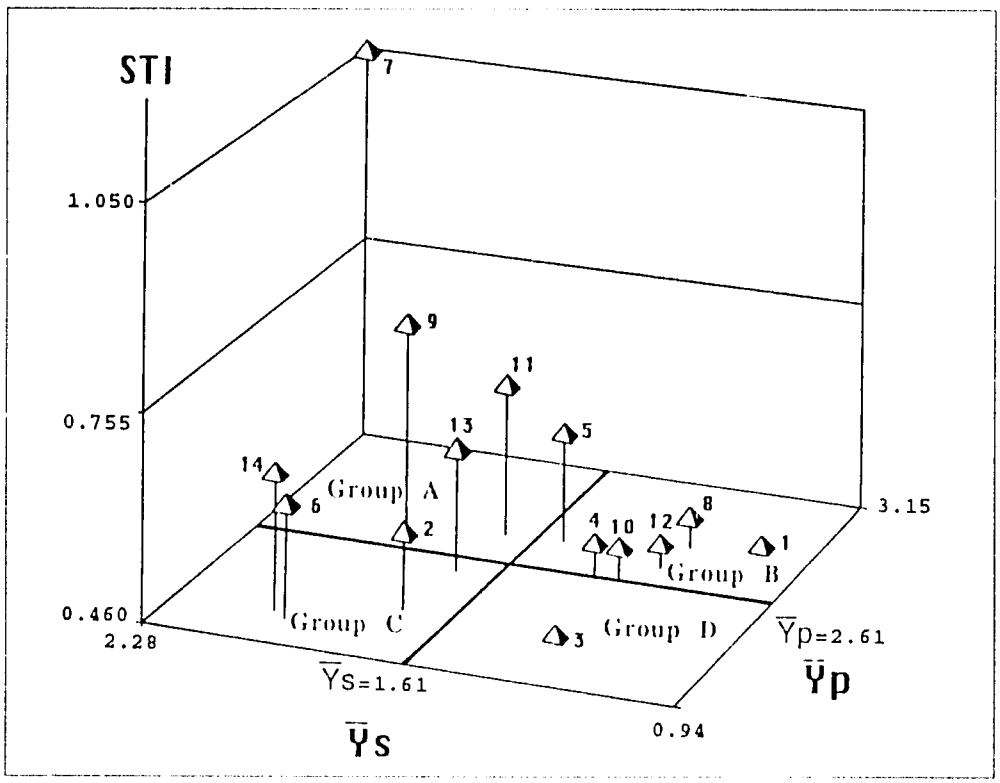

Fig. 4. **The 3-D plot among STI, Yp, and Ys under moderate conditions (SI = 0.38), AYT 2 spring 1993**

Group			
A	B	C	D
(7)[a] GC GC 84058-18-4	(1) GC GC 86017-170-1N	(2) GC 84058-21-4	(3) GC 84058-21-2
(9) GC 86018-427-3	(5) GC GC 84051-32-1	(6) GC 84051-9-1	(4) GC 86049-35-2-1-1-8-1N
	(11) GC 84040-7-1	(8) GC 84040-27-1	(13) AGS 302
	(10) GC 84040-16-1	(14) SRE-D-14B	
	(12) AGS 129		

[a]Numbers in parentheses are code numbers.

AYT, 1992. The results of the analysis of variance for spring and summer; summer and autumn; and spring, summer, and autumn 1992 for AYT 1 are presented in tables 5-7. As in the past years, highly significant differences were observed between genotypes (G) and between seasons (S), and the GxS interaction was also significant for yield and 100-seed weight (tables 5-7). The estimates of components of variance for yield in AYT 1 were calculated as shown in table 8. The proportion of variance due to seasons for yield was substantial compared to that due to G or GxS. The differences in environmental conditions between years and seasons influence the performance of the genotypes considerably. The direction of breeding should be geared toward selection for specific season adapted genotypes. However, the genotype should be less

sensitive to photoperiod and temperature within a given season. The mean yield of genotypes is shown in table 9. Two genotypes, GC 87019-4-1B-4 and GC 86004-9, have adapted to multiple seasons combined with levels of resistance to both downy mildew and bacterial wilt (table 9). Although these genotypes have adapted to multiple season, the stability analysis for yield showed that possibly only GC 87016-12S-2B had yield stability regardless of environment.

Table 5. Combined analysis of variance of AYT 1 data from spring and summer 1992

Source of variance	Yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
Between genotypes (G)	13	0.0919	2.57	0.0053	13	0.0644	54.24	0.0001
Between seasons (S)	1	53.6558	1499.69	0.0001	1	2.0657	1739.37	0.0001
GxS	13	0.2543	7.11	0.0001	13	0.0121	10.21	0.0001
Error	78	0.0358			78	0.0012		

Table 6. Combined analysis of variance of AYT 1 data from summer and autumn 1992

Source of variance	Yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
Between genotypes (G)	13	0.0752	2.75	0.0029	13	0.0479	73.77	0.0001
Between seasons (S)	1	3.2892	120.41	0.0001	1	1.2758	1963.49	0.0001
GxS	13	0.1696	6.21	0.0001	13	0.0058	8.93	0.0001
Error	78	0.0273			78	0.0006		

Table 7. Combined analysis of AYT 1 trial data in spring, summer, and autumn 1992

Source of variance	Yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
Between genotypes (G)	13	0.0948	2.63	0.0030	13	0.0909	86.95	0.0001
Between seasons (S)	2	29.1068	806.28	0.0001	2	1.1454	1095.5	0.0001
GxS	26	0.1893	5.24	0.0001	26	0.0096	9.21	0.0001
Error	117	0.0361			117	0.001		

Table 8. Percent contribution of each component of variance to the total variance for yield of AYT 1, 1992

Component of variance	SP + SU	SU + AU	SP + SU + AU
σ^2G	0.66 (0.0053)	4.71 (0.0029)	1.22 (0.0030)
σ^2S	90.76 (0.0001)	45.82 (0.0001)	86.4 (0.0001)
σ^2SG	5.18 (0.0001)	27.97 (0.0001)	6.38 (0.0001)
σ^2	3.39	21.49	6.0

Table 9. Promising selections from the combined analysis of AYT 1 in spring, summer, and autumn 1992

Adaptation to seasons	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction DM	BP	Rust (%)
Spring, summer, and autumn						
GC 87019-4-1B-4	2.3 a[a]	100 c	21.7 c	R	MS	36
Summer and autumn						
GC 86004-9	1.8 a-d	97 bc	16.4 i	MR	R	35
Spring and autumn						
GC 86004-9	1.9 a	102 ab	17.9 g	MR	R	35
Spring and summer						
GC 87019-4-1B-4	2.4 a	101 c	20.8 d	R	MS	36
GC 86004-9	2.4 a	103 ab	17.4 f	MR	R	35

[a]Values followed by the same letter are not significantly different from each other at 5% level (DMRT).

Incorporation of Bacterial Pustule and Downy Mildew Resistance into Advanced Lines

Summary

One of the major objectives of AVRDC's soybean program is to combine resistance to bacterial pustule (BP) and downy mildew (DM) with high yield. This is in addition to incorporating adaptation to more than one season and tolerance to soybean rust. A number of entries have been entered into advanced and intermediate yield trials. The analysis of the data from different seasons confirmed our previous findings that spring is the highest yielding season followed by summer and autumn. Two selections, GC 87019-4-1B-4 and GC 86004-9, have adaptation to multiple seasons with resistance to BP and DM. GC 87016-12S-2B proved to have stable high yield across environments. Selections GC 86017-170-1N, GC 84040-27-1, and GC 84040-16-1 had high yield and resistance to BP and DM and tolerance to soybean rust. Several selections with multiple disease resistance and high yield were observed in the intermediate yield trial.

Introduction

In Asian countries bacterial pustule caused by *Xanthomonas phaseoli* var. *sojensis* is a serious disease during the hot-wet season. Downy mildew incited by *Peronospora manshurica* occurs in most growing areas. Resistance to BP is controlled by a single recessive allele (*rxp*) while resistance to DM is governed by a single dominant allele (*Rpm*). At AVRDC the objective of the varietal development project includes the selection for specific season and multiple season-adapted lines with high yield potential and multiple disease resistance.

Materials and Methods

Types of grain soybean trials conducted, number of entries evaluated and their respective sowing dates are given in table 1. The advanced yield trials (AYT) during February and August planting were conducted using a split-plot design with fungicide and no fungicide as main plots

and genotypes as subplots. Four replications were used. In the July planting, AYT was planted using RCBD with four replications. They were planted in 6-m-long, six-row plots. The harvest plot size was 5 x 2 m (four middle rows).

The intermediate yield trial (IYT) was planted in RCBD with two replications. Each 5 x 2 m plot was composed of four rows.

Results and Discussion

AYT, 1991-93. The yield data from spring, summer, and autumn 1991 AYT; spring and autumn 1992 AYT 2; and spring 1993 AYT 2 were analyzed together to understand the GxE interaction. The combined analysis of variance confirmed our previous findings for individual year analysis that seasonal factors are highly significant for yield. Differences between genotypes and GxS interaction were also highly significant (table 10). Higher yields were obtained from spring followed by summer and autumn (table 11).

Table 10. Combined analysis of variance of AYT data from spring 1991 to spring 1993

Source of variance	Yield			
	DF	MS (x10^6)	F	Pr>F
Between season (S)	5	9.0076	57.71	0.0001
R (S)	18	0.1561	2.90	0.0001
Between genotype (G)	13	1.3133	24.44	0.0001
SxG	65	0.2612	4.86	0.0001
Error	234	0.0537		

Table 11. Mean yield of genotypes in different seasons and years

Year and season	Mean yield (t/ha)
1991 spring	2.7 b[a]
1991 summer	2.6 b
1991 autumn	2.2 c
1992 spring	3.2 a
1992 autumn	2.1 c
1993 spring	2.6 b

[a]Values followed by the same letter are not significantly different at the 5% level (DMRT).

The estimates of components of variance for yield showed that the proportion of variance due to seasons was the largest while that due to genotypes was next to season. Three genotypes, GC 86017-170-1N (2.9 t/ha), GC 84040-27-1 (2.9 t/ha), and GC 84040-16-1 (2.8 t/ha), had significantly higher yield than the check varieties (2.4 t/ha). Their standard error of b in the stability analysis was also significant suggesting that they are stable. Among the three GC 86017-170-1N has the highest yield and has the best stability (fig. 5). It has moderate resistance to DM and BP, and the lowest rust percentage (31%). However, according to 3-D plotting of potential yield, yield with rust stress, and rust stress index, GC 86017-170-1N belonged to group B which performed favorably only with fungicide treatment.

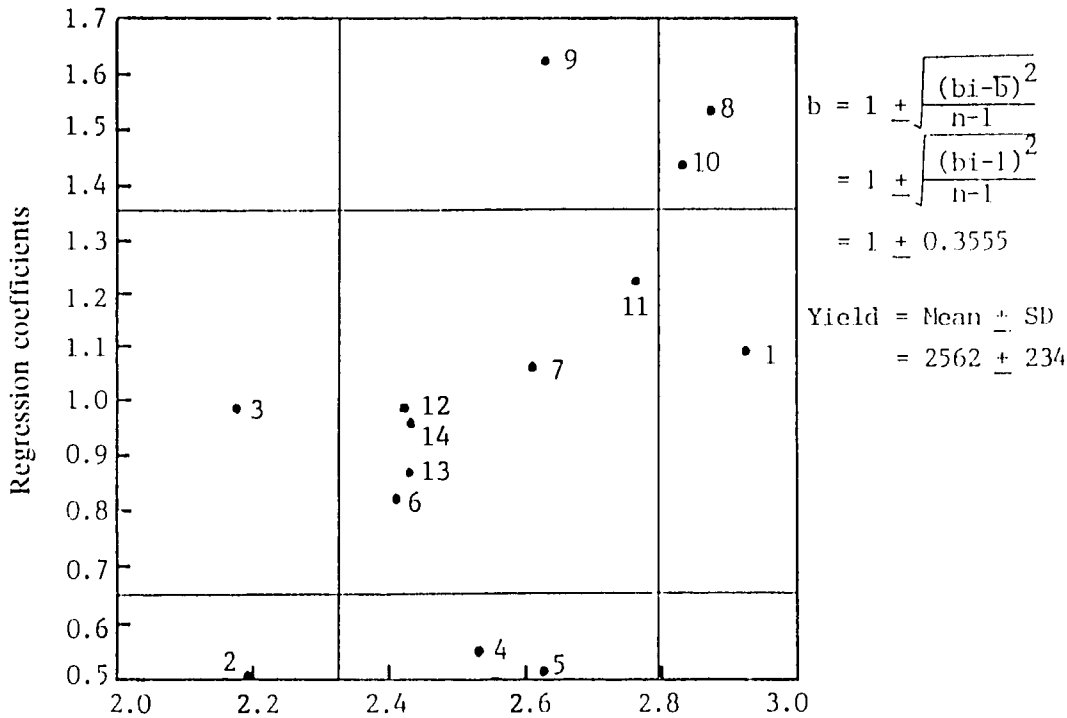

Fig 5. The relationship of variety adaptation (regression coefficient) and variety mean yield in AYT; 14 soybean varieties grown in six seasons from spring 1991 to spring 1993

Evaluation of the same genotypes can be conducted in more locations for at least two years so that reliable rust-tolerant high-yielding lines could be selected.

IYT 1 and 2, 1992. A combined analysis of spring, summer, and autumn IYT 1, and IYT 2 showed that there were highly significant differences for yield and 100-seed weight between genotypes, seasons, and GxS. However, in both IYT 1 and IYT 2 the proportion of variance due to seasons was predominant for both yield and 100-seed weight (table 12). Promising selections with resistance to BP and DM are shown in tables 13 and 14. The highest yield was 3.5 t/ha in 109 days by GC 87031-3-9 in IYT 2.

Table 12. Combined analysis of IYT trial data in spring, summer, and autumn 1992

Source of variance	Yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
AYT 1								
Between genotypes (G)	53	0.5835	10.28	0.0001	53	82.0333	95.59	0.0001
Between seasons (S)	2	158.2793	2789.63	0.0001	2	1054.5075	1228.77	0.0001
GxS	106	0.2399	4.23	0.0001	106	4.4648	5.2	0.0001
Error	159	0.0567			159	0.8582		
IYT 2								
Between genotypes (G)	41	29.4849	9.09	0.0001	41	134.9722	151.96	0.0001
Between seasons (S)	2	285.9437	3356.43	0.0001	2	1343.6402	102.47	0.0017
GxS	82	17.2606	2.66	0.0001	82	6.1195	6.89	0.0001
Error	123	0.0791			123	0.8882		

Table 13. Promising selections from IYT 1, autumn 1992

Entry	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction DM	BP
GC 87033-8-B-2	2.9	108	13.4	MR	MS
GC 87033-21-B-1	2.7	106	11.7	MR	R
GC 87036-2-2	2.4	100	23.3	R	MR
GC 87034-1-2	2.4	99	17.9	R	MR
GC 88037-35-1-1	2.4	103	24.9	MR	MR
GC 87032-1-1-2	2.3	100	14.3	R	MR
GC 87033-22-B-3	2.3	103	13.1	MR	MR
GC 87033-22-B-4	2.1	101	14.3	MR	MR
AGS 302 (ck)	2.1	100	25.3	R	MR
AGS 129 (ck)	2.0	99	18.1	HS	HR
AGS 181 (ck)	1.8	87	15.5	R	MS
Mean of 54 entries	2.2	102	17.6		
c.v. (%)	7.7	2	3.7		
LSD (0.05)	0.4	3	1.3		

Table 14. Promising selections from IYT 2, autumn 1992

Entry	Yield (t/ha)	Days to maturity	100-seed wt (g)	Disease reaction DM	BP
GC 87031-3-9	3.4	109	10.8	MR	MR
GC 87032-2-10	2.8	105	10.8	R	MR
GC 87023-2-2	2.8	102	12.0	MR	MS
GC 87027-3-7	2.4	98	12.5	MR	MR
GC 86004-727-1	2.4	104	19.7	R	MR
GC 88041-11-4-1	2.3	105	19.1	R	R
GC 87027-3-6	2.3	104	9.4	MR	R
GC 87030-1S-1	2.2	104	19.2	R	MR
GC 87027-1S-1	2.1	100	10.4	R	MR
373-1	2.1	99	18.8	R	MR
AGS 302 (ck)	2.0	99	25.5	R	MR
AGS 129 (ck)	2.0	99	18.0	HS	HR
AGS 181 (ck)	1.6	87	14.5	R	MS
Mean of 42 entries	2.1	100	18.2		
c.v. (%)	10.1	2	4.2		
LSD (0.05)	0.4	4	1.5		

Breeding Appropriate Vegetable Soybean

Summary

Vegetable soybean (known as *edamame* in Japan, *maotou* in China, and *poot kong* in Korea) is one of the tastiest soyfoods in the East. It has great potential to enhance the nutritional health in the developing countries of Asia and Africa. Many Asian, African, and American countries are currently using grain soybeans as vegetable soybeans. Therefore, AVRDC's vegetable soybean program is specifically directed to develop varieties adapted for the tropics and subtropics with high yield potential disease resistance and good consumer qualities. A total of 726 crossed seeds from 54 hybridizations were obtained. Selections from the crosses were entered into advanced and intermediate yield trials at AVRDC and at Kaohsiung District Agricultural Improvement Station (DAIS) in spring and autumn. Higher yields were obtained at AVRDC but low yields at Kaohsiung (DAIS) during spring. During autumn high yields were obtained at Kaohsiung DAIS and low yields at AVRDC. Since photoperiod is almost similar in both locations, it is likely that temperature and edaphic factors were responsible for these differences in yield. New breeding lines with standard pod yield of up to 9 t/ha have been identified in the 1992 trials. In the 1993 trials, the standard pod yield were up to 10.5 t/ha in selected entries. The quality characteristics are highly location and season specific. It is essential to understand the heritability of these traits to systematically design the breeding method to combine desirable quality traits.

Introduction

Vegetable soybean is soybean harvested after the R_6 and before R_7 growth stage while the pod is still green and the seeds have developed to fill 80-90% of the pod. It has great potential to enhance the nutritional value of most cereal-based diets, particularly in developing Asian and African countries. It can be cooked and eaten as a snack. The green beans can be shelled, cooked alone or with meat and other vegetables. They have a slightly sweet taste compared to grain soybean. In the past, vegetable soybeans adapted to the tropics were unavailable. Therefore, many countries used grain soybeans as vegetable soybeans.

AVRDC's vegetable soybean program is designed specifically for the tropics and subtropics. The spin-off from the program could be used for temperate environments as well. The major breeding objectives in developing tropical and subtropical vegetable soybean are higher yield potential, disease resistance, and good consumer qualities. The horticultural quality characteristics include pod and seed color, appearance, flavor, texture, taste, size of pod and seed, and the number of seeds per pod.

High yield and quality characters are some of the criteria used for making new cross combinations. Selections from F_2 to F_5 generations are used to cross with better quality vegetable soybean to incorporate quality characteristics. Large-pod soybeans from the tropics are used as one parent to retain the tropical adaptation, while temperate vegetable soybeans are used as the other parent. Bacterial pustule, downy mildew, and soybean rust resistance/tolerance are the other objectives in crossing.

Vegetable soybean breeding activities include greenhouse and field observation of new accessions, generation advance, pedigree evaluation, quality assessment in the laboratory, and yield trials. Yield trials were conducted both at AVRDC and at Kaohsiung DAIS. The results of crosses and yield trials are presented here.

Materials and Methods

Selections from F_5 generation of crosses between large-seeded Neu Ta Pien from China were crossed with Ryokkoh which has excellent and desirable green color. Similarly, F_2 selections from large-seeded Tanbaguro from Japan were also crossed with Ryokkoh. OCB from Thailand crossed with Neu Ta Pien was crossed with Kaohsiung No. 2 to improve the size and color.

Some of the varieties adapted to Thailand (such as TVB-5, White Lion, and KPS 292) have been crossed with other promising crosses with large seed and good quality such as Ryokkoh.

In 1992, AYT for vegetable soybean (AYT VS) and IYT for vegetable soybean (IYT VS) were conducted at AVRDC and Kaohsiung DAIS. In 1993 AYT VS was conducted at Kaohsiung DAIS. The number of entries and their planting dates are given in table 15. All trials were conducted using RCBD. AYT VS had four replications while IYT VS had two replications. AYT VS trials were planted in four-row plots of 5 x 2 m, and the harvest plot size was 5 x 1 m (the middle two rows). IYT VS was planted in four-row plots of 3 x 2 m. AVRDC's suggested cultural practices were followed at AVRDC. At Kaohsiung DAIS, vegetable soybean was planted following rice without land preparation. Observations were made on days to R_1 and R_2 growth stages; 100-seed weight at R_6 growth stage; graded pods (two-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 noted. Number and weight of damaged pods, as well as harvest index for graded pod and total pod were also calculated.

Table 15. Details on number of entries and planting date for vegetable soybean yield trials at Kaohsiung DAIS and AVRDC, 1992 and 1993

Experiment	No. of entries plus (checks)	Date of planting
1992		
AYT (AVRDC)	15 (3)	1 October 1992
AYT (KS DAIS)	15 (3)	6 October 1992
IYT (AVRDC)	21 (3)	2 October 1992
IYT (KS DAIS)	21 (3)	8 October 1992
1993		
AYT (AVRDC)	11 (3)	1 March 1993
AYT (KS DAIS)	11 (3)	10 February 1993
IYT (KS DAIS)	13 (3)	10 February 1993

All the data from each location were analyzed. Whenever seasons were involved, a combined analysis was done and estimates of components of variance were determined for graded pod yield.

Results and Discussion

A total of 726 crossed seeds from 54 cross combinations were obtained. Seven crosses were made specifically as part of the ROC Council of Agriculture's special project. Majority of the remaining crosses were made for adaptation to the tropics and to combine resistance/tolerance to downy mildew, bacterial pustule and soybean rust.

Yield trials, 1992. Estimates of the components of variance for standard pod yield for AYT in spring and autumn 1992 showed that at AVRDC the proportion of variance due to season was the largest followed by genotypes and GxS (table 16). However, at Kaohsiung DAIS the proportion of variance due to GxS was the largest followed by genotypes and the season was the lowest, although it is also highly significant (table 16).

Tables 16. Estimates of the components of variance for standard pod yield of AYT VS, 1992

Component of variance	SP + AU estimate
AVRDC	
σ^2G	26.06% (0.0001)
σ^2S	47.68% (0.0001)
σ^2SG	14.36% (0.0001)
σ^2	11.90%
Kaohsiung DAIS	
σ^2G	20.93% (0.0001)
σ^2S	6.71% (0.0001)
σ^2SG	54.93% (0.0001)
σ^2	17.43%

A combined analysis of spring and autumn at both locations for standard pod yield, 100-seed weight, total pod yield and biomass yield showed that the differences between G, S, locations (L), and all the first order and second order interactions were highly significant (tables 17a and 17b). The estimates of the components of variance are presented in table 18; all of them are highly significant. For standard pod yield the major component of variance was σ^2L. Kaohsiung DAIS had higher yield than AVRDC. But for 100-seed weight and pod yield σ^2S was the highest. For total biomass σ^2S had 30% and σ^2SL 42% of the variance. The results of the 1992 AYT data contradicted those of 1991.

Table 17a. Combined analysis of AVRDC and Kaohsiung DAIS of AYT VS, spring and autumn 1992

Source of variance	Standard pod yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
Between genotypes (G)	17	6.9093	17.88	0.0001	17	2.6820	16.79	0.0001
Between seasons (S)	1	108.7258	281.3	0.0001	1	85.5868	535.66	0.0001
GxS	17	3.2416	8.39	0.0001	17	0.9259	5.79	0.0001
Between location (L)	1	493.5440	1276.91	0.0001	1	27.5158	172.21	0.0001
SxL	1	40.7442	105.41	0.0001	1	1.2535	7.85	0.0056
VxL	17	5.1507	13.33	0.0001	17	1.6252	10.17	0.0001
VxSxL	17	3.4779	9.0	0.0001	17	1.5447	9.67	0.0001
R (SxL)	12	0.4667	1.21	0.2796	12	0.1074	0.67	0.7769
Error	204	0.3865						

Table 17b. Combined analysis of AVRDC and Kaohsiung DAIS of AYT VS, spring and autumn 1992

Source of variance	Pod yield				100-seed wt			
	DF	MS (10^6)	F	Pr>F	DF	MS (10^2)	F	Pr>F
Between genotypes (G)	17	9.6822	17.35	0.0001	17	66.6018	32.8	0.0001
Between seasons (S)	1	428.5216	767.8	0.0001	1	1825.9105	899.14	0.0001
GxS	17	3.7059	6.64	0.0001	17	8.0434	3.96	0.0001
Between location (L)	1	87.2505	156.33	0.0001	1	128.1945	63.13	0.0001
SxL	1	160.8865	288.27	0.0001	1	1249.4852	615.29	0.0001
VxL	17	5.9046	10.58	0.0001	17	22.5910	11.12	0.0001
VxSxL	17	2.7293	4.89	0.0001	17	7.4570	3.67	0.0001
R (SxL)	12	0.8449	1.51	0.1212	12	4.0287	1.98	0.0272
Error	204	0.5581			204	2.0307		

Table 18. Estimates of the components of variance (%) for AVRDC and Kaohsiung DAIS of AYT VS, spring and autumn 1992

Component of variance	Standard pod yield	100-seed wt	Pod yield	Biomass yield
σ^2G	6	9	7	10
σ^2S	10	34	35	30
σ^2L	47	11	7	2
σ^2GS	5	6	5	2
σ^2GL	8	10	8	6
σ^2SL	8	1	26	42
σ^2SLG	11	20	6	3
σ^2	5	9	6	5

The differences in maximum and minimum temperature between AVRDC and Kaohsiung DAIS are shown in fig. 6. In spring the temperature is slightly higher in Kaohsiung DAIS than at AVRDC. Although the maximum temperature in the autumn was higher at Kaohsiung DAIS, the minimum temperature was almost the same. The soil at Kaohsiung DAIS is clay loam and is better in inherent fertility than at AVRDC which is calcareous with low organic matter. These factors together with differences in genotypes resulted in the variability of performance between years and locations. At least at present, a widely adapted single vegetable soybean is unavailable among the new genotypes.

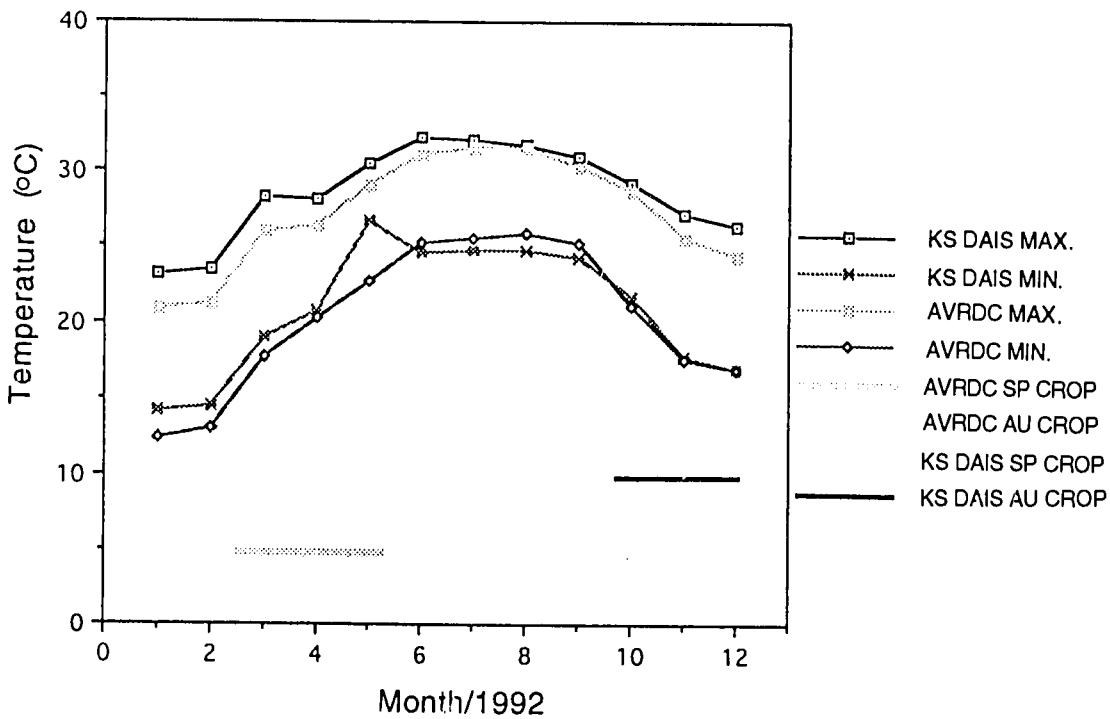

Fig 6. Differences in maximum and minimum temperature between AVRDC and Kaohsiung DAIS in 1992

At AVRDC GC 87009-8-4-2 had significantly higher standard pod yield (7.3 t/ha) than all the three checks, but almost all the entries except GC 87010-34-3-1 outyielded KS No. 1. All selected genotypes were 3 to 11 days later maturing than KS No. 1; GC 87009-8-4-2 matured 81 DAS, the same as KS No. 2 and No. 3.

At Kaohsiung DAIS the standard pod yield of GC 87010-34-1 (8.7 t/ha) was significantly higher than those of the checks KS No. 1 and KS No. 2. GC 86057-6-1-9 had a standard pod yield of 8.6 t/ha in 65 days, three days earlier than KS No. 1.

In general, protein content of vegetable soybean was lower (38- 43.3%) at AVRDC than at Kaohsiung DAIS (41.7-44.1%). Similarly, the fat content was also lower at AVRDC (18.0%-19.3%) than at Kaohsiung DAIS (18.2-19.5%). But sugar and starch contents were higher at AVRDC than at Kaohsiung DAIS. A color value of below 3.5 was acceptable. The lower the value the darker is the green color which is preferred by consumers. Fiber content and hardness should have lower value for better consumer acceptance.

Analysis of the spring and autumn AYT data from AVRDC for quality traits showed that the genotypic differences were highly significant for dry matter, protein, sugar, color value and hardness (tables 19a-19e). The data suggest that the proportion of variance due to seasons was highest for all quality attributes. Only for dry matter and hardness was the proportion of variance due to GxS high followed by genotypes (table 20). The results suggest that the quality characters are influenced by specific seasons and environmental fluctuations between years. The conclusion is substantiated by the nonsignificant correlation between the two locations for all quality attributes (table 21). Therefore, quality traits are highly location specific. Further studies are needed to determine the heritability of these traits so that appropriate breeding methods can be used.

AYT VS, 1993. In spring, the yield differences between AVRDC and Kaohsiung DAIS were dramatic. At AVRDC, there were no significant differences between the highest yielding genotypes and the check varieties. However, some of those with yields up to 10 t/ha need to be reexamined at other locations. During spring AVRDC is a higher yielding location than Kaohsiung DAIS.

IYT VS, 1992. Unlike the AYT VS spring data, the results of IYT VS were quite the opposite. Graded pod yield at AVRDC was considerably lower than at Kaohsiung DAIS. The highest yield at AVRDC was 5.6 t/ha while at Kaohsiung DAIS it was 9.0 t/ha. Although the yield differences were not significant among the selected high yielding entries and the check varieties, some of the newer selections had higher sugar content than the check varieties.

Table 19a. Combined analysis of AYT vegetable soybean trial data, spring and autumn 1992

Source of variance	Dry matter				Protein				Fat			
	DF	MS	F	Pr>F	DF	MS	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	17	5.7983	4.37	0.0001	17	6.9236	4.32	0.0001	17	1.0947	1.93	0.0229
Between seasons (S)	1	0.611	0.46	0.4991	1	110.32	68.85	0.0001	1	111.496	196.94	0.0001
GxS	17	7.0803	5.33	0.0001	17	7.6454	4.77	0.0001	17	0.8338	1.47	0.1199
Error	102	1.3281			102	1.6024			102	0.5661		

Table 19b. Combined analysis of AYT vegetable soybean trial data, spring and autumn 1992

Source of variance	Sugar				Starch				Hardness			
	DF	MS	F	Pr>F	DF	MS	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	17	1.6651	2.61	0.0015	17	1.2037	1.6	0.0767	17	0.0404	1.2	0.2788
Between seasons (S)	1	73.345	115.06	0.0001	1	49.444	65.87	0.0001	1	19.6028	581.2	0.0001
GxS	17	1.1627	1.82	0.0346	17	1.9531	2.6	0.0016	17	0.0577	1.71	0.0524
Error	102	0.6375			102	0.7506			102	0.0337		

Table 19c. Combined analysis of AYT vegetable soybean trial data, spring and autumn 1992

Source of variance	Color value				Hardness			
	DF	MS	F	Pr>F	DF	MS	F	Pr>F
Between genotypes (G)	17	0.1163	2.85	0.0006	17	1.3716	9.69	0.0001
Between seasons (S)	1	0.8867	21.72	0.0001	1	6.3085	44.57	0.0001
GxS	17	0.0899	2.2	0.0080	17	1.4985	10.59	0.0001
Error	102	0.0408			102	0.1415		

Table 20. Estimates of the components of variance (%) for chemical content of AYT vegetable soybean, spring and autumn 1992

Component of variance	Dry matter	Protein	Fat	Sugar	Starch	Fiber	Color value	Hardness
σ^2G	16.82	12.67	3.11	6.81	3.35	0.32	14.29	20.83
σ^2S	-	28.54	68.45	52.88	37.99	86.81	14.29	12.5
σ^2SG	43.24	28.54	3.11	6.81	16.76	3.22	14.28	47.22
σ^2	39.94	30.25	25.33	33.5	41.9	9.65	57.14	19.45

Table 21. Correlation between AVRDC and Kaohsiung DAIS AYT VS, autumn 1992

	Pearson correlation coefficient					
Dry matter	Protein	Fat	Sugar	Starch	Fiber	Hardness
-0.164 NS	0.020 NS	0.175 NS	0.266 NS	0.176 NS	-0.091 NS	-0.104 NS

Breeding for Limabean Pod Borer Resistance in Soybean Using Brazilian Lines

Summary

Among the pests of soybean limabean pod borer, *Etiella zinckenella* is serious since it directly affects the economic product: pods and seeds. Control of the insect by conventional means, including insecticide, is difficult due to its concealed feeding habit. Soybean lines resistant to stink bug developed using PI 227687, an insect-resistant line, were used as parents in crosses with AGS lines to develop limabean pod borer-resistant lines. F_4 generation pedigrees selected for least limabean pod borer damage were used for further selection. Progenies of 33 F_4 pedigrees in F_5 were screened for pod borer damage. Pod borer damage ranged from 0 to 88%. Both the Brazilian resistant parent and the susceptible AGS lines had no pod damage. It is likely that resistant alleles are present in both susceptible and resistant parents. Using a truncation point of less than or equal to 5% damaged pods, effective selection intensity for different crosses varied from 0.9 to 1.6. Results suggest that some crosses such as GC 90014 and GC 90004 have higher favorable gene frequencies than other crosses.

Introduction

Limabean pod borer, *Etiella zinckenella*, is a serious pest of soybean and several other species of legumes in tropical to subtropical Asia. Adults lay eggs on green pods and larvae bore inside and feed on developing seeds. Fully mature larvae escape the pods and pupate in the soil. Because of its concealed feeding and pupation habits, this insect is difficult to control by conventional means, including insecticide use. Therefore, research at AVRDC aims at breeding pod borer-resistant soybean cultivars. Despite repeated screenings of soybean germplasm, a truly resistant soybean accession has not been found.

In 1993, F_5 generation from crosses between AGS lines and stink bug-resistant lines from Brazil were screened for resistance to limabean pod borer. These were derived from 54 F_4

pedigrees from six crosses. Among them, 33 pedigrees were selected as least damaged by the limabean pod borer. In the F_3 and F_4 generations also the statistical analysis of the data indicated that there was no correlation between seed size and percentage of pods damaged by the pod borer. Therefore, the data suggested that true genetic resistance to the pest is present in the selections. To ascertain further segregation for resistance the progenies of 33 pedigrees were screened.

Materials and Methods

A parcel of land was rototilled and 0.75-m-wide beds were formed. The beds were divided into 13.5-m-long single-row plots. Seeds of progenies of 33 F_4 pedigrees from six crosses were sown at a spacing of 10 cm between plants within the row. Susceptible check KS 9, four susceptible parents — AGS 129, AGS 313, 269, and AGS 327 — and three resistant parents were planted in each plot with other entries once at the beginning of the trial, then again at 3 wk and 6 wk after the first planting to compensate for differences in damage due to differences in days to maturity. A month after the first planting (15 January 1993), the entire planted area was covered by a 2-m-high fine mesh nylon net cover. At irregular intervals throughout the pod filling and maturing period, a large number of laboratory-reared limabean pod borer adults were released inside the cage to initiate insect infestation. At full maturity, individual plants were harvested separately and the total number of pods and damaged pods were recorded; the percent of damaged pods was calculated. Simultaneously, 4 x 100 seed samples from each entry were weighed and 100-seed weight was determined.

Results and Discussion

The pod borer damage ranged from 0 to 88% (table 22). Among the resistant parents only IAC 78-2318 had plants with no damage. Among the susceptible parents AGS 327 and 269 also had plants with 0% damage. Assuming they are not escapes it is likely that resistant alleles are also present in the susceptible parents used in this study. Mean damaged pod ratio also suggested such a conclusion.

Table 22. Mean pod damage ratio of seven parents and a susceptible check

Parent	No. of plants	Damage pod ratio			
		Min.	Max.	Mean	Std. Dev.
AGS 129	28	2.22	31.75	13.4	7.39
AGS 327 (OCB)	65	0	88.46	29.06	27.03
269	27	0	42.31	12.02	8.27
IAC 100	38	3.08	30.77	12.87	7.18
IAC 78-2318	37	0	39.29	11.20	9.09
IAC 80-4228	21	3.85	30.77	11.30	7.40
AGS 313	78	2.86	72.06	29.73	16.69
KS 9 (ck)	71	2.27	100	66.17	33.44

After evaluating the damaged pods in each plant, a truncation point of less than or equal to 5% damaged pods per plant was used for effective selection.

The intensity of selection was calculated using the formula $i = S/\sigma p$, where S is the effective selection differential, IX selection - X totall. Out of a total of 1010 progenies from six crosses 117 pedigrees were selected (11.6%). The mean percent of damaged pods for the population in each cross varied from 7.8 ± 5.1 for GC 90014 to 20.0 ± 12.5 for GC 89048. As a result of selection based on a truncation point of less than or equal to 5% damaged pods, the mean of selected

pedigrees was 2.1 ± 2.5 to 4.1 ± 0.9. The effective selection intensity ($i = S/\sigma p$) ranged from 0.94 to 1.60. Where the selection intensity (i) was less, more plants have been selected; there were fewer selections when i is larger.

Assuming that the gene frequencies are the same in all populations derived from all crosses, the number of selections would tend to increase as the population increases. However, if the gene frequencies are different in different populations to begin with, then the number of selections will be more in the crosses with higher favorable gene frequencies. Based on this argument, it appears that GC 90014 has more favorable gene frequencies than G 90001. GC 90004 is a reciprocal of GC 90014. The results from the succeeding generations will throw more light on this conclusion.

International Cooperation

Summary

In 1993, four new AVRDC lines were released and extended to farmers for cultivation in Taiwan (Tainan No. 2), Bangladesh [G 2120 (M7) 69-1], Vietnam (AK-05), and Sri Lanka (AGS 190). As of 1993 12 countries have released 26 improved varieties using AVRDC soybean selections. Thirty-two cooperators in 17 countries received 6 ASETS and 453 other lines. Another 26 cooperators from 14 countries received 8 AVSETS and 348 other vegetable soybean lines for evaluation. In Vietnam AGS 327, AGS 314, SRE-B-15C, and G 9956 significantly outyielded local checks. In the Philippines vegetable soybean G 10142 produced 19 t/ha graded pod in 60 days. A total of 46 kg seeds of F_2 and bulk population were produced at AVRDC during the off-season and airfreighted to Korea.

Introduction

Researchers from the national agricultural research systems (NARS) and from private agencies request germplasm and improved breeding lines from AVRDC, either for direct release to their farmers after evaluation or for use in their breeding programs. Majority of the scientists return the data from their trials to AVRDC, commenting on the performance of the AVRDC materials relative to their local check varieties. NARS scientists also periodically raise issues confronted by their farmers in cultivating soybeans efficiently and economically. AVRDC recognizes the ongoing national research activities, anticipates the future needs of different NARS, and tries to undertake research which can assist and strengthen their efforts.

Variety Release

On 20 May 1993 the Tainan DAIS released AVRDC selection GC 81077-4S-33 as Tainan No. 2. It is higher yielding than KS No. 10, has narrow leaflet, is suitable for spring and summer planting, is resistant to downy mildew, and moderately resistant to bacterial pustule. It is also suitable for mechanical harvesting.

In Bangladesh, the Mennonite Central Committee (MCC) has identified G 2120 (M7) 69-1 as a good variety; it is planted by farmers. It is early maturing and high yielding with good seed viability and germination.

In Vietnam, AVRDC accession G 2261 has been released as AK-05. It is tolerant to soybean rust, resistant to bacterial pustule and suitable for spring and winter planting.

In Sri Lanka, the Plenty Canada is extending AGS 190 to the farmers. It is large-seeded, high-yielding, and suitable for making soybean milk and soy ice cream. It has a less beany flavor which is acceptable to consumers. The list of varieties released so far are given in table 23.

Table 23. AVRDC soybean released by cooperators (as of November 1993)

Local name	AVRDC ID no.	Year	Country	Remarks
	G 2120 (M7) 69-1	1993	Bangladesh	HY, EM, LSV, G
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
Krakatau	AGS 66	1992	Indonesia	R, CMMV
Taiwan 30050	AGS 17	1982	Malaysia	HY, MH
BPI Sy4	AGS 73	1985	Philippines	HY, EM, UM, LSV, BP, R, L, S, WA
La Carlotta Soy-1 (PSBSY-1)	Clark 63 x AGS 129 (LGSY 01-24)	1990	Philippines	(BP, R), EM, UM, L, (S), acceptable to Nestlé
BPI-Sy6 (Saguisag)	AGS 19	1990	Philippines	NL, HY, resistant to virus
AGS 190	AGS 190	1993	Sri Lanka	HY, suitable for soymilk and ice cream making and soynuts, less flavor
beany				
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
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
Tainan No. 2	GC 81077-4S-33	1993	Taiwan	NL, MH, HY, DM, (BP), suited to spring & summer planting
Sukothai No. 1	AGS 9	1986	Thailand	NL, HY, NP, (R, DM, PSS)
KPS 292	AGS 292	1992	Thailand	HY, VS
Dowling	G 58[a]	1978	USA	R, HY
AKO 3	G 2261[a]	1988	Vietnam	HY, EM
AK-05	G 2261[a]	1993	Vietnam	R, BP, HY, suited to spring and winter planting
	GC 30229-8 (AGS 19)	1983	Zimbabwe	NL, EM
Total	26		12	

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

RF: suited to cultivation in rice fallow
EM: early maturing
UM: uniformly maturing
HY: high-yielding
CLS: resistant to Cercospora leaf spot
NL: narrow leaflet
L: nonlodging
MH: suitable for mechanical harvesting
RCI: suitable for intercropping with rice or corn
ST: preferred for making tempeh
BF: resistant to beanfly
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
LSC: long seed viability
S: nonshattering
G: good germination
SP: suited to summer planting
WA: wide adaptability
BS: suited to bean sprouting
PSS: resistant to purple seed stain
CMMV: tolerant to CMMV

Distribution of AVRDC Germplasm and Elite Lines

Thirty-two cooperators from 17 countries requested and received 6 ASETS, 123 AGS selections, 171 pedigree lines, and 157 germplasm accessions for evaluation (table 24). Interest in vegetable soybean continues to be strong. A total of 26 cooperators from 14 countries requested and received 8 AVSETS, 64 AGS selections, 119 GC pedigrees, and 165 other germplasm accessions for evaluation and use in their breeding programs (table 25).

Table 24. Distribution of AVRDC soybean evaluation trial (ASET) and other enhanced germplasm to national programs in different countries, 1993

Country	No. of cooperators	Type of seed sent					
		ASET	AGS line	GC pedigree	Acc.	New acc.	Other
Bangladesh	2		5	14		1	
Brasil	1		5				
India	1	1					
Indonesia	2	1	2	6	5		1
Japan	2		3	2	4		6
Korea	1						67
Malaysia	1				1		
Mexico	2	1	10		1		
Oman	1		5				
Philippines	4	2	3	40	1		2
Sierra Leone	1		6	13			1
Singapore	2	1	4	6	4		
Taiwan, ROC	7		63	75	5	8	13
Thailand	2		7	9	3		
Ukraine	1		8	6		1	4
USA	1		2				
Vietnam	1				20		9
Total	32	6	123	171	44	10	103

Table 25. Distribution of AVRDC vegetable soybean evaluation trial and other enhanced germplasm to national programs in different countries, 1993

Country	No. of cooperators	Type of seed sent					
		ASET	AGS line	GC pedigree	Acc.	New acc.	Other
Bangladesh	1		1	4			1
India	2		18	11	5		
Indonesia	1	1		5			
Italy	1		1	4	2		
Korea	2	1	12	62	21	79	3
Lesotho	1		2		2		2
Malaysia	1	1					
Nepal	1		1	4			1
Philippines	6	3	16	6	2	3	
Taiwan, R.O.C.	4		3	11	2	2	9
Thailand	1	1					
Ukraine	1		1				
USA	3		7	12	14	9	3
Vietnam	1	1	2		5		
Total	26	8	64	119	53	93	19

Grain Soybean Trials

A summary of the results received from the cooperators from Vietnam are given in table 26.

In Vietnam, AGS 327, AGS 314, SRE-B-15C, and G 9956 has significantly outyielded the local check varieties. AVRDC entries were earlier maturing than the local checks.

Table 26. Summary of international cooperation results

Country/ Location/ Cooperator	Entry	Yield (t/ha)	Days to maturity	100-seed wt (g)	Seed quality	Remarks
Vietnam	AGS 327	1.3 a	78 f	15.8 ab	1 b	Date planted:
Lat. 10°57'	SRE-B-15C	1.3 a	84 d	13.6 bcd	1 b	15 Aug. 1992
50 m	SRE-D-14B	1.2 ab	89 b	17.1 ab	2 a	T: 14
Mr. Ha Huu Tien	AGS 9	1.2 ab	86 c	9.8 d	1 b	R: 2
	Local check	1.2 ab	84 d	13.3 bcd	1 b	Autumn
	Local check	1.1 ab	83 e	11.5 cd	1 b	
Vietnam	AGS 314	1.6 a	78 f	5.3 e	1 c	Date planted
Lat. 10°48'N	AGS 327	1.6 a	74 g	16.7 c	1 c	15 Dec. 1992
50 m	G 9956	1.5 ab	78 f	16.0 c	2 b	T: 14
Mr. Hoang Kim	AGS 205	1.5 bc	74 g	13.0 d	2 b	R: 3
	AGS 299	1.5 bc	80 c	15.7 c	2 b	Winter-spring
	AGS 9	1.4 c	82 b	15.7 c	2 b	
	AGS 129	1.3 d	82 b	16.0 c	2 b	
	Local check	1.4 c	82 b	13.7 d	1 c	
	Local check	1.1 e	85 a	13.3 d	1 c	
Vietnam	AGS 327	1.3 a	75 h	16.5 cd	1 c	Date planted:
Lat. 10°48'N	G 9956	1.3 a	84 d	17.0 c	1 c	14 Sept. 1992
50 m	AGS 314	1.2 ab	82 ef	6.0 h	1 c	T: 14
Mr. Hoang Kim	AGS 205	1.1 bcd	81 fg	13.5 fg	1 c	R: 2
	AGS 299	1.1 cde	80 g	15.5 de	2 b	Autumn-winter
	SRE-D-14B	1.0 def	89 a	22.5 a	3 a	
	AGS 9	1.0 def	89 a	15.5 de	2 b	
	AGS 73	1.0 efg	83 de	16.5 cd	3 a	
	AGS 129	0.9 fgh	86 bc	14.5 ef	2 b	
	Local check	1.2 abc	86 bc	13.5 fg	1 c	
	Local check	0.9 gh	90 a	13.0 g	1 c	

Vegetable Soybean

Philippines. A graded pod yield of up to 19 t/ha has been obtained with G 10142 in 60 days which shows the potential for vegetable soybean production in the Philippines (table 27).

Malaysia. AGS 334 and AGS 292 appear to be promising in Malaysia. The data given in table 28 are in plots of 5 x 1 m^2.

Seed Multiplication for Korea

As in the past years, generation advance and seed multiplication of Korean soybean breeding lines were successfully carried out during spring 1993. An F_3 bulk population was multiplied and 60 kg seeds were harvested by SSD. A total of about 46 kg seeds of F_2 and bulk population were airfreighted to Korea on 28 May 1993. Since the rain did not affect the harvest, seed quality was excellent. The seeds will be planted in Suwon and Milyang Experiment Stations.

Table 27. Promising selections from PYT vegetable soybean in the Philippines, wet season, 1992

Entry	Yield (t/ha) grade 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 pod/ 500 g
G 10142	19.3	22.4	52.51	45.24	60	5.2	1.4	52.0	171
G 10494	18.8	20.7	42.45	38.55	61	5.0	1.3	37.3	216
G 10503	18.5	22.4	39.09	32.33	61	5.0	1.3	44.0	231
AGS 190	18.3	19.9	25.25	23.24	77	5.2	1.5	51.0	204
AGS 191	17.8	19.4	26.37	24.27	81	5.7	1.4	56.0	192

Table 28. Promising selections of vegetable soybean, in Malaysia 1993

Entry	Yield (t/ha) grade 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 pod/ 500 g
AGS 334	3.1	8.4	42.12	15.78	78	4.6	1.1	64.3	296
AGS 292	2.8	6.3	51.35	22.81	66	4.9	1.1	57.0	265
AGS 328	2.2	6.2	44.12	15.99	77	5.4	1.2	69.9	248
AGS 335	2.2	6.9	44.85	14.25	74	5.0	1.2	66.7	274
AGS 331	1.6	6.1	45.62	12.39	69	4.7	1.1	69.9	281

Soybean Pathology

Bacterial Pustule Development and Associated Yield Loss in Nine Soybean Lines

Summary

Nine soybean lines were inoculated with *Xanthomonas campestris* pv. *glycines*, the cause of bacterial pustule, or kept disease-free in an experiment in 1991 and 1992. In each trial, data were recorded on the percent leaf area infected, defoliation, 100-seed weight (OSW), and yield. Calculations were made to determine the area under the disease progress curve (DPC), area under defoliation progress curve (DEFPC), and area under green leaf area progress curve (GLAPC). Percentage yield, OSW, DEFPC and GLAPC of control plots were used to compare lines. Bacterial pustule development, DPC, DEFPC, and GLAPC differed significantly ($P < 0.05$) among lines. Lines G 2424, AGS 129, G 8190 had significantly lower DPC values in both years compared to other lines except for AGS 66 in 1991 and G 2034 in 1992. Lines that had more bacterial pustule also had higher DEFPC and lower GLAPC. Seed weight and yield differed significantly among lines in both years except for yield in 1992. In 1991, there was a significant correlation between DPC and GLAPC to OSW and yield.

Introduction

Bacterial pustule of soybeans, caused by *Xanthomonas campestris* pv. *glycines* (Nakano) Dye, frequently occurs under humid and high rainfall conditions. Initial lesions are individually associated with raised pustules on the underside of leaves and are often surrounded by chlorotic haloes. Lesions coalesce causing large amounts of leaf necrosis and plants may prematurely defoliate.

Soybeans are attacked by a number of foliar pathogens including *X. c.* pv. *glycines*. Significant yield reductions have been reported for pathogens that cause bacterial blight, brown spot, mosaic virus, red leaf blotch. Conversely, bacterial pustule has not been reported to cause major losses in temperate areas, i.e., 4.3% on susceptible lines, no significant yield loss on Pella, a susceptible cultivar and even at times an increase in yield under severe disease pressure. Yield losses associated with bacterial pustule may be more prevalent under humid subtropical and tropical conditions where continuous and severe rainfall with higher temperatures occurs more frequently than under temperate conditions.

Resistance to *X. c.* pv. *glycines* was initially reported in 1929. Cultivar CNS has a recessive gene, *rxp*, which has been used widely as a resistance source to develop commercial cultivars with resistance in the United States. Pathogenic races of *X. c.* pv. *glycines* have not been reported and cultivars with the *rxp* gene continue to be highly resistant in the United States where yield loss estimates remain low.

The objectives of this experiment were to evaluate resistant sources to bacterial pustule and determine associated yield losses of resistant and susceptible soybean lines.

Materials and Methods

Experimental plots and soybean cultivars. Experiments were conducted at AVRDC in Shanhua, Taiwan from 4 September to 6 December 1991 and from 15 May to 25 August 1992. The soil type was a sandy clay loam and the previous crop in both years was tomato.

Experimental plots measured 4 x 6 m with 2 m between each plot. Seeds were planted in eight rows, 50 cm apart, i.e., 10 cm between hills with two seeds per hill. The experiment was arranged as a split plot in a randomized complete block design with four replications. The main plots were inoculated with the bacterium or protected regularly with applications of a bacteriacide (Kocide). The subplots were nine lines selected from previous studies based on information on their reaction to pustule in the field (table 1).

Table 1. Soybean lines, sources, and reaction to bacterial pustule caused by *Xanthomonas campestris* pv. *glycines*

Line	Source	Reaction[1]
G 2424	SRF400	HR
AGS 129	Shih-Shih x SRF400	HR
G 8190	PI 371611	HR
G 2034	CNS	MR
AGS 59	CH#2 x KS528	MR
AGS 66	Forrest x Shih-Shih	MR
G 38	Shih-Shih	HS
TN 4	H-15	HS
AGS 284	PI 248407 x Clark 63	HS

Inoculations. A strain of *X. c.* pv. *glycines* was isolated from infected field-grown soybean leaves before each trial. A single colony was isolated after streaking macerated lesions on yeast dextrose agar. The bacterium was increased on nutrient agar and plants were inoculated by spraying a suspension of about 10^8 cfu/ml on leaves with a pressurized sprayer set at 9.8-14.7 x 10^4 Pa on a weekly basis during the vegetative growth stages. Plots were furrow-irrigated initially, and at the time of inoculation, overhead mist-irrigated 3 days per week for 10-min intervals for 8 h per day.

Disease and yield assessment. Leaf area infected was estimated by recording the percent infection on a per plot basis at 6- to 8-day intervals. Since the lines varied in their maturity, comparisons among lines were made by using the relative life time from planting to full maturity as a percent of the life span from 0 to 100%. Area under the disease progress curve (DPC) was calculated. Leaf area infected was converted to logits and slopes over relative maturity were compared for each line. Along with each disease assessment, five plants per plot were evaluated for the number of nodes with leaves and the number of nodes without leaves. The area under the defoliation curve (DEFPC) as percentage of the control DEFPC was calculated. Green leaf area (GLA) was calculated as follows: GLA = 100 - percentage defoliation - (proportion of healthy tissue x percentage leaf area affected). Area under the green leaf area progress curve (GLAPC) was calculated like the DPC. The percentage GLAPC of the control plot was determined for comparing cultivar/lines.

Yield was measured from a 3 x 5 m area in the center of each plot. Weight of 100 seeds was recorded in grams. Both weights were adjusted to 13% seed moisture. Reduction in yield and seed weight was expressed as a percentage of the yield from plants in uninoculated-protected plots within each replication.

Data were analyzed by analysis of variance. Fisher's least significant difference (FLSD) values were calculated ($P < 0.05$) for the slope values of logit leaf area infected. Seed weight and yield data for each plot were correlated with percent leaf area infected, DEFPC, and the percentage of GLA, DPC, and GLAPC to control plots.

Results and Discussion

Disease development. Symptoms of bacterial pustule developed 2 to 4 days after inoculating plants in the vegetative growth stage. The severity of bacterial pustule differed between control and inoculated plots in both years as the disease severity increased during the growing season. There was a wider range of DPC values in the 1992 than in the 1991 season. Based on the logit of the percent leaf area infected, the slope values ranged from 0.025 to 0.058 in 1991 and 0.04 to 0.097 in 1992, respectively. Highly resistant lines G 2424 and G 8190 had significantly ($P < 0.05$) lower slope values than all other lines. In general, those lines that were previously classified highly resistant (table 1) had much lower DPC values than highly susceptible lines; however, the resistant sources even with the *rxp* gene had some pustule development and were not immune. These resistant lines have partial or possible minor genes associated with the *rxp* gene conferring less disease.

Plant defoliation increased throughout the season in both years and was most evident in inoculated susceptible lines which had 116 to 132% more defoliation than plants in the control plots (table 2). DEFPC differed significantly ($P < 0.05$) between main plots and differed between lines with a greater range of differences in 1991. The DEFPC values for main plots were 1512 and 1728 in the control and inoculated plots, respectively (LSD 0.05 = 90). There was no interaction between main and subplots in either year. Susceptible lines averaged 129% and 119% compared to 112 and 109% for resistant lines in 1991 and 1992, respectively. Although the difference in defolation between the lines was not large, the general trend was that defoliation increased when the disease was more severe, i.e., plants in inoculated plots and highly susceptible lines.

The percentage GLAPC values compared to those in the control plots over lines ranged from 39 to 81% with an average of 61% in 1991 and ranged from 49 to 101% with an average of 74% in 1992. The three susceptible lines had significantly lower percentage GLAPCs in both years. The percentage GLAPC was lower than the percentage DEFPC indicating that available green leaf area was lowered more by leaf area infected by pustules than by defoliation.

Yield. Percentage yield of plants in inoculated plots compared to plants in protected plots was 89% in 1991 and 78% in 1992. The percentage yield of lines was significant in 1991 but not in 1992. Yield data from 1992 was three times as variable than that of 1991, making differences difficult to detect in 1992. Percentage seed weight differed significantly ($P < 0.05$) among lines in control vs. inoculated plots in each year with the more susceptible lines having a lower percentage of weight than the other lines. These data indicate that bacterial pustule significantly reduced yields and seed weight.

Relationship of yield to disease. There was a significant ($P < 0.05$) correlation between percentage yield and seed weight of control plots to DPC, DEFPC, and GLAPC in 1991 and in 1992 except for yield.

Table 2. Percentage yield and 100-seed weight of control, and area under the disease progress curve (DPC), and percentage green leaf area progress curve (GLAPC) and defoliation progress curve (DEFPC) for nine soybean lines inoculated with *Xanthomonas campestris* pv. *glycines* in two seasons

	Yield (%)[a]		Seed weight (%)		DPC		GLAPC (%)		DEFPC (%)	
Lines	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
G 2424	97	76	98	97	1072	416	78	95	109	109
AGS 129	97	64	97	85	1291	468	69	101	118	98
G 8190	90	67	94	112	1118	634	74	90	110	119
G 2034	85	81	86	99	1676	753	65	91	102	106
AGS 59	79	96	95	86	1706	2379	54	58	114	109
AGS 66	96	78	95	88	1162	1377	81	79	95	111
G 38	86	69	87	71	2336	3277	39	49	127	119
TN 4	79	96	88	84	2218	2569	42	49	132	121
AGS 284	93	71	89	78	2030	2711	48	53	127	116
LSD (P<0.05)	12	NS	7	9	212	191	7	12	15	13
c.v. (%)	9	30	6	7	9	8	4	6	6	6

[a]Percentages based on the following $[(x_1 - x_2)/x_1] \cdot 100$ where x_1 = value obtained in protected plots (control) and x_2 = value obtained in inoculated plots.

Soybeans have the capacity to yield well despite some foliar stresses including leaf lesions and premature defoliation. Although bacterial pustule may appear to be very severe causing lesions on most of the leaves throughout the plant and often causing premature defoliation, it does not cause as much yield loss as has been reported for other soybean foliar pathogens such as red leaf blotch, rust, and Septoria brown spot. Although bacterial pustule has not been a serious problem in yield in the United States, the bacterium has overcome the resistance conferred by the *rxp* gene in our study and resulted in significant yield loss. It is not known whether races of *X. c.* pv. *glycines* have developed in the humid subtropics and tropics or if environmental conditions restrict the expression of resistance.

Field Evaluation of Soybean Lines for Reactions to Anthracnose, Charcoal Rot, and Pod and Stem Blight

Soybean anthracnose, *Colletotrichum truncatum*; charcoal rot, *Macrophomina phaseolina*; and pod and stem blight, *Diaporthe phaseolorum* var. *sojae*, are major fungal diseases in tropical and subtropical production areas. The objective of this study was to evaluate soybean lines from the AVRDC soybean rust program for their reactions to these other fungal pathogens. In two separate field studies, severity of anthracnose, charcoal rot, and pod and stem blight were recorded on a total of 28 soybean lines. Twenty plants collected at random from each of eight plots (replications), were rated individually for severity of the three diseases. Significantly different ($P \leq 0.01$) disease severities were recorded among the lines for all three diseases. Lines showing least symptoms of anthracnose included: OCB, SRE-D-14B, and SRE-B-15C in study 1 (table 3) and GC 84058-21-4, GC 84040-16-1, and GC 8458-21-2 in study 2 (table 4). Lines showing least symptoms of charcoal rot included: PI 379618, SRE-D-14A, and GC00002-100 in study 1 (table 3) and GC 84058-21-4, GC 84051-32-1, GC 84040-16-1, and GC 84058-21-2 in study 2 (table 4). Symptom development was much less for pod and stem blight than for the other two diseases, therefore the data are likely to be less reliable. Results in general suggest that useful levels of

resistance to anthracnose, charcoal rot, and pod and stem blight are available in advanced soybean lines, and responses of soybean lines to these diseases should be considered when making selections in the future. This is the first report of charcoal rot on soybean in Taiwan.

Table 3. Severity[a] of anthracnose, charcoal rot, and pod and stem blight among advanced AVRDC soybean lines in AYT 1, spring 1993

Lines	Anthracnose	Charcoal rot	Pod & stem blight
GC 60020-8-7-7-18	44	31	2
GC 82146-43-9-9	51	26	3
G 9947-21-9	62	34	5
GC 00002-100	38	9	1
GC 00138-29	78	27	3
SRE-B-15C	27	17	1
SRE-C-56A	50	11	2
SRE-D-14A	33	5	1
SRE-D-14B	23	11	1
PI 379618	48	3	1
269	49	38	4
AGS 129	46	36	2
AGS 302	40	31	1
OCB	18	10	1
Average	43	21	2
FLSD (P≤0.01)	23	12	2

[a]Percentage of main stem surface area showing disease symptoms; average of eight replications with 20 plants each.

Table 4. Severity[a] of anthracnose, charcoal rot, and pod and stem blight among advanced AVRDC soybean lines in AYT 2, spring 1993

Lines	Anthracnose	Charcoal rot	Pod & stem blight
GC 86017-170-1N	66	42	2
GC 84058-21-4	40	29	2
GC 84058-21-2	49	32	2
GC 86049-35-2-1-1-1N	59	46	3
GC 84051-32-1	63	30	2
GC 84051-9-1	61	33	2
GC 84058-18-4	60	60	4
GC 84040-27-1	74	63	2
GC 86018-427-3	58	54	13
GC 84040-7-1	59	38	3
GC 84040-16-1	49	31	2
AGS 129	68	62	3
AGS 302	52	47	3
SRE-D-15B	64	50	4
Average	59	44	3
FLSD (P≤0.01)	16	19	4

[a]Percentage of main stem surface area showing disease symptoms; average of eight replications with 20 plants each.

Tomato Breeding

Bacterial Wilt Evaluation of Breeding Lines and Introductions

Summary

Two heat-sensitive introductions, H 7997 and TBL-4, showed high bacterial wilt resistance (BWR) and may be useful new sources of resistance. Twenty-four indeterminate fresh market lines showed no mortality in BW evaluations while 34 lines had survival rates of about 90%. Fifteen of these lines were also heat-tolerant and firm-fruited and will be included in 1994 preliminary yield trials.

Introduction

BWR is one of the most important components of tropical adaptation in tomato, and continues to receive high priority. In 1993, we screened a number of tropical fresh market breeding lines, hybrids and new germplasm for resistance using a soil drench inoculation method at the seedling stage in the plastichouse.

Materials and Methods

Types of materials evaluated for BWR in 1993:

Type of materials	No. of entries	Sown	Inoculated	Recorded
Introduced germplasm	13	07/13/93	08/11/93	08/18 – 09/08/93
Indeterminate lines	130	06/10/93	07/08/93	07/15 – 07/29/93
Fresh market hybrids	36	09/12/93	10/07/93	10/12 – 10/24/93

Entries were tested at the seedling stage during the 1993 summer under the plastichouse using a soil drench inoculation method (20 ml of 10^8 cell/ml strain SSP no. 1 added to each 6-cm diam pot containing 1 plant). Twenty-four plants per entry were inoculated 25 days after sowing (about five true-leaf stage) inside the plastichouse. Pots were arranged in a randomized complete block design with two replications for tropical breeding lines and hybrids; entries of introductions were not replicated. Mean temperatures in the plastichouse during the test ranged from 25 to 42°C. Wilt evaluations began 1 wk after inoculation and continued for 3 wk.

Results and Discussion

Survival rates (SR) of resistant introductions are listed in table 1. H 7997 and TBL-4 showed levels of BWR equal to the resistant check, L 285.

Table 1. Bacterial wilt resistance of the best promising germplasm vs. checks; AVRDC, summer 1993

Entry	Variety name	SR (%)[a]
L 285 (R ck)	Chang No. 1	94.1
BL 814	TBL-4	100.0
BL 782	H 7997	90
BL 809	LS 1811-2-14	86
BL 810	LS 1811-2-8	86
BL 781	GA 1565	86
L 390 (S ck)	Nan-Tzu Apple	0

[a]percent of inoculated plants surviving after 4 weeks.

Of the 136 large-fruited indeterminate fresh market tomato breeding lines evaluated for BWR, 25 lines showed highly resistant (100% survival rate) reactions and 34 lines had survival rates of about 90%. Fifteen lines were also heat-tolerant, with firm, large fruit.

Among the fresh market hybrids tested, FMTT 408, FMTT 565, and FMTT 500 had survival rates >80%. FMTT 565 and FMTT 500 also produced good yields in separate yield trials.

The Relationship Between Bacterial Wilt Resistance and Fruit Quality Traits

Summary

Experiments to determine the relationship between bacterial wilt resistance (BWR) and fruit quality characters were conducted in 1992 fall and 1993 summer. BWR and fruit size were negatively correlated, but a positive correlation between BWR and fruit color, as well as BWR and fruit acidity was detected. There were no significant relationships between BWR and marketable yield, or BWR and soluble solids content. More backcrosses increased BWR, but reduced fruit size and tended to increase fruit acidity.

Introduction

BWR is often associated with small fruit size. Tropical lines bred early on at AVRDC invariably produced small fruit, averaging only 30 g per fruit. This is probably because available sources of heat tolerance and bacterial wilt resistance had small fruit size. Later attempts to increase fruit size through changes in breeding strategies met with moderate success — fruit size improved to about 60 to 120 g per fruit in some advanced lines. In the AVRDC 1991 Progress Report, it was reported that a high level of BWR could be easily recovered in early backcross (BC_2) generations. The objective of this experiment was to determine the correlation between bacterial wilt resistance, fruit size, color, acidity, and marketable yield, as affected by number of backcrosses.

Materials and Methods

Randomly selected F_7 backcross-inbred lines of two backcross generations (BC_1 and BC_3) from two crosses (CLN 690 and CLN 735) were used. CLN 690 is a cross between a tropically adapted bacterial wilt-resistant line CL 5915-93D$_4$-1-0 and susceptible line BL 284 (cv. Cavalier,

a large-fruited variety from Petoseed Co.); CLN 735 was derived from a cross between CLN 65-349D_5-2-0, a tropical bacterial wilt-resistant line, and BL 284. The resistant parent in both crosses served as the recurrent parent.

The experiment was arranged in a randomized complete block design with two replications. Seventy-two backcross-inbred lines from each backcross generation were included with four check cultivars for a total of 76 treatments. Checks included the parental lines, L 285 (resistant) and L 390 (susceptible). In the trial, 24 plants per line were evaluated for BWR (% survival). BWR testing was conducted in the greenhouse using the seedling inoculation method described earlier. Sowing was done on 15 June and 12 July, and plants were inoculated on 15 July and 11 August, respectively. (Average max/min temperatures in the plastichouse were 42°C/25°C). Weekly wilt readings started on 22 July and 18 August for the first and second inoculation dates, respectively and were completed on 6 August and 2 September. Individual survival rate % data of the experimental units were transformed by arcsine prior to statistical analysis.

A separate trial to observe horticultural characteristics was conducted in fall 1993. Fruit size, fruit color, Brix and acid contents, and marketable yields for lines were determined. Plots consisted of a single 4-m-long row with 12 plants, with 1.5 m between adjacent rows, and within-row spacing of 40 cm.

Results and Discussion

BWR levels increased significantly from BC_1 to BC_3 for CLN 690, but only slightly in CLN 735 (table 2). Average fruit sizes decreased from BC_1 to BC_3 in both crosses, although no effect on marketable yield was noted.

Table 2. Bacterial wilt reactions and horticultural characteristics of F_7 backcross-inbred lines averaged over crosses and backcross generations; AVRDC, fall 1992 - summer 1993

Cross	Generation	Survival rate (%)	Fruit size (g)	Mkt. yield (t/ha)	Brix (%)	Color (a/b)	Acidity (% citric acid)
CLN 690	BC_1F_7	59	81	80	4.0	1.83	0.44
CLN 690	BC_3F_7	73	69	82	3.7	1.85	0.45
CLN 735	BC_1F_7	83	64	70	3.8	1.98	0.40
CLN 735	BC_3F_7	86	58	70	3.9	1.89	0.40
CL 5915-93D_4-1-0		85	65	92	3.8	1.78	0.44
CL 65-349D_5-1-0		95	61	67	3.6	2.04	0.46
BL 284 = Cavalier		39	211	101	4.3	1.78	0.36
L 285 (R ck)		98	12	10	6.0	1.74	0.58
L 390 (R ck)		11	42	23	5.6	0.21	0.37

Correlations between BWR (% survival) and other horticultural traits are presented in table 3. Highly significant negative correlations between BWR and fruit size were detected, but a positive correlation between BWR and fruit color was observed. Marketable yield and BWR showed no significant correlation (in the absence of the BW pathogen). Similarly, there was no significant negative correlation between BWR and soluble solids content, except for CLN 735BC_3F_7. BWR and titratable acidity showed a significant positive correlation, except for CLN 735BC_1F_7.

Table 3. Correlation coefficients between bacterial wilt resistance and horticultural traits in two crosses and backcross generations; AVRDC, fall 1992 - summer 1993

Cross and backcross generation	Correlation between SR[a]/Fruit size	SR/Mkt. yield	SR/Brix	SR/Acidity	SR/Color
CLN 690 BC_1F_7	−0.2534[a]	−0.1672[NS]	−0.0075[NS]	0.3122[b]	0.3107[b]
CLN 690 BC_3F_7	−0.3589[b]	−0.0123[NS]	−0.1887[NS]	0.3739[b]	0.3201[b]
CLN 735 BC_1F_7	−0.2942[b]	0.1126[NS]	−0.2070[NS]	0.1681[NS]	0.6009[b]
CLN 735 BC_3F_7	−0.3106[b]	0.0458[NS]	−0.3468[b]	0.3172[b]	0.6068[b]

[a]significant at 5% SR: Survival rate (%)
[b]highly significant at 1%

Conclusions

Results of this experiment reconfirmed that high levels of BWR can be easily recovered in the BC_3 generation. Unfortunately, fruit size and BWR were negatively correlated. This could be due to linkage between genes conditioning fruit size and BWR or possibly a pleiotropic effect of BWR genes on fruit size. To obtain larger fruit size and BWR, foregoing backcrossing altogether and simply screening large numbers of progeny for large-fruited individuals with BWR might be better. Fortunately, large-fruited, bacterial wilt-resistant materials from INRA in Guadaloupe are available as alternative sources of BWR.

Performance of Tropical Breeding Lines

Summary

The best BW-resistant lines from the CLN 735BC_3F_7 series, tested in the 1993 summer advanced yield trial (AYT) 1, yielded 15 to 19 t/ha, as high as the best-yielding checks and the bacterial wilt-resistant parent. These lines produced medium- to large-sized fruit with good firmness and no cracking.

The best lines, CLN 1301DC_4-637-11-0, CLN 1301DC_4-720-11-0, and CLN 1301DC_4-376-19-0, in the 1993 summer AYT 2 yielded 16 – 22 t/ha, greater than heat-tolerant checks CL 5915-93DC_4-1-0-3 and CL 5675BC_1F_2-1-2-2-12. These lines were also superior to the checks in fruit size and firmness.

Introduction

We continued to pursue the development of tropical lines with broad resistance to diseases and improved horticultural characteristics such as larger fruit size, better fruit firmness, small blossom end scar, thick pericarp, smooth, tough skin, and resistance to cracking.

Materials and Methods

Two trials were performed during the hot and wet summer season. Information on the entry numbers, trial types, sowing, planting, and harvest dates are given below:

Type of trial	No. of entries	Sown	Transplanted	Harvested
AYT 1	12	03/24/93	04/22/93	06/17 – 06/28/93
AYT 2	14	03/24/93	04/22/93	06/17 – 07/05/93

AYTs were planted in a randomized complete block design with three replications. Each plot consisted of three 4-m-long beds spaced 1.5 m apart; within-row spacing was 40 cm.

Results and Discussion

Bacterial wilt-resistant lines in the CLN 735BC$_3$F$_7$ series were tested in the 1993 summer AYT 1 and data on the best entries are listed in table 4. Five entries gave statistically comparable yields (15--19 t/ha) as the heat-tolerant checks and parental line CLN 65-3491D$_5$-2-0. These five lines not only produced larger, firmer, and more crack-resistant fruit, but also had better flavor than the checks based on the sugar:acid ratio.

The six best entries from the AYT 2 are presented in table 5. CLN 1301DC$_4$-657-11-0, CLN 1301DC$_4$-702-11-0, and CLN 1301DC$_4$-376-19-0 performed well, showing good marketable yields and medium fruit sizes. These entries also produced firmer fruit, better foliage cover, and less cracking than the checks. AYT 2 was flooded on 26 May; differences among lines in flood damage were detected. The best lines will be increased and made available to international cooperators in 1994.

Performance of Fresh Market Tomato Breeding Lines

Summary

Two preliminary yield trials of indeterminate fresh market inbred lines were carried out in the 1992 late fall. The best entries significantly outyielded the check, commercial hybrid KY 301. Range of fruit set over all entries was good, about 76–83% per cluster. Fruit sizes of the best entries were close to the ideal size of 120 g per fruit, and the fruits showed better firmness, color and crack resistance than KY 301. None of the selected entries compared well with KY 301 in soluble solids content but this could have been due to the low yield of KY 301 since soluble solids and yield are inversely related.

Of the heat-tolerant indeterminate fresh market inbred lines evaluated in the 1993 summer observational yield trial (OYT), only CLN 1462-22-10-49-1 yielded as high as the check hybrid, FMTT 22 (8 t/ha). This line produced good plant vigor and foliage cover, firm fruit, good color, and crack resistance.

Two preliminary yield trials were conducted during the hot and wet summer season to identify fresh market lines with large fruit, good foliage cover, and disease resistance. Some lines had comparable yields as the heat-tolerant checks CL 5915, CL 5675, and FMTT 22, and had firmer and larger fruits than CL 5915 and CL 5675.

Introduction

Fresh market tomato lines with the following characteristics are sought after: heat tolerance; resistance to bacterial wilt, tomato mosaic virus, and root-knot nematode: large, firm, smooth fruit with good flavor, dark green shoulders, crack resistance, and a small blossom end scar.

Materials and Methods

Two fresh market trials were conducted in the fall of 1992, and three trials were performed during the hot and wet summer of 1993. Information on the trial types, and sowing, transplanting, and harvest dates are presented as follows:

Table 4. Yield and other horticultural characteristics of the best determinate tropical breeding lines and check cultivars in AYT 1; AVRDC, summer 1993

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b)	Sugar/ acid ratio	Crack-ing[a]	Blotchy ripening[b]	Firm-ness[c]	Vine cover[d]	ToMV[e]
CLN 735BC$_3$F$_6$-51	19.0 b[f]	43	63 a	16 a	54 ab	0.41 b-d	5.3 a	1.44 ab	12.9	0	VSL	F	G	2^s/2^s
CLN 735BC$_3$F$_6$-72	18.9 ab	48	63 a	13 bc	53 b	0.42 bc	5.4 a	1.44 ab	12.9	0	SL	MF	E	2^s/2^s
CLN 735BC$_3$F$_6$-29	15.4 a-c	49	57 a	13 bc	54 ab	0.42 b-d	5.1 a	1.54 ab	12.1	0	M	MF	G	2^s/2^s
CLN 735BC$_3$F$_6$-33	14.8 a-c	47	55 a	16 a	53 b	0.41 b-d	5.4 a	1.41 b	13.2	0	SL	MS	F	2^s/2^s
CLN 735BC$_3$F$_6$-43	14.7 a-c	50	62 a	14 ab	55 ab	0.42 b-d	5.1 ab	1.53 ab	12.1	0	M	MF	G	2^s/2^s
CLN 735BC$_3$F$_6$-31	14.2 bc	49	61 a	14 ab	56 a	0.41 b-d	5.4 a	1.47 ab	13.2	0	SL	MF	F	2^s/2^s
CLN 735BC$_3$F$_6$-52	13.8 bc	41	55 a	14 ab	54 ab	0.44 bc	5.4 a	1.49 ab	12.3	0	SVL	MF	F	2^s/2^s
CL 5915-93D$_4$-1-0-3 (ck)	19.9 a	50	32 b	12 c	50 c	0.45 b	4.8 ab	1.30 bc	10.7	VSLR	SL	MS	G	2^s/2^s
CL 5675BC$_1$F$_2$-1-2-2-12 (ck)	17.1 a-c	48	28 c	13 bc	50 c	0.50 a	5.3 a	1.03 c	10.6	VSLR	VSL	MS	G	2^s/2^s
CLN 65-349D$_5$-2-0 (ck)	16.3 a-c	45	59 a	14 ab	54 ab	0.42 b-d	5.3 a	1.73 a	12.6	0	SL	F	G	2^s/2^s
Mean of all entries	15.8	47	54	14	54	0.43	5.3	1.44	12.3	-	-		-	-
c.v. (%)	17.7	11	8.8	7.3	2.6	6.6	3.9	11.2	-	-	-		-	-

[a] 0 = none; VSLR = very slight radial cracking.
[b] VSL = very slight; SL = slight; M = moderate.
[c] MS = moderately soft; MF = moderately firm; F = firm.
[d] F = fair; G = good; E= excellent.
[e] 2^s/2^s = homozygous for allele Tm–2^s, conditioning tomato mosaic virus resistance.
[f] Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Table 5. Yield and other horticultural characteristics of the best determinate tropical breeding lines and checks in the AYT 2; AVRDC, summer 1993

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b)	Sugar/ acid ratio	Crack-ing[a]	Firm-ness[b]	Vine cover[c]	Scale of flooding damage[d]	ToMV[e]
CLN 1301DC$_4$-637-20-0	21.8 a[f]	57 ab	99 b	15 a-c	57 a	0.53 ab	4.8 de	1.64 ab	9.1	SLR	F	G	3	2[e]/2[e]
CLN 1301DC$_4$-702-11-0	18.2 ab	55 ab	89 bc	19 a	57 a	0.51 ab	5.1 b-e	1.42 ab	10.0	VSLR	F	G	4	2[e]/2[e]
CLN 1301DC$_4$-376-19-0	18.1 ab	55 ab	114 a	14 bc	57 a	0.47 b	4.6 e	1.32 ab	9.8	SLSA/R	VF	G	3	2[e]/2[e]
CLN 1301DC$_4$-637-20-0	15.9 bc	59 ab	80 cd	14 bc	57 a	0.54 ab	5.2 b-e	1.33 ab	9.6	VSLR	F	G	3	2[e]/2[e]
CLN 1301DC$_4$-243-8-0	14.3 b-e	60 ab	71 de	13 bc	54 ab	0.54 ab	4.8 de	1.36 ab	8.8	SA VS C/R	MF	F	5	2[e]/2[e]
CLN 1301DC$_4$-326-15-0	13.4 b-d	59 ab	90 bc	13 bc	54 ab	0.47 b	5.0 b-e	1.42 ab	10.6	SLR	MF	F	4	2[e]/2[e]
CLN 1301DC$_4$-376-0-0	12.8 c-e	64 a	74 de	18 ab	54 ab	0.60 a	5.5 ab	1.27 ab	9.2	SLR	VF	F	4	2[e]/2[e]
CLN 1301DC$_4$-487-5-0	11.9 c-e	54 ab	73 de	13 bc	54 ab	0.51 ab	5.4 a-c	1.22 ab	10.5	SLSA	F	F	5	2[e]/2[e]
CL 5915-93D$_4$-1-0-3 (ck)	14.5 b-d	50 ab	32 b	12 c	50 c	0.53 ab	4.9 c-e	2.37 a	9.2	SLSA/C	MF	F	2	2[e]/2[e]
CL 5675BC$_1$F$_2$-1-2-2-12 (ck)	9.4 d-f	49 ab	29 h	14 bc	52 bc	0.47 b	5.3 b-d	0.98 b	11.3	MR	MF	F	6	2[e]/2[e]
Mean of all entries	13.1	55	70	14	55	0.51	5.09	1.39	9.9	-	-	-	-	-
c.v. (%)	21.1	10.7	7.3	13.1	2.9	8.7	4.3	35	-	-	-	-	-	-

[a]VSLR = very slight radial cracking; SLR = slight radial cracking; SLSA/R = slight superficial abrasion and radial cracking; SLSA/C = slight superficial abrasion and concentric cracking.

[b]MF = moderately firm; F = firm; VF = very firm.

[c]F = fair; G = good.

[d]Rating scale of 1 = none; 2–3 = slight; 4–5 = moderate; 6–7 = serious; 8–9 = very serious.

[e]2[e]/2[e] = homozygous for allele Tm–2[a], conditioning tomato mosaic virus resistance.

[f]Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Type of trial	No. of entries	Sown	Transplanted	Harvested
Observational	18	04/12/93	05/12/93	06/17 – 08/03/93
Preliminary 1	24	10/22/92	11/18/92	02/02 – 03/19/93
Preliminary 2	24	10/22/92	11/18/92	02/02 – 03/19/93
Preliminary 3	9	04/13/93	05/13/93	06/17 – 08/03/93
Preliminary 4	10	04/13/92	05/13/92	06/17 – 08/03/93

OYT was made up of two-row, unreplicated plots. OYTs are designed to identify lines deserving further testing. Preliminary yield trials (PYT) were conducted using a randomized complete block design with two replications. Plot size was identical to the OYT.

Results and Discussion

In the OYT 1, CLN 1462-22-10-49-1 yielded comparably to the heat-tolerant hybrid check, FMTT 22, displaying good plant vigor and foliage cover, firmer fruit, very slight cracking, and better color than FMTT 22.

Mean yields of entries in the 1992 fall PYT 1 ranged from 81 to 105 t/ha, greater than checks Rodade (78 t/ha) and FMTT 33 (70 t/ha); however, only CLN 977BC$_1$F$_2$-44-24-21-2-23 yielded significantly greater than the checks. Fruit set averaged over entries was 76% per cluster. The fruit of some entries were as large as the checks with better firmness, color, and crack resistance. None of the entries had comparable soluble solids and flavor (sugar-acid ratio) as FMTT 33.

Data for nine selected entries from PYT 2 are presented in table 6. Entries significantly outyielded the commercial cultivar, KY 301, but not AVRDC fresh market tomato hybrid, FMTT 33. Average fruit set was about 83% per cluster. Fruit size of the selected entries was 123–155 g, close to the ideal size of 130 g per fruit; fruit had better firmness and crack resistance than the check, KY 301. None of the best entries had comparable soluble solids as KY 301.

The best experimental determinate fresh market hybrids in the 1993 summer PYT 3 yielded from 14 to 22 t/ha, statistically comparable to heat-tolerant checks CL 5915-93DC$_4$-1-0-3 and CL 5675 BC$_1$F$_2$-1-2-2-12. The best entries -- FMTT 501, FMTT 500, FMTT 454, FMTT 486, and FMTT 506 -- had better fruit set (44 – 51% per cluster), larger fruit size (64 – 97 g per fruit), firmer fruit, good foliage cover, low fruit cracking, and less foliar disease than the check cultivars.

Yields of the best indeterminate fresh market experimental hybrids in the 1993 summer PYT 4 ranged from 10 to 21 t/ha, better than commercial check KY 301 but less than AVRDC hybrid FMTT 22. Few significant differences in marketable yields among hybrids were detected, probably due to high environmental variation, indicated by the large coefficient of variation (40.8%) for marketable yield. There were few differences among experimental hybrids in fruit size. FMTT 385 and FMTT 526 had good soluble solids contents, comparable to checks FMTT 22 and KY 301, but tended to crack. All entries had firm fruit, fair foliage cover, and blotchy ripening.

Table 6. Yield and other horticultural characteristics of selected fresh market tomato lines and checks in PYT 2; AVRDC, fall 1992

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b)	Sugar/ acid ratio	Crack-ing[a]	Firm ness[b]	Vine cover[c]	ToMV[d]
CLN 399BC,F_2-19-10-12-12-8-22-0	98.0 a[e]	87 a	123 ab	27	83 bc	0.38 a-d	4.9 b-d	1.7 a-c	12.7	0	VF	G	2[s]/2[s]
CLN 399BC,F_2-19-60-12-12-8-12-9	97.7 a	88 a	123 ab	24	83 bc	0.37 a-d	4.7 cd	1.8 a-c	12.7	0	VF	F	2[s]/2[s]
CLN 399BC,F_2-19-6-18-19-1-0	96.0 ab	90 a	127 ab	27	83 bc	0.38 a-d	5.4 b	1.7 a-c	14.2	0	F	F	2[s]/2[s]
CLN 399BC,F_2-19-60-8-5-11-10	95.6 ab	89 a	136 ab	29	90 a	0.37 a-d	5.0 b-d	1.8 a-c	13.5	0	VF	F	2[s]/2[s]
CLN 399BC,F_2-19-60-8-5-11-0	91.8 ab	73 ab	128 ab	26	82 bc	0.35 a-d	4.7 cd	1.8 a-c	13.2	0	MF	F	2[s]/2[s]
CLN 399BC,F_2-19-6-18-17-7-1-0	90.8 ab	81 ab	134 ab	28	82 bc	0.35 a-d	5.1 b-d	1.9 a-c	14.3	SLR	MF	F	2[s]/2[s]
CLN 399BC,F_2-19-6-18-17-7-9	90.6 ab	80 ab	155 a	24	83 bc	0.38 a-d	4.9 b-d	1.9 a-c	13.8	0	F	F	2[s]/2[s]
CLN 399BC,F_2-19-60-8-5-11-6	90.1 ab	81 ab	124 ab	26	83 bc	0.34 b-d	4.6 d	1.7 a-c	13.3	0	VF	F	2[s]/2[s]
CLN 399BC,F_2-19-60-8-5-6-13	88.3 ab	84 a	124 ab	27	83 bc	0.38 a-d	4.6 d	1.7 a-c	12.1	0	VF	F	2[s]/2[s]
FMTT 33 (ck)	87.9 ab	78 ab	133 ab	24	83 bc	0.39 a-c	5.15 b-d	1.9 a-c	13.0	SLR	MF	G	2[s]/+
KY 301 (ck)	44.6 c	59 b	141 ab	26	80 c	0.35 a-d	6.0 a	2.1 a	16.9	MR	MF	G	+/+
Means of all entries	83	83	128	26	82	0.37	5.0	1.8	-	-	-	-	-
c.v. (%)	14.5	9	8	6	1	6.1	3.7	7.2	-	-	-	-	-

[a] 0 = none; SLR = slight radial cracking; MR = moderate radial cracking.
[b] MF = moderately firm; F = firm; VF = very firm.
[c] F = fair; G = good.
[d] 2[s]/2[s], 2[s]/+, + + = Tm-2[s] homozygote; Tm-2[s] heterozygote, and wild type susceptible, respectively.
[e] Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Performance of Tropical Cherry Tomato

Summary

Selected SN series cherry lines outyielded the check hybrid, Santa, in the 1993 early summer observational yield trial, showing high soluble solids content, good flavor, high fruit set (71–87%), desirable fruit size (6–8 g per fruit), and firmness. SN cherry lines developed less cracking than Santa.

In the 1993 preliminary yield trial 5, selected SN series were significantly more heat-tolerant than checks CHT 264, Santa, and Season Red, although yields ranged from only 2.6 to 4.4 t/ha. Selected entries were better than checks in fruit firmness, fruit set, flavor, and crack resistance.

The best determinate and indeterminate cherry hybrids were tested in 1992 fall PYT 1 – 2. Entry yields were comparable to checks, but they produced lower soluble solids content than the checks. Entries were better than checks in firmness and foliage cover.

The best determinate experimental hybrid, CHT 500, did not significantly outyield check cultivars CHT 261, CHT 264, and Season Red in 1993 summer PYT 3. Foliage cover, firmness, and soluble solids content of CHT 500 were acceptable. All entries suffered from cracking and blotchy ripening due to flooding and heat.

Six indeterminate cherry hybrids in the 1993 summer PYT 4 yielded 18 – 30 t/ha, outperforming Santa (6.4 t/ha). Hybrids showed high soluble solids content and firm fruits, comparable to the check. Entries and checks developed high incidences of cracking and blotchy ripening due to flooding.

Introduction

The AVRDC tomato improvement project seeks to develop tropically adapted cherry tomato lines and hybrids, emphasizing selection for the following characteristics: heat tolerance; resistance to bacterial wilt, tomato mosaic virus, and root-knot nematode; good fruit traits such as firmness, crack resistance, uniform fruit size within a long cluster, high soluble solids content, and a high sugar:acid ratio (greater than 16) for better flavor.

Materials and Methods

Six cherry tomato trials were conducted in 1992-93. General information on the kind of materials evaluated, type of trials, sowing, planting and harvest dates are given below:

Type of trial	No. of entries	Sown	Transplanted	Harvested
Observational	43	03/17/93	04/18/93	06/20/93 –07/15/93
Preliminary 1	13	09/21/92	10/21/92	12/28/92 –02/02/93
Preliminary 2	21	09/21/92	10/21/92	12/28/92 –02/02/93
Preliminary 3	10	04/13/93	05/11/93	07/12/92 –08/02/93
Preliminary 4	10	04/13/93	05/11/93	07/12/92 –08/02/93
Preliminary 5	17	06/11/93	07/08/93	08/07/93 –08/10/93

Plots for OYT consisted of one two-row bed. Bed spacing was 1.5 m and row length was 4 m. Between and within-row spacing was 60 cm and 40 cm, respectively.

Preliminary yield trials 1 and 3 included determinate cherry lines and hybrids, while PYT 3, 4, and 5 consisted of indeterminate cherry hybrids and semideterminate lines. PYT experimental

units were the same size as OYT except that indeterminate and semideterminate PYTs included two beds instead of one. Entries were replicated twice and arranged in RCBD.

Results and Discussion

Data on selected cherry breeding lines from the 1993 early summer OYT are presented in table 7. Selected lines on average yielded twice as much as the check Santa, and produced high soluble solids content (5.2 – 6.3%), good flavor based on sugar:acid ratio (16.3 – 18.1), high fruit set (71 – 87%), desirable fruit size, and firmness. Most entries showed more crack resistance than the check. Although Santa and experimental lines showed good fruit set and similar fruit weights, the lines produced more clusters and more fruit than Santa.

Lines tested in PYT 5 yielded poorly (2.6 – 4.4 t/ha), but significantly outyielded check cultivars Season Red, CHT 264, and Santa. Fruit-set, fruit per plant, and flavor were significantly better than the checks. Lines were also superior in fruit firmness, crack resistance, and disease resistance, especially compared to Season Red and CHT 264. Bacterial leaf spot infection ranged from moderate to severe on entries.

Few significant differences in marketable yield were found in the 1992 fall PYT 1 and 2 among entries and solids content was lower than in the checks. Indeterminate cherry hybrid CHT 460 yielded 33.4 t/ha and determinate cherry hybrids CHT 500, CHT 495, CHT 589, and CHT 499 yielded 50 t/ha or more. These hybrids produced moderate to very firm fruit, good foliage cover, and were less damaged from flooding.

Table 8 presents data on the performance of six determinate cherry hybrids in the 1993 summer PYT 3. The best hybrid, CHT 500, did not significantly outyield check cultivars CHT 261, CHT 264, and Season Red. Selected entries produced acceptable soluble solids content and fruit sizes, good foliage cover, firm fruit but with moderate to severe cracking, and blotchy ripening due to flooding. All entries except CHT 448 and CHT 264 were heavily infected with Taiwan tomato leaf curl virus (TTLCV), a whitefly-vectored geminivirus.

Results of six indeterminate entries evaluated in the 1993 PYT 4 are presented in table 9. New entries outperformed the check cultivar, Santa, in marketable yield, but were similar in yield to heat-tolerant checks CHT 104 and CHT 264. All entries had soluble solids content and firmness comparable to the checks, but developed cracking and blotchy ripening due to flooding. Some entries were also susceptible to TTLCV, a severe problem in the field this year.

Performance of Processing Tomato Lines

Summary

Six new processing tomato lines and hybrids were selected for further testing from the fall 1992 observational yield trial. Yields of the best entries ranged from 74 to 89 t/ha, comparable to the best check, PT 4121; they also showed good foliage cover, vine compactness, acceptable fruit size, color, and crack resistance.

The best processing tomato hybrids in the 1992 fall AYT had improved fruit size and firmness, and yielded 93–104 t/ha, better than checks PT 4454, UC 204A, and UC 82. The best yielding hybrid, PT 4717, produced larger and firmer fruit, but not better soluble solids content than the checks. PT 4714, PT 4691, and PT 4708 carry the jointless pedicel trait for easy machine harvest.

Table 7. Yield and other horticultural characteristics of selected cherry tomato breeding lines and hybrid check in OYT; AVRDC, early summer 1993

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Acidity (% citrate)	Brix (%)	Color (a/b)	Sugar/ acid ratio	Crack (%)	Growth habit	Vine[a] cover	Firm-ness[b]	No. of fruit/ cluster	Uniform[a] size with cluster
SN-60-7	27.7	83	7	0.33	5.8	1.14	17.6	11	Semideterminate	G	VF	12	E
SN-240SD-4	23.8	87	8	0.33	5.4	1.60	16.3	34	Semideterminate	G	F	12	E
SN-664-1	21.9	59	6	0.38	6.3	1.49	16.5	7	Semideterminate	G	MF	12	E
SN-60-10	21.7	84	6	0.32	5.2	1.37	16.3	1	Semideterminate	G	VF	10	E
SN-310-10	21.0	74	6	0.32	5.8	1.60	18.1	22	Semideterminate	G	F	10-16	E
SN-531-0	20.7	72	8	0.38	6.3	1.14	16.5	10	Semideterminate	G	F	10	G
SN-60-1	18.7	83	6	0.36	6.2	1.88	17.2	11	Determinate	F	VF	10	E
SN-240SD-2	18.3	71	8	0.36	6.1	1.02	16.9	26	Semidetermiante	G	VF	10	E
Santa (ck)	7.8	89	7	0.32	5.6	1.28	17.5	45	Indeterminate	G	F	11	F

[a] F = fair; G = good; E = excellent.
[b] MF = moderately firm; F = firm; VF = very firm.

Table 8. Yield and other horticultural characteristics of selected determinate cherry tomato hybrids vs. check cultivars in PYT 3; AVRDC, summer 1993

Entries	Mkt yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b) ratio	Sugar/ acid	Crack-ing[a]	Blotchy ripening[b]	Plant vigor[c]	Vine cover[c]	Firm-ness[d]	ToMV[e]	TTLCV[f]
CHT 500	27.4 a[g]	46 c	15 a	14	49	0.49 b	5.9 b-d	1.59	12.0	SVC/R	M	P	F	MF	2[e]/+	M
CHT 497	25.9 a	48 bc	23 ab	14	49	0.51 b	5.7 cd	1.56	11.2	SVC/R	SL	G	G	VF	2[e]/+	SL
CHT 499	24.7 a	52 a-c	21bc	15	50	0.51 b	5.9 b-d	1.73	11.6	SVC/R	M	F	G	VF	2[e]/+	MSV
CHT 448	19.7 a	64 ab	10 d	15	49	0.56 ab	6.2 a-d	1.72	11.1	MR	SL	F	G	F	2[e]/+	0
CHT 493	18.4 a	47 bc	19 c	16	51	0.53 ab	6.0 b-d	1.47	11.3	SLC/R	SL	F	G	F	2[e]/+	SV
CHT 264 (ck)	18.5 a	56 a-c	11 d	14	48	0.51 b	6.6 a-c	1.62	12.9	MC/R	SL	G	G	F	2[e]/+	0
CHT 261 (ck)	17.2 a	57 a-c	11 d	14	50	0.53 ab	6.9 a	1.95	13.0	MSVC/R	SL	F	E	F	2[e]/+	VSL
Season Red (ck)	15.9 a	69 a	19 c	16	49	0.61 a	5.9 b-d	1.66	9.6	SVC/R	MSV	G	G	MF	2[e]/+	MSV
Means of all entries	20.2	56	17	15	49	0.52	6.1	1.66	11.7	–	–	–	–	–	–	–
c.v. (%)	18.0	9	6	6	2	4.6	4.2	8.2	–	–	–	–	–	–	–	–

[a] SL C/R = slight concentric and radial crack; MR = moderately radial crack; R C/R = moderately concentric and radial crack; MSV C/R = moderately severe concentric and radial crack; SV = severe concentric and radial crack.
[b] SL = slight; M = moderate; MSV = moderately severe.
[c] P = poor; F = fair; G = good.
[d] MT = moderately firm; F = fair; G = good.
[e] $2^e/2^e$, $2^e/+$, + + = Tm-2^2 homozygote; Tm-2^2 heterozygote, and wild type susceptible, respectively.
[f] TTLCV = Taiwan tomato leaf curl virus; 0 = none; VSL = very slight; SL = slight; MSV = moderately severe.
[g] Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Table 9. Yield and other horticultural characteristics of the best indeterminate cherry tomato hybrids vs. check cultivars in PYT 4; AVRDC, summer 1993

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b) ratio	Sugar/ acid	Cracking[a]	Blotchy ripening[b]	Firmness[c]	ToMV[d]	TTLCV[e]
CHT 491	29.9 a[f]	50 cd	12 d	11 b	44	0.52 b-d	6.5 ab	1.05 ab	12.5	MSVR	MSV	F	2[g]/+	0
CHT 492	27.5 ab	51 cd	11 d	11 b	44	0.44 e	6.5 ab	1.06 ab	14.8	MSVR	SL	F	2[g]/+	0
CHT 480	20.8 a-c	75 ab	17 b	16 a	48	0.50 b-e	6.6 ab	1.14 a	13.2	SLC	MSV	F	2[g]/+	SL
CHT 377	20.3 a-c	56 cd	17 b	11 b	48	0.49 b-e	6.2 b	1.10 a	12.7	VSLC	MSV	VF	2[g]/+	M
CHT 479	18.3 bc	76 ab	16 bc	15 ab	49	0.52 b-d	6.5 ab	1.10 a	12.5	SLC/R	SV	F	2[g]/+	0
CHT 484	18.3 bc	74 ab	16 bc	14 ab	48	0.53 bc	6.7 ab	1.16 a	12.6	MSLC/R	MSV	VF	2[g]/+	M
CHT 104 (ck)	29.0 a	62 a-c	22 a	14 ab	48	0.52 bd	6.3 b	1.13 a	12.1	SLR	SL	F	2[g]/+	M
CHT 264 (ck)	28.9 a	52 cd	11 d	14 ab	49	0.47 c-e	6.6 ab	0.92 ab	14.0	MR	MSV	F	2[g]/+	0
CHT 217 (ck)	21.9 a-c	46 cd	11 d	14 ab	50	0.55 b	6.8 ab	1.16 a	12.3	SLC/R	M	F	2[g]/+	0
Santa (ck)	6.4 d	36 d	8 e	11 b	49	0.46 de	6.8 ab	0.81 b	14.8	VSVR	VSL	F	+/+	0
Golden Pearl (ck)	15.8 cd	78 a	7 e	14 ab	46	0.72 a	7.1 a	0.07 c	9.7	VSVC/R	0	MF	+/+	MSV
Means of all entries	20.8	60	14	13	47	0.52	6.6	0.97	12.6	–	–	–	–	–
c.v. (%)	14.8	10	3	8	3	3.9	3.2	7.8	–	–	–	–	–	–

[a]VSLC = very slight concentric cracking; SLC = slight concentric cracking; SLC/R = slight concentric and radial cracking; MSLC/R = moderately slight concentric and radial cracking; MR = moderate radial cracking; RC/R = moderate concentric and radial cracking; MSVR = moderately severe radial cracking; VSVR = very severe radial crack; VSVC/R = very severe concentric and radial cracking.

[b]VSL = very slight; SL = slight; M = moderate; MSV = moderately severe.

[c]MF = moderately firm; F = fair; VF = very firm.

[d]2[g]/2[g], 2[g]/+, + + = Tm-2[g] homozygote; Tm-2[g] heterozygote, and wild type susceptible, respectively.

[e]TTLCV = Taiwan tomato leaf curl virus; 0 = none; SL = slight; M = moderate; MSV = moderately severe.

[f]Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Introduction

We continued our search for new processing tomato lines and hybrids with good yield, disease resistance (tomato mosaic virus, bacterial wilt, and root-knot nematode), high concentrated fruit set and firmness for mechanical harvesting, and acceptable processing quality. In addition, we looked for materials with the jointless pedicel for easy machine harvest.

Materials and Methods

Two trials were conducted during the 1992 fall season. Information on numbers of entries, trial types, sowing, planting, and harvest dates are given below:

Type of trial	No. of entries	Sown	Transplanted	Harvested
Observational	16	09/22/92	10/21/92	02/08 – 2/23/93
Advanced	21	09/22/92	10/21/92	02/09 – 2/23/93

OYT was arranged in a randomized complete block design with two replications. Plots consisted of two, 4-m-long beds spaced 1.5 m apart. Within-row spacing was 40 cm.

The advanced yield trial was aranged in a randomized complete block design with three replications. Plots consisted of four instead of two beds. Spacing was identical to the OYT.

Results and Discussion

Six introduced lines and hybrids from the Petoseed Co., listed in table 10, were evaluated. Entries yielded comparably to check PT 4121, and displayed good foliage cover, vine compactness, acceptable fruit size (61 – 91 g per fruit), good color, and crack resistance. BL 787 produced a high marketable yield and Brix content.

The best lines in the AYT (table 11) — PT 4717, PT 4714, and PT 4659 — produced high yields (101 – 104 t/ha), high soluble solids content, and good color, comparable to checks, PT 4454, UC 204A, and UC 82. The best entries produced firmer and larger fruits than the checks. PT 4714, PT 4691, and PT 4708 have the jointless pedicel advantageous for machine harvest. All entries were resistant to bacterial wilt and tomato mosaic virus.

Crosses and Segregating Populations

Objectives and numbers of crosses completed in 1993 are presented in table 12. About 25% of the crosses were designed to improve tropical tomato lines for Taiwan tomato leaf curl virus (TTLCV) or cucumber mosaic virus (CMV) resistance. Several TTLCV crosses involved interspecific hybridization between *Lycopersicon esculentum* x *Lycopersicon chilense*, but viable F_1 plants were obtained via embryo rescue from only one cross (CL 5915-93D$_4$-1-0-3 x LA 1969). Backcrosses are planned to transfer virus resistances into tropical tomato backgrounds and develop populations for RFLP analysis of virus resistance genes. Sixteen crosses were made to introgress CMV resistance from *L. hirsutum* into tropical tomato. Two fertile F_2 families from *L. esculentum* x *L. pennellii* crosses were backcrossed to *L. esculentum* to obtain BC_1F_1; the objective is to transfer the acyl sugar trait for insect resistance into cultivated tomato. The majority of crosses were made to test combinations for possible hybrids. Crosses intended for RFLP

Table 10. Yield and other horticultural characteristics of introductions and checks in OYT; AVRDC, fall 1992

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to first flower	Days to first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b) ratio	Cracking[a]	Firmness[b]	Vine cover[c]	Vine compactness
BL 681 = p 56594	88.8	76	79 a-c[d]	15	76	0.27 h	4.4	2.16 ab	0	MS	E	E
BL 787 = psR 74208	87.1	86	76 a-d	16	69	0.36 a-d	5.2	2.22 ab	0	MF	G	G
BL 789 = ps x p 1596	83.2	86	65 b-d	16	73	0.35 a-e	4.9	2.26 a	0	MF	G	G
BL 786 = psR 13010	81.1	88	61 cd	15	69	0.31 e-h	4.4	2.12 ab	0	MS	G	G
BL 680 = Hysol 649	75.6	78	87 ab	16	69	0.36 a-c	4.8	2.16 ab	0	MS	G	G
BL 685 = Nema 1435	74.4	82	91 a	16	76	0.27 h	4.9	2.24 a	0	MS	E	E
PT 4121 (ck)	77.2	83	73 a-d	15	67	0.34 b-f	4.7	2.09 ab	0	MF	G	G
BL 444 (ck) = UC 204A	68.8	83	68 b-d	16	73	0.38 ab	4.9	2.16 ab	0	MF	G	G
UC 82 (ck)	66.3	85	60 c-d	16	69	0.30 f-h	4.5	2.10 ab	0	MF	E	E
Means of all entries	72.6	83	71	16	70	0.33	4.8	2.17	-	-	-	-
c.v. (%)	18.6	7	9	6	4	5	6.7	3.1	-	-	-	-

[a]0 = none
[b]MS = moderately soft; MF = moderately firm.
[c]G = good; E = excellent.
[d]Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

Table 11. Yield and other horticultural characteristics of the best processing tomato hybrids and checks in AYT; AVRDC, fall 1992

Entries	Mkt. yield (t/ha)	Fruit set (%)	Fruit size (g)	Fruit first flower	Fruit first ripe fruit	Acidity (% citrate)	Brix (%)	Color (a/b) ratio	Jointless	Firmness[a]	Vine cover[b]	Vine compactness[b]	ToMV[c]
PT 4717	104.2 a[d]	78	89 a-c	21 b	79 b	0.29 ab	4.6 b-f	2.25	-	VF	G	F	2^{a}/+
PT 4714	103.2 ab	77	80 b-f	21 b	76 bc	0.32 ab	5.1 a-c	2.19	+	VF	F	F	2^{a}/+
PT 4659	100.7 ab	73	89 a-c	19 bc	77 b	0.27 ab	4.5 d-f	2.15	-	VF	E	E	2^{a}/+
PT 4691	100.5 a-c	80	72 f	21 b	76 bc	0.31 ab	4.9 a-e	2.10	+	MF	F	F	2^{a}/+
PT 4716	98.8 a-c	81	88 a-d	21 b	88 b	0.30 ab	4.7 b-f	2.22	-	F	G	F	2^{a}/+
PT 4708	95.9 a-c	79	81 b-f	21 b	77 b	0.32 ab	5.1 a-d	2.16	+	F	G	F	2^{a}/+
PT 4681	94.9 a-c	79	95 a	21 b	80 b	0.29 ab	4.7 a-f	2.17	-	VF	E	E	2^{a}/+
PT 4718	93.4 a-c	70	86 a-e	20 bc	79 b	0.26 b	4.8 a-f	2.16	-	MF	G	G	2^{a}/+
PT 4454 (ck)	82.3 bc	77	76 d-f	18 c	72 c	0.40 a	5.0 a-e	2.16	-	MF	G	E	2^{a}/+
UC 204A (ck)	79.4 c	79	71 f	20 b	77 b	0.39 ab	5.3 a	2.23	-	MF	E	E	+/+
UC 82 (ck)	82.4 bc	80	71 f	19 bc	76 bc	0.31 ab	4.7 a-f	2.15	-	MF	G	G	+/+
Mean of all entries	92	76	83	21	78	0.30	4.8	2.15	-	-	-	-	-
c.v. (%)	11.7	8	6	4	2	16.2	5.3	4.1	-	-	-	-	-

[a]MF = moderately firm; F = firm; VF = very firm.
[b]F = fair; G = good; E = excellent.
[c]2^{a}/+ = heterozygous for allele Tm-2^{a}; +/+ = susceptible.
[d]Means in the same column followed by the same letter are not significantly different at 5% (DMRT).

analysis of particular traits were advanced by single seed descent to eventually obtain recombinant inbred lines.

Table 12. Crosses developed in 1993 in the tomato improvement project

Objective of crosses	No. of crosses
1. Incorporation of TTLCV resistance	53
2. Incorporation of cucumber mosaic virus resistance (from *L. hirsutum*)	16
3. Further improvement of tropical tomato (heat tolerance and bacterial wilt)	26
4. Combining ability test (fresh market and cherry tomatoes)	162
5. Crosses designed for RFLP analysis	
Late blight resistance	4
Heat tolerance	2
Black leaf mold	2
Bacterial leaf spot	3
Flood tolerance	2

Segregating populations were planted in 1993 as part of an overall program to select desirable traits in appropriate seasons. Ninety-two heat-tolerant F_4 lines with improved fruit size were selected from F_3 parthenocarpic families. One hundred-thirty (DC_6) fresh market lines carrying high levels of bacterial wilt resistance and heat tolerance, as well as large fruit size, and firmness were selected for further testing. Fifty-two DC_5 cherry lines with heat tolerance and improved flavor were also selected.

Evaluation of New Germplasm for Heat Tolerance

Summary

Forty-three entries were evaluated for heat tolerance in the summer with average maximum/minimum temperatures of 33°C/25°C. One line from mainland China was better in fruit set to other entries, but comparable to AVRDC heat-tolerant checks CL 5675 and CL 5915. Three heat-tolerant U.S. hybrids set fruit poorly under Taiwan summer conditions.

Introduction

Introduced tomato lines and hybrids are routinely evaluated each summer for tropical adaptation, particularly for fruit set under high temperatures, as well as desirable horticultural traits.

Materials and Methods

Two trials of new germplasm were evaluated during the 1993 summer season. Information on entry numbers, sowing, and planting dates are given below:

Materials	No. of entries	Sown	Transplanted
Trial 1	39	06/21/93	07/15/93
Trial 2	4	07/22/93	08/16/93

Entries were evaluated in one 4-m-long row and not replicated. Beds were spaced 1.5 m apart, and plants within the row were 40 cm apart.

Results and Discussion

Majority (86%) of the 43 introductions evaluated for summer fruit-set (33 C/25 C) failed to set fruit or set 1-4 fruits. One line from China had better fruit-set than other introductions and equal to AVRDC heat-tolerant checks CL 5675 and CL 5915. 'Tayninh', from Vietnam, was moderately heat-tolerant but its medium-sized fruit tended to be severely cracked, soft, and catfaced. Both could prove to be useful sources of new heat tolerance genes. Three U.S. heat-tolerant hybrids, Heatwave, NC 82162, and Solar Set, set fruit poorly under Taiwan lowland summer conditions.

International Cooperation

Official Cultivar Releases

Three AVRDC lines coded by a scientist in Bangladesh as TM-0111, TM-6387, and TM-0054, were officially released as Red Gold in Bangladesh.

Processing tomato hybrid Hung-Za No. 16 was released in China in 1992. One parent of the hybrid is AVRDC line CL 1069-0-5-4, sent to the Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences in 1986.

Trial Feedback

China. Mr. Yong-jian Zhou, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences, reported that processing hybrid Hung Za No. 16, a parent of which is AVRDC line CL 1069-0-5-4, significantly outyielded the check cultivar, Hung Ma-Nau No. 140 by 135% in the staked/pruned planting of 1988, and also increased yields by 111% in the unstaked/unpruned planting of 1989 (table 13).

Table 13. Yield and other horticultural characteristics of the best processing hybrid Hung Za No. 16 vs. the check cultivar; China 1988/1989

Year	Varieties	Days to maturity	1st Harvest Yield (t/ha)	1st Harvest % of harvest	Brix (%)	Acidity (% citrate)	Lycopene (mg/100 g)
1988	Hung Za no. 16	110	84	80	4.8	0.49	9.67
1988	Hung Ma-Nau No. 140	115	36	68	4.6	0.39	9.43
1989	Hung Za no. 16	109	78	94	5.2	0.62	9.70
1989	Hung Ma-Nau No. 140	116	54	83	5.2	0.48	12.40

Advantages of CL 1069-0-5-4 were better concentrated set (early harvest included about 80% of total yield), uniform color, smooth, small blossom end and pedicel scars, early maturity, crack resistance, and resistance to TMV.

Mozambique. Mr. George Horlings, agronomist with World Vision International, observed that CLN 657BC$_1$F$_2$-285-0-21 did well in northern Mozambique despite heavy infection by root-knot nematodes. He hopes to multiply seed for on-farm trials in 1994.

Nepal. Dr. D.S. Rana of the Vegetable Seed Production Project, GCP/FAO, at Kathmandu has tested 11 AVRDC tropical lines since 1987. Two lines, CL 1131-0-0-13-0-6 and CL 1131-0-0-7-2-0-9, performed very well and seem adapted to the high temperature environment of Kathmandu, Nepal. They will multiply seeds for on-farm testing in 1994.

Tomato Entomology

Effect of Temperature and Photoperiod on the Production of Acylsugars in *Lycopersicon pennellii*

Summary

One *Lycopersicon pennellii* accession shows consistent resistance to tomato fruitworm. (*Helicoverpa armigera*) in Taiwan and to several other insect species in the United States. The insect resistance is due to production of acylsugars in the foliage which are toxic to insects. AVRDC is using this accession to breed tomato resistant to tomato fruitworm. Effect of temperature and photoperiod on the production of acylsugar was investigated in two laboratory experiments. *L. pennellii* plants in the first experiment were grown under four sets of temperatures: 15, 20, 25, and 35°C and 12:12 h light and dark conditions. In the second experiment these plants were grown under 12:12, 14:10, and 16:8 h light and dark condition at 25°C. Six weeks later we extracted second and third leaflets from the topmost leaf with methylene chloride and estimated the acylsugar content by chemical assay method. As the temperature increased, production of acylsugars also increased. A significant positive correlation was found between temperature and concentration of acylsugar. Length of photoperiod did not affect acylsugar production. These studies indicate that the acylsugar-mediated insect resistance in *L. pennellii* will not be adversely affected by the high temperatures and photoperiod common in the tropics.

Introduction

Tomato fruitworm, *Helicoverpa armigera*, is economically the most important insect pest of tomato in all countries of Asia. Adults lay eggs on foliage and newly emerged larvae feed on leaves during the first and occasionally the second instar stage. Older larvae bore into the fruits and remain there until pupation which takes place in soil. Once inside the fruit, larvae remain inaccessible to any conventional control practices such as often-used insecticide applications. Besides tomato, this polyphagous insect attacks many other economically important crops such as cotton, tobacco, and corn. Indiscriminate use of insecticides to control this pest on these crops has resulted in the insect becoming resistant to a large number of insecticides which is adversely affecting the control of this pest on tomato. At AVRDC we have been studying host-plant resistance with a view of breeding tomato cultivars resistant to this pest. We have been using one *L. pennellii* accession, found to be resistant to various pest species in the U.S., to breed tomato cultivars resistant to tomato fruitworm. The resistance is due to production of toxic acylsugars in the foliage which kill insect larvae feeding on leaves. Since tomato in tropical to subtropical Asia is cultivated under relatively higher temperatures and shorter photoperiods, we studied the effect of these two environmental parameters on the production of acylsugars by *L. pennellii* plants.

Materials and Methods

In the first experiment where effects of temperature on the produciton of acylsugar was studied, *L. pennellii* plants were grown under four sets of temperatures: 10, 20, 25, and 30°C, and 12:12 h light and dark period for 6 wk. In the second experiment, where influence of photoperiod was investigated, *L. pennellii* plants were grown at 12:12, 14:10 and 16:8 light:dark hour conditions at 25°C for 6 wk. After 6 wk of growth, we extracted the second and third leaflet of the topmost leaf from each of eight plants, each plant being one replicate, placed under different environmental conditions. Leaflets were momentarily dipped in methylene chloride and acylsugar concentration in the methylene chloride extract was analyzed by colorimetric method.

Results and Discussion

There was no significant difference in the concentration of acylsugar when plants were grown at varying lengths of photoperiod ranging from 12 to 16 h. Temperature, however, had a significant influence on acylsugar production (table 1).

Table 1. Influence of temperature on production of acylsugars in *L. pennellii* foliage

Temperature °C	µg cm² leaf area
15	4.164±1.118
20	5.053±1.994
25	5.114±1.520
30	6.521±1.897
LSD(0.05)	1.709

As the temperature increased from 15°C to 30°C, the concentration of acylsugars also increased. There was a statistically significant positive correlation (r = 0.945) between temperature and acylsugar production. This indicates that the high temperatures commonly encountered during tomato growing season in the tropics will not adversely affect acylsugar production and thereby resistance of these cultivars to tomato fruitworm.

Tomato Pathology

Tomato Black Leaf Mold: Host Range and Evaluation of Resistance in Accessions of *Lycopersicon* Species

Summary

Five white potato cultivars and eight tobacco lines (*Nicotiana* spp.) were inoculated under controlled conditions with two tomato isolates of *Pseudocercospora fuligena*. None of the plants developed symptoms of black leaf mold. Known susceptible tomato, eggplant, sweet pepper, and *Solanum nigrum* were planted in the field along with a hot pepper selection and a local *Physalis* sp. selection with an unknown disease response. The plants were inoculated five times with a tomato isolate and observed for black leaf mold development from November 1992 to February 1993. Symptoms developed only on tomato and eggplant. Forty-six Lycopersicon accessions representing 10 species were inoculated under controlled conditions and evaluated for resistance to black leaf mold. High levels of resistance (< 10% leaf area affected) were identified among entries of *L. cheesmanii*, *L. chimielewskii*, *L. glandulosum*, *L. hirsutum*, *L. pennellii*, *L. parviflorum*, *L. peruvianum*, and *L. pimpinellifolium*.

Introduction

Black leaf mold caused by *Pseudocercospora fuligena* (Roldan) Deighton is an important foliar disease of tomatoes in subtropical and tropical countries. There is little information on host range or sources of resistance in tomato. The reported host range of *P. fuligena* is tomato, *Solanum nigrum*, and pepper. Our objectives were to determine whether this pathogen could infect other solanaceous plants and to identify sources of resistance to black leaf mold by screening accessions of *Lycopersicon* spp. for their reactions to the pathogen.

Materials and Methods

Inoculum and plant inoculation

Two tomato isolates of *P. fuligena* were used in this study: isolate Pf-2 collected from Tainan in west Taiwan and isolate Pf-14 from Haulien in east Taiwan. Conidial inoculum was prepared from cultures grown on tomato-oatmeal agar (TOA). TOA was made with boiling water extracts from 50 g tomato leaves and 15 g oatmeal combined with 20 g agar and adjusted to 1 liter with distilled water before autoclaving. Petri plate cultures grown for inoculum were established by streaking the agar surface with conidia and incubated at 28° C with 12 h/day fluorescent light for 10 days. Conidia were harvested by flooding the plate culture with distilled water and scraping the colony surface with the edge of a glass microscope slide. The conidial suspension was decanted and filtered through a 40 µm sieve, quantitated using a hemacytometer, and diluted with

distilled water to the desired concentration for inoculation. Plants were inoculated by spraying the foliage to the point of run-off with a conidial suspension using a hand pump sprayer.

Laboratory inoculation of potato and tobacco. Five white potato cultivars including Feng-white, Seangre, Cardina, Kennebec, and Omega and eight tobacco entries including *Nicotiana tabacum* cv. Havana, Xanthi, Samsun, White Burley, and Van-Hicks plus single lines of *N. glauca*, *N. rustica*, and *N. benthamiana* were inoculated to determine if they could serve as hosts for *P. fuligena*. Tomato cv. Taichung ASVEG No. 4 was included as a susceptible control. One replication of each entry consisted of three plants in a single 15-cm-diam clay pot. There were four replications. Seeding was done on 12 December 1992, and plants were inoculated 9 February 1993 with an equal mixture of 5 x 10^3 conidia/ml suspensions from isolates Pf-2 and Pf-14 of *P. fuligena*. The inoculated plants were maintained in a growth room at 28±2°C and 95±2% RH with 14 h of light (49.3 µE/m²/s) per day. They were observed 15 and 20 days after inoculation (DAI) for disease development and symptom expression.

Field studies with solanaceous plants. Solanaceous crop and weed species were planted in the field and inoculated with *P. fuligena* to observe their responses to the pathogen. Eggplant (Pingtung Long and Known You Long); hot pepper (Szechwan); sweet pepper (Blue Star); black nightshade (*Solanum nigrum*); ground cherry (*Physalis* sp.); susceptible tomato (Known You 301 and L 194); and resistant tomato (L 733 and L 3718) were transplanted to the field on 24 September 1992. Each treatment consisted of a single 6-m-long row with 12 plants. The experimental design was a randomized complete block with three replications. All plants were inoculated on 14, 19, 28 October and 3, 4 November 1992 by spray application of a 10^4/ml conidial suspension of *P. fuligena*, isolate Pf-2. The plants were observed from 28 October 1992 to 3 February 1993 at 2-wk intervals for symptoms, and those exhibiting symptoms were evaluated on a per plot basis for disease severity based on the percentage of leaf area affected.

Screening Lycopersion accessions for resistance. Forty-six Lycopersicon accessions representing 10 species and an interspecific hybrid, *L. esculentum* x *pimpinellifolium*, were assayed for their black leaf mold responses. Three known susceptible cultivars, Known You 301, Taichung ASVEG No. 4, and TN-2, were included as positive controls. Seeds were soaked for 1 min in 1% sodium hypochlorite, rinsed with water, transferred onto moist filter paper in petri dishes, and germinated in a 24°C incubator with a 12 h/day light period. Seedlings were transplanted in a steam sterilized soil mix in 9-cm-diam plastic pots, with one plant per pot, and placed on the greenhouse bench where they were shaded with a black net during the first 2 wk. One month after transplanting, the plants were inoculated by spraying the foliage with a 5 x 10^3 conidia/ml suspension of *P. fuligena*, isolate Pf-2, and subsequently maintained in a growth room at 28±2°C and 95±2% RH with 14 h of light (49.3 µE/m²/s) per day. Seventeen days after inoculation the plants were rated for disease severity by estimating the percentage of leaf area affected. The number of plants for each entry ranged from 4 to 67 depending on availability of seedlings.

Results and Discussion

Laboratory inoculation of potato and tobacco. Plants were observed for symptoms at 15 and 20 DAI. None of the potato nor tobacco entries developed any disease symptoms suggesting that they are not hosts of *P. fuligena*. The susceptible tomato, Taichung ASVEG No. 4, developed severe symptoms under the same conditions with 60% of the leaf area affected 15 DAI and 70% affected on the 20th day. These data show that viable inoculum was used and that conducive environmental conditions were provided.

Field studies with solanaceous plants. Following repeated inoculation with *P. fuligena*, black leaf mold symptoms developed only on the two highly susceptible tomato entries and the two eggplant entries (table 1). Szechwan pepper and ground cherry did not develop symptoms in the field nor in a previous laboratory study (AVRDC 1992 Progress Report), thus they appear not to be hosts of *P. fuligena*. Blue Star pepper, resistant tomato lines L 733 and L 3718, and black nightshade failed to develop symptoms in this field study although each had developed limited symptoms in the previous laboratory study. These results show that the laboratory conditions used in the previous study were more conducive to black leaf mold development than the field conditions that prevailed during the winter season of 1992-93 at AVRDC.

Table 1. Black leaf mold development on field grown solanaceous plants inoculated with tomato isolate Pf-2 of *Pseudocercospora fuligena*[a]

Crop / Weed	Cultivar / Selection	Leaf area affected (%)[b]
Tomato	L 733	0
Tomato	L 3718	0
Tomato	L 1914	17
Tomato	Known You 301	62
Sweet pepper	Blue Star	0
Hot pepper	Szechwan	0
Eggplant	Pingtung Long	15
Eggplant	Known You Long	15
Black nightshade	Native	0
Ground cherry	Native	0

[a]Transplanted to the field 24 September 1992; inoculated on 14, 19, 28 October and 3, 4 November 1992.

[b]Percent leaf area affected was recorded 3 February 1993.

Screening Lycopersicon accessions for resistance. High levels of black leaf mold resistance (< 10% leaf area affected) were identified among individual entries of *L. cheesmanii*, *L. chimielewskii*, *L. glandulosum*, *L. hirsutum*, *L. pennellii*, *L. parviflorum*, *L. peruvianum*, and *L. pimpinellifolium* (table 2). None of the *L. esculentum* nor *L. esculentum* x *pimpinellifolium* entries were resistant. These results show that there are numerous available sources of resistance to black leaf mold. Some of these sources have been provided to the breeder and crosses have been made in an attempt to incorporate resistance into more horticulturally acceptable types and to study the inheritance of resistance.

Table 2. Evaluation of Lycopersicon accessions for their response to black leaf mold following inoculation with *Pseudocercospora fuligena*, isolate Pf-2

Entry	Species	No. of plants tested	Leaf area affected (%) Each entry	Species average
L 4253	*L. cheesmanii*	41	20.24	
TL 1044	*L. cheesmanii*	35	3.43	
TL 1052	*L. cheesmanii*	24	30.20	
TL 1078	*L. cheesmanii*	15	5.65	
TL 1082	*L. cheesmanii*	40	11.50	
LA 317	*L. cheesmanii*	23	36.09	
LA 1402	*L. cheesmanii*	13	11.50	16.94
TL 1169	*L. chilense*	11	30.00	
TL 1171	*L. chilense*	14	12.50	
TL 1175	*L. chilense*	20	11.00	
LA 1932	*L. chilense*	4	10.00	
LA 2884	*L. chilense*	10	20.40	16.78
LA 1028	*L. chimielewskii*	10	5.50	
LA 1306	*L. chimielewskii*	20	2.45	
LA 2663	*L. chimielewskii*	15	10.00	5.98
L 1	*L. esculentum*	34	25.00	
L 2	*L. esculentum*	48	23.54	
L 3	*L. esculentum*	48	25.68	24.74
LA 1546	*L. esc.* v. *cerasiforme*	24	12.50	
LA 1673	*L. esc.* v. *cerasiforme*	22	25.45	18.98
L 634	*L. glandulosum*	41	7.32	
L 639	*L. glandulosum*	38	16.05	
L 641	*L. glandulosum*	36	11.11	11.49
L 643	*L. hirsutum*	36	8.33	
L 645	*L. hirsutum*	33	9.09	
L 733	*L. hirsutum*	67	0.75	
LA 1353	*L. hirsutum*	20	10.00	
LA 1908	*L. hirsutum*	16	1.32	
LA 1223	*L. hirsutum* f. *glabratum*	15	2.10	5.27
LA 1326	*L. parviflorum*	12	8.75	8.75
LA 1505	*L. pennellii*	11	6.05	6.05
L 631	*L. peruvianum*	40	16.75	
L 635	*L. peruvianum*	22	10.45	
L 638	*L. peruvianum*	32	6.25	
LA 111	*L. peruvianum*	67	19.10	
LA 385	*L. peruvianum*	4	5.15	
LA 1292	*L. peruvianum* f. *glandulosum*	16	9.40	11.18
L 139	*L. pimpinellifolium*	45	22.22	
L 140	*L. pimpinellifolium*	46	22.61	
L 141	*L. pimpinellifolium*	48	9.38	
LA 722	*L. pimpinellifolium*	20	9.40	
LA 2184	*L. pimpinellifolium*	7	37.14	
LA 2584	*L. pimpinellifolium*	10	26.00	21.13
L 457	*L. escu.* X *L. pimp.*	14	40.00	
L 483	*L. escu.* X *L. pimp.*	49	26.94	
L 486	*L. escu.* X *L. pimp.*	46	23.91	30.28
KY 301 (ck)	*L. esculentum*	24	54.71	
Taichung ASVEG No. 4	*L. esculentum*	24	45.83	
TN-2 (ck)	*L. esculentum*	24	60.05	53.35
Mean			17.53	

Screening Lycopersicon Accessions for Resistance to Late Blight

Summary

In an attempt to identify sources of resistance to tomato late blight, 795 Lycopersicon accessions representing four species were tested for their reactions to a Taiwan isolate, Pi1, of *Phytophthora infestans*. Eight 4-wk-old seedlings of each accession were inoculated (10^4 sporangia/ml) and maintained at 22±2°C in a lighted growth room with an intermittent overhead water mist for 7 days. Four highly resistant accessions were identified: PI 365904 (*L. hirsutum*), PI365905 (*L. hirsutum*), PI 365951 (*L. peruvianum*), and PI 365957 (*L. pimpinellifolium*). Intermediate levels of resistance were found in 18 accessions.

Introduction

Late blight caused by *Phytophthora infestans* is one of the most destructive diseases of tomato in wet temperate climates and tropical highlands. The pathogen attacks all aboveground parts of the plant causing rapid defoliation and fruit rot. Durable host resistance to late blight is not available thus chemical control is the only alternative for disease management when the tomato crop is grown under conducive conditions. The first objective of this study was to determine an appropriate level of inoculum to evaluate the late blight reactions of tomato accessions. The second objective was to assay accessions of wild *Lycopersicon* spp. for their reactions to *P. infestans* in the laboratory to identify sources of resistance.

Materials and Methods

Inoculum and plant inoculation

Isolate Pi1 of *P. infestans* obtained from tomato plants in the Hsin Yi area in Taiwan was used throughout these studies. The isolate was maintained on Rye Agar slant tube cultures at 18°C. Sporangia for inoculum were produced on detached tomato leaves maintained in 15-cm-diam petri dishes on moist filter paper with wet cotton covering the cut end of the petiole. Detached leaves were spray inoculated with a sporangial suspension from Rye Agar or detached-leaf cultures of *P. infestans*. The petri dishes were sealed with parafilm and incubated at 18°C with a 12 h/day light period for 7 to 14 days. Infected leaves were transferred to a beaker of sterile distilled water and agitated to dislodge the sporangia. The sporangial suspension was filtered through three layers of cheesecloth to remove leaf fragments and then diluted, based on hemacytometer counts, to the desired concentration. Tomato plants were inoculated by spraying the foliage to the point of run-off with a sporangial suspension and incubated in a growth room maintained at 22±2°C and 98±2% RH with 14 h of light (68 $\mu E/m^2/s$). The plant foliage was kept wet by an overhead water system that emitted a fine mist for 30-sec periods twice each hour.

Disease assessment scale

Disease severity ratings (DSR) were made according to the following scale: 0 = no visible symptoms; 1 = 1 - 10% leaf area affected; 2 = 11 - 20% leaf area affected; 3 = 21 - 40% leaf area affected and/or 1 - 10% stem area affected; 4 = 41 - 70% leaf area affected and/or 11 - 50% stem area affected; 5 = 71 - 90% leaf area affected and/or 51 - 100% stem area affected; and 6 = 91 - 100% leaf area affected and/or plant dead.

Inoculum concentration and disease development. A known susceptible tomato line, LV 01249, was used to evaluate the effect of inoculum concentration on disease development. Tomato plants were propagated under standard greenhouse conditions individually in 9-cm-diam plastic pots containing a steam sterilized soil mix. Thirty-day-old plants were inoculated with *P. infestans* sporangial suspensions of 1×10^2, 5×10^2, 1×10^3, 5×10^3, 1×10^4, 5×10^4, and 1×10^5 sporangia/ml. Three plants were included in each treatment with four replications. The plants were arranged in a randomized complete block design on the growth room bench and sprayed to the point of run-off with the appropriate sporangial suspension.

Screening tomato plants for late blight resistance. Seven hundred ninety-five Lycopersicon accessions representing four species were tested for their reactions to a Taiwan isolate, Pi1, of *P. infestans*. Plants of each accession were propagated in the greenhouse with a single plant in a 6-cm-diam plastic pot containing a steam sterilized soil mix. Eight plants of each accession were grouped in a flat with five other lines. When the plants were 4 wk old they were transferred to the growth room (described above) and spray inoculated with a suspension of 10^4 sporangia/ml. Overhead misting of the plants was suspended 5 DAI, and disease severity ratings were made 7 DAI.

Results and Discussion

Inoculum concentration and disease development. The disease severity ratings were recorded daily from 3 to 7 DAI. The three plants in each replication were scored individually and averaged to obtain the DSR value for each replication. These data were used to calculate the area under the disease progress curve (AUDPC) for comparison of treatments (table 3). An increase in disease severity was associated with increasing inoculum levels at concentrations from 10^2 to 10^4 sporangia/ml. However, at concentrations from 10^4 to 10^5 there was no difference in disease severity. Based on this information, the 10^4 sporangia/ml concentration was chosen as the standard inoculum concentration for evaluation of tomato accessions for resistance to late blight.

Screening tomato plants for late blight resistance. Disease assessment of each accession was done by scoring each of the eight plants according to the disease severity scale described earlier and calculating a mean DSR. Four highly resistant accessions (DSR < 2) were identified: PI 365904, *L. hirsutum*; PI 365905, *L. hirsutum*; PI 365951, *L. peruvianum*; and PI 365957, *L. pimpinellifolium* (table 4). In addition, 18 accessions with intermediate levels of resistance (DSR 3 to 4) were identified among the 795 accessions tested. Durability of these highly resistant and intermediate resistant sources will be tested in field plantings at several geographic locations and by laboratory inoculations at the University of Wales using a series of internationally collected isolates of *P. infestans*.

Table 3. Effect of inoculum level on the rate of tomato[a] late blight[b] development under laboratory conditions[c]

Concentration (sporangia/ml)	AUDPC[d]
1 x 102	8.7
5 x 102	12.3
1 x 103	15.5
5 x 103	18.9
1 x 104	21.2
5 x 104	21.2
1 x 105	20.2
LSD (0.05)	2.2

[a]A known susceptible AVRDC tomato accession, L 1249 (PI 169576).
[b]*Phytophthora infestans*, isolate Pi1.
[c]Plants were spray inoculated to the point of run-off and incubated in a lighted growth room at 22±2°C and 98±2% and 98±2% RH with an intermittent overhead mist system.
[d]Area under disease progress curve, calculated from disease severity ratings made daily from 3 to 7 days after inoculation.

Table 4. Sources of resistance to *Phytophthora infestans* identified among 795 accessions of wild *Lycopersicon* spp.

Accession no.	Plant introduction no.	Disease[a] severity rating	Species[b]
Highly resistant			
L 3683	365904	1.5	*hirsutum*
L 3684	365905	1.6	*hirsutum*
L 3707	365951	1.9	*peruvianum*
L 3708	365957	1.0	*pimpinellifolium*
Moderately resistant			
L 0637	126437	3.1	*esculentum* x *pimpinellifolium*
L 0901	128664	3.3	*esculentum* x *pimpinellifolium*
L 1468	198912	3.3	*esculentum* x *pimpinellifolium*
L 1533	205012	3.6	*pimpinellifolium*
L 1742	251299	3.6	*esculentum* x *pimpinellifolium*
L 1948	266376	3.9	*peruvianum*
L 1959	270150	3.9	*esculentum* x *pimpinellifolium*
L 2106	270436	3.9	*esculentum* x *pimpinellifolium*
L 2107	270437	3.9	*esculentum* x *pimpinellifolium*
L 2110	270440	3.6	*pimpinellifolium*
L 3689	365913	3.4	*pimpinellifolium*
L 4155	-[c]	3.4	*pimpinellifolium*
L 4862	407533	3.5	*pimpinellifolium*
L 4863	407534	3.6	*pimpinellifolium*
L 4885	407556	3.8	*pimpinellifolium*
L 4969	432362	3.1	*pimpinellifolium*
L 5392	-	3.9	unknown
L 5948	306216	3.4	*pimpinellifolium*

[a]Disease severity rating on a scale of 0 to 6 in which 0 = symptoms and 6 = 91 to 100% leaf area affected.

Resistance Screening of Tomato to *Xanthomonas campestris* pv. *vesicatoria*

Summary

Resistance screening of tomato to *Xanthomonas campestris* pv. *vesicatoria* was conducted in the greenhouse and field. A total of 44 entries of tomato were tested. The greenhouse inoculation methods, such as dipping and atomization were not suitable for resistance screening, possibly due to the high temperature in the greenhouse. Based on the field screening, three accessions, L 1951 (*Lycopersicon esculentum* x *pimpinellifolium*), L 2120 (*L. pimpinellifolium*), and L 4848 (*L. peruvianum*), were as resistant as Hawaii 7998, the resistant control. Among the 11 breeding lines tested, CHT 14-171C-16-10-0, CHT 14-171C-3-1-1, and CHT 33-7C-14-5-2 were the most resistant. None of the six commercial cultivars tested were resistant to bacterial spot. L 4848 is a reliable source of resistance which was as resistant as Hawaii 7998 during the four field-screening trials.

Introduction

Bacterial spot caused by *Xanthomonas campestris* pv. *vesicatoria* (Xcv) is one of the most widespread and serious diseases of tomato under the hot and humid regions of the tropics and subtropics. The disease is endemic in most regions possibly due to the survival of Xcv in seeds, soil, plant debris, and weeds, etc. Resistance breeding is the most promising control method for bacterial spot due to the resistance of the pathogen to chemicals such as streptomycin and copper compound. It has been demonstrated that planting resistant materials such as Hawaii 7998 can reduce disease severity on foliage from 89% to 26% and on fruit from 56% to 2% under high disease pressure. Hawaii 7998 has been the only reliable resistant source to bacterial spot. However, the resistance in this line is quantitatively inherited and its resistance mechanism is not expressed when the plants are kept at 30°C constantly. Moreover, there is a new race of Xcv to which Hawaii 7998 is susceptible. Therefore, it is necessary to look for other resistant sources for the breeding program.

Resistance screening of the tomato germplasm collection from GRSU of AVRDC has been conducted. A total of 544 accessions have been tested in the field. The screening results of 27 selected tomato entries and other materials in the field, and the attempt to develop a greenhouse screening method are reported here.

Materials and Methods

A total of 27 tomato accessions from GRSU were used for the greenhouse and field screening conducted during fall 1991 and spring 1992 (table 5). They were selected based on the results of previous field screening. Another 29 tomato accessions were used for the field trials conducted during fall 1992 and spring 1993 (table 6). Twelve of them were selected from the 27 GRSU materials, 11 which were tolerant to bacterial spot based on field observation were AVRDC breeding lines, and six were common commercial cultivars in Taiwan. Seeds of tomato were germinated in vermiculite then transplanted to 9-cm-diam plastic pots. Seedlings were transplanted to the field or the greenhouse for screening at about 30 DAS. Hawaii 7998 was used as resistant control and CL 5915-153-3-3-0 as the susceptible control for all screening tests.

Table 5. Values of the area under disease progress curve (AUDPC) for 27 tomato entries inoculated in the field with *Xanthomonas campestris* pv. *vesicatoria* in two seasons

AVRDC no.	PI or name	Species [a]	Fall 1991	Spring 1992
L 1165	155372	escu	–	236.6
L 491	114967	escu	141.0	233.0
L 510	117898	escu	116.3	217.9
L 715	127808	escu	154.6	277.7
L 719	127813	escu	81.5	160.4
L 911	129019	escu	112.7	219.2
L 305	BonnyBest	escu	–	278.4
L 2772	283930	escu	140.1	359.6
L 4486	401770	escu	173.9	274.9
L 486	114038	escu x pimp	138.4	294.4
L 531	118784	escu x pimp	103.6	256.7
L 1161	155368	escu x pimp	176.3	–
L 1171	155378	escu x pimp	121.2	179.9
L 1452	195784	escu x pimp	165.7	253.4
L 1499	204978	escu x pimp	171.2	252.3
L 3312	319369	escu x pimp	100.0	213.8
L 1951	269139	escu x pimp	156.9	236.6
L 135	LA1237 SAL318-1	pimp	157.0	208.1
L 142	LA1263 SAL345	pimp	198.8	–
L692	126949	pimp	211.4	267.1
L 714	127807	pimp	128.6	235.7
L 1533	205012	pimp	114.0	240.2
L 2117	270447	pimp	126.3	243.9
L 2120	270450	pimp	131.8	223.3
L 4421	390715	pimp	142.5	222.2
L 1034	129145	peruv	176.8	313.7
L 4848	390687	peruv	58.8	63.3
R ck	Hawaii 7998	escu	77.7	65.8
S ck	CL 5915-153-3-3-0	escu	350.4	498.1
Avg.			145.5	241.7
LSD (0.05)			67.8	75.2

[a] escu : *Lycopersicon esculentum*, pimp : *L. pimpinellifolium*, peruv: *L. peruvianum*.

Strain XVT-77 which belongs to race 3 of the tomato-pepper group based on the classification system reported by Minsavage et al. (1990) was used as inoculum. Bacterial suspension was prepared from 24-h-old culture on 523 media at 30°C. The concentration was adjusted with distilled water until the O.D. value was equal to 0.3 at 600 nm which contained approximately 10^8 cfu/ml. Another concentration was prepared by dilution from the above suspension.

For greenhouse screening, three methods were used: (1) dipping method: plants were kept in the dark overnight and inoculated early the next morning. The aboveground part of seedlings was dipped into bacterial suspension (10^6 cfu/ml) containing 0.025% (v/v) of surfactant L-77 (Union Carbide) for 30 seconds. Plants were moved into the greenhouse after inoculation; (2) atomization method: leaves of each seedling were atomized with bacterial suspension (10^8 cfu/ml) under 1.5 kg/cm^2 pressure. Plants were kept under high humidity for 2 days then moved to the greenhouse; (3) infiltration method: three leaflets from three different fully expanded leaves were infiltrated with bacterial suspension (10^8 cfu/ml). Hypersensitive reaction was observed at 24 °C for 72 h. Each experiment was conducted twice using a complete randomized design with five replications. The percentage of diseased leaf area of each plant was evaluated when the lesions were fully developed for the first two methods.

Table 6. Values of the area under the disease progress curve (AUDPC) for 29 tomato entries inoculated in the field with *Xanthomonas campestris* pv. *vesicatoria* in two seasons

Variety	AUDPC	
	Fall 1992	Spring 1993
L 1499	1376	741
L 4421	2143	746
L 1951	912	782
L 0692	2162	725
L 3312	1610	607
L 1452	2149	840
L 2117	1330	505
L 0135	1304	644
L 1171	1372	756
L 2120	1029	519
L 0719	1179	697
L 4848	978	382
CHT 14-171C-3-1-1	766	757
CHT 14-171C-3-1-12	776	861
CHT 14-171C-16-10-0	920	775
CHT 14-171C-20-6-0	963	850
CHT 14-171C-16-1-0	930	916
CHT 33-7C-14-5-2	1262	833
CHT 33-7C-14-5-5	1256	875
CLN 819TC1F1-3-16-27-1-19	1024	981
CLN 824TC1F1-5-21-3-10-2	1541	1141
CLN 824TC1F1-5-21-3-10-11	1388	829
CLN 824TC1F1-5-21-3-10-15	1611	937
Farmers 301	945	1073
ASVEG No. 4	620	944
Double Fortune	675	1107
Hei-Shiu	689	1158
Season Red	715	1141
Santa	652	977
Hawaii 7998 (R ck)	951	680
CL 5915-153-3-3-0 (S ck)	1632	1569
Avg.	1189	850
LSD (0.05)	353	160

The 27 accessions in the field were screened twice. Seedlings of the first trial were transplanted on 30 October 1991. Plants were inoculated with bacterial suspension (10^8 cfu/ml) by atomization in the field on 14 and 21 November. Seedlings of the second trial were transplanted on 14 April 1992. Plants were inoculated on 6 May. Both trials used randomized complete block design with three blocks. Plot size was 1.5 m x 1 m with 10 plants per plot. Five plants were randomly selected and rated based on the Barratt and Horsfall scale. Estimated mean percentage of diseased leaf area was obtained based on the conversion table. Area under disease progress curve (AUDPC) values were calculated.

Field screening of the 29 accessions was conducted twice. Transplanting was conducted on 8 October 1992 for the first trial and on 31 March 1993 for the second trial. Plants were inoculated four times during the experiment for both trials. The experimental design was randomized

complete block design with three blocks. Plot size was 1.5 m x 3.2 m with 16 plants per plot. Disease rating was conducted as described above.

Results and Discussion

None of the test entries showed hypersensitive reactions, except Hawaii 7998 72 h after infiltration. This indicated that they were all susceptible to Xcv or hypersensitive reaction is not associated with resistance of the test entries. Disease severity of the resistant control (Hawaii 7998) was not significantly different from the susceptible control (CL 5915-153-3-3-0) based on the results of the other two greenhouse screening methods. Disease severity of all test entries was not significantly less than the susceptible control based on the results of the atomization method. However, six entries were more resistant than the susceptible control based on the results of the dipping method: L 3312, L 486, L 1171, L 1452, L 135, and L 4848. Results of field and greenhouse screening were subjected to correlation analysis. The response to Xcv in both dipping and atomization methods was not significantly correlated with AUDPC data from the field screening. Therefore, these two methods are not suitable as replacements for field screening for bacterial spot. It is known that the resistance in Hawaii 7998 is associated with hypersensitive reaction (HR) which is sensitive to high temperature. The incompatible interaction between Hawaii 7998 and Xcv becomes compatible when plants were kept constantly at 30°C. During the greenhouse experiment (from inoculation until observation), the average maximum temperature ranged from 34.2 to 37.4°C and the average minimum temperature ranged from 21.1 to 26.7°C in the greenhouse. It is possible that the resistance mechanism in Hawaii 7998 and other entries was not expressed fully under this environment.

AUDPC values were used to determine the resistance level of the test lines. The results of field screening of the 27 entries selected from previous trials are listed in table 5. The AUDPC value of Hawaii 7998 was significantly less than that of CL 5915-153-3-3-0 in both trials. The percentage of diseased leaf area was 4.9% in Hawaii 7998 and 54.4% in CL 5915-153-3-3-0 at 42 DAT in the 1992 trial. The average maximum and minimum temperature ranged from 17.8 to 28.8°C and 11.6 to 20°C during the 1991 trial, and from 22 to 31.8°C and 16 to 24.6°C during the 1992 trial. The resistance in Hawaii 7998 can be expressed under this environment. The AUDPC values of 15 entries were not significantly different from that of Hawaii 7998 in the 1991 trial. However, only one entry, L 4848, was as resistant as Hawaii 7998 in the 1992 trial.

Based on the results of greenhouse and field screening, 12 of the 27 entries were selected for further screening. Other AVRDC tomato breeding lines and commercial cultivars were screened to determine their resistance to bacterial spot. Among the 29 test entries, 17 were as resistant as Hawaii 7998 in the fall 1992 trial and 14 were as resistant or more resistant than Hawaii 7998 in the spring 1993 trial. Six were common in both trials. These were L 1951, L 2120, L 4848, CHT 14-171C-3-1-1, CHT 14-171C-16-10-0, and CHT 33-7C-14-5-2 (table 6).

The AUDPC values of all the commercial cultivars were not significantly different from that of Hawaii 7998 in the fall trial but were significantly different in the spring trial. This is possibly due to the higher disease severity in the spring (83.4% diseased leaf area of the susceptible control) than in the fall trial (57.5%). The results of the spring trial are thus more reliable. The total precipitation during the 1993 spring trial was 834 mm, but it was only 40.5 mm during the 1992 fall trial. Spring weather is more suitable for resistance screening of bacterial spot.

L 4848 (*L. peruvianum*) is the most promising entry as a new resistance source for bacterial spot based on the greenhouse and four field screening trials. This resistance was not associated with hypersensitive reaction and possibly was not as sensitive as that in Hawaii 7998 to high temperature. The characteristics and inheritance of the resistance in L 4848 will be studied further.

Biovar Identification of Strains of *Pseudomonas solanacearum* and Development of Molecular Detection Methods Using DNA Probes

Summary

Bacterial wilt caused by *Pseudomonas solanacearum* (Ps) can be a major limiting factor in the cultivation of many agronomically important plants in tropical and subtropical areas of the world. The extreme variability of the pathogen makes it difficult to control the disease. It is, therefore, necessary to develop effective approaches to detect and identify Ps strains. The pathogen can be classified into five biovars based on the utilization of different carbohydrates. Forty-four of the 64 Ps strains from stored cultures were identified as biovar 3, 17 were biovar 4, and three were unidentified after three repeats. A more efficient nucleic acid-based technique was also used to differentiate the pathogen in this study. Three DNA probes were tested for their specificities of Ps strains. The biovar nonspecific probe (092-03B col.5) can hybridize with all Ps strains tested but not other plant pathogenic bacteria. The biovar 4 specific probe (092-03A col.18) can only hybridize with strain 092 (biovar 4 from Australia) and one *Xanthomonas campestris* pv. *vesicatoria* race 1 strain. None of the biovar 4 strains from Taiwan showed any hybridization bands. The biovar 3 specific probe (0171-10 no. 9) can hybridize with both biovars 3 and 4 strains. All strains, but one Taiwan biovar 4, had the same pattern which was different from that of strain 092. The biovar 3 strains from Taiwan showed three different patterns and were different from that of most Australian biovar 3 strains.

Introduction

Pseudomonas solanacearum is the causal agent of bacterial wilt, one of the most destructive plant diseases in the tropical and subtropical areas of the world. The disease can affect more than 44 families of plants and most of the economic damage is caused to solanaceous plants such as potato, tomato, tobacco, eggplant, and pepper, and some nonsolanaceous hosts such as banana, peanut, and ginger.

To control the disease, the pathogen should first be detected and identified. Effective techniques to identify the different Ps strains should be developed since this pathogen is very diverse. Traditionally, semi-selective agar plates (such as TZC plates) are used to detect the pathogen by observing the colony morphology. This method is time-consuming, laborious, and cannot differentiate the bacteria into biovars or races. Serological approaches (such as ELISA) are easy to apply, but not very specific. It is not known if any biovar-specific antibody has been developed. The nucleic acid-based techniques, which require the development of a specific probe (as in hybridization or blotting methods) or a set of specific primers (as in polymerase chain reaction amplifications) have been developed recently and are fast, specific, and sensitive. Several phytopathogenic bacteria such as *P. syringae* pv. *phaseolicola* and *Clavibacter michiganense* ssp. *sepedonicum* can be detected using specific DNA probes. The specific DNA probes can be obtained by random cloning, genomic subtraction, or specific sequence of cloned genes, etc.

At present, there are two classification systems of Ps: the biovar and the race systems. The pathogen can be differentiated into five biovars based on its ability to use different carbohydrates. It can also be classified into three major races according to the host range. The aim of the study was to develop a DNA probe that can be used to detect and identify the pathogen. The study also aimed to: (1) differentiate the Ps strains into biovars by acid production from carbohydrates; and (2) determine the specificity of different DNA probes to the Ps strains in Taiwan.

Materials and Methods

Bacterial strains and plasmids

A total of 64 Ps strains were used in biovar identification. They were isolated from tomato, sweet pepper, tobacco, eggplant, potato, bird of paradise, and perilla in Taiwan. Selected strains from different biovar groups were used in the hybridization with different probes. Other plant pathogenic bacteria used in this study were *Xanthomonas campestris* pv. *vesicatoria* (Xcv) race 1 (XVT28), 2 (XVT48), and 3 (XVT77) isolated from tomato; Xcv strains isolated from pepper (XVP25, 41, 59, and 64); *Xanthomonas campestris* pv. *campestris* (Xcc4 and 10); *Xanthomonas campestris* pv. *glycenia* (Xcg3 and 7); *Erwinia carotovora* ssp. *carotovora* (Ecc, TSR1 and TSR5); *Erwinia chrythanthemi* (Ech); *P. cepacia* (Pc5); and *P. gladioli* (Pc10). The plasmids containing different inserts of Ps DNA fragments were provided by Dr. J. Timmis, University of Adelaide, Australia. The inserts were unique polymerase chain reaction (PCR) products by random primers and cloned with the vector pCR™II. Plasmid 092-03A col.18 contains biovar 4 specific DNA; 092-03A col.5 contains biovar nonspecific DNA; 0171-10 no. 9 contains biovar 3 specific DNA.

Differentiation of Ps into biovars

Ps strains from stored cultures were grown on TZC agar plates first. Typical colonies were picked and grown on 523 agar plates. The bacteria were then resuspended in sterile distilled water and inoculated into tubes with basal media (4) plus different carbohydrates at a final concentration of 1%. The tubes of inoculated bacteria were incubated at 30°C and examined after 2, 7, 14, and 21 days. The basal medium was made by dissolving the constituents ($NH_4H_2PO_4$, 0.1%; KCl, 0.02%; $MgSO_4.7H_2O$, 0.02%; Difco Bacto Peptone, 0.1%; Bromthymol blue, 0.008%) in distilled water; then adjusting the pH to 7.0-7.1 with 40% NaOH. The agar concentration was 0.3%.

Genomic DNA isolation and restriction enzyme digestion

Bacteria were grown overnight on nutrient agar plates at 30°C, washed once, and resuspended in TE8 buffer (50 mM Tris, pH8, 20 mM EDTA). The bacterial suspension was incubated at 70°C for 15 min to inactivate DNAase and cooled to room temperature. After the addition of Sarkosyl and proteinase K, the bacterial suspension was incubated at 50°C for 15 h. Phenol and chloroform extraction were performed and the DNA was precipitated by ethanol and dried. The pellets were dissolved in TE buffer and the DNA concentrations were calculated by measuring the O.D. value at 260 nm using a spectrophotometer. One microgram of DNA was digested by 5 units of EcoR I at 37°C for 5 h.

Probe preparation

The plasmids were digested by EcoR I and separated by 0.8% low-melting agarose gel electrophoresis at 4°C to get sharper bands. The gel was stained with ethidium bromide and the insert DNA fragment was cut under the UV light from the gel. The insert DNA was purified by the following procedure. The cut agarose gel was melted at 65-70°C and diluted to the final

concentration of agarose below 0.3% by the addition of TE buffer. One-tenth volume of 5 M NaCl was added and the mixture was incubated at 65-70°C for 5-10 min. The mixture was cooled to room temperature. After the extraction of phenol and chloroform, the DNA was precipitated, dried, and dissolved in a small volume of TE buffer (Sambrook et al. 1989[1]). The DNA was then labeled with DIG-dUTP following the Boehringer Mannheim manual.

Southern blotting and detection

The digested genomic DNA (1 µg) was fractionated by 0.8% agarose gel electrophoresis at 50 volts. The gel was stained, photographed, and transferred overnight to positively charged nylon membrane directly using 0.4 N NaOH as the transferring buffer according to the manufacturer's recommendation. The membrane was then air-dried, baked at 120°C for 30 min, prehybridized at 65°C for 2 h, and hybridized at 65°C overnight. The membrane was washed under a high stringent condition (68°C) and detected following the BM manual.

Results and Discussion

Differentiation of *Pseudomonas solanacearum* into biovars by acid production from carbohydrates

To differentiate Ps strains isolated from Taiwan into biovars, the bacteria were inoculated into tubes with basal media (olive green) plus different carbohydrates, incubated at 30°C, and examined after 2, 7, 14, and/or 21 days. The media will change to yellow if the bacteria can utilize the carbohydrate and produce acid. In the first trial, the growth of bacteria was observed up to 14 days. Most strains can be classified into biovar 3 or 4. However, about 20 strains did not belong to any of the existing five biovars. These 20 strains can be separated into nine groups according to the reaction patterns. They were identified again. In the second trial, the growth of bacterial was observed up to 21 days. Some strains were still not differentiated due to contamination or different reaction patterns. Thus, the unidentified seven strains were inoculated for the third time.

Table 7. Oxidation of carbohydrates by strains of *P. solanacearum*

Carbohydrate	PSS 4	PSS 27	PSS 34			PSS 74			PSS 86		
	(biovar 3)	(biovar 4)	1[a]	2	3	1	2	3	1	2	3
Lactose (L)	+[c]	-[b]	-	?[e]	+	-	+	+/-[d]	-	-	-
Maltose (ML)	+	-	+	+	+	+/-	+/-	+/-	+/-	-	-
Cellobiose (C)	+	-	-	+	+	-	-	+/-	-	-	-
Mannitol (M)	+	+	+/-	+/-	-	+/-	+	+/-	+/-	+/-	+/-
Sorbitol (SB)	+	+	+/-	+/-	+/-	+/-	+	+	+/-	+/-	+/-
Dulcitol (D)	+	+	+/-	?	+/-	+/-	+	+/-	+/-	+/-	+/-

[a]The number of repeats.
[b]Color of medium did not change 21 days after inoculation.
[c]Color of medium changed from olive green to yellow 21 days after inoculation.
[d]Color of medium changed slightly 21 days after inoculation.
[e]The media was contaminated.

[1]Sambrook, J., Fritsch, E.F, and Maniatis, T. 1989. Molecular cloning. A laboratory manual. 2nd edition. Cold Spring Harbor Laboratory Press.

All but three strains (PSS 34, 74, and 86) (table 7) can be classified into biovar 3 or 4. To summarize the results, 44 of the 64 tested strains were identified as biovar 3, and 17 were biovar 4.

Several reasons may contribute to the different results of the three repeats. (1) The carbohydrate concentrations were slightly different each time. This should not make any difference to the strains that can utilize the carbohydrate efficiently since the final concentration of carbohydrate was about 1%. However, it may affect the results if the strain is more sensitive to the carbohydrate concentration. (2) The strains were different each time because of the high mutation rate of Ps. Experience is required to be able to pick a typical and normal colony from TZC plates. Thus, it was possible that a mutated colony was picked for the test. It is not known whether the mutants would affect the biovar differentiation. (3) The observation time was not long enough. A longer time may be required for some strains to utilize the carbohydrates and to accumulate enough acids that can change the color of the media. In fact, two strains showed different results based on the observations at 14 and 21 days.

Specificity of DNA probes

Several specific DNA probes developed by Dr. J. Timmis are thought to be able to differentiate Ps into biovars. To test the specificity of these DNA fragments in Ps and other plant pathogenic bacteria in Taiwan, the DNA inserts were repurified from low-melting agarose gel and labeled with DIG-dUTP. Bacterial genomic DNA was digested with EcoR I and fractionated by agarose gel electrophoresis. Southern blotting and detection of the homologous sequences were performed as described in Materials and Methods.

The biovar nonspecific probe (092-03B col.5) can hybridize with all Ps strains tested and showed a single band only (fig.1). The other tested plant pathogenic bacteria (such as Xcv, Xcc, Xcg, Ecc, Ech, Pc) cannot hybridize with this probe. The result suggests that this probe can be used to differentiate Ps from other bacteria since only Ps strains contain this specific DNA sequence.

The biovar 4 specific probe (092-03A col.18) can only hybridize with strain 092 from Australia but not any biovar 4 strains isolated from Taiwan (fig. 2). The interesting finding was that one Xcv race 1 strain showed a homologous sequence with this probe (fig. 2). More Xcv race 1 strains need to be tested to be able to draw any conclusions about the specificity of this probe. However, it is also not known if this DNA sequence is present in all biovar 4 strains in Australia. Based on our preliminary results, this probe cannot be used as a biovar 4 specific probe in Taiwan.

The biovar 3 specific probe (0171-10 no. 9) can hybridize with both biovar 3 and four strains from either Australia or Taiwan. Out of the four Australian strains of biovar 3 tested (0171, PSS no. 21, PSS no. 22, PSS no. 25), three had the same hybridization pattern. PSS 25 had a pattern similar to some Taiwan biovar 3 strains (fig. 3). The biovar 3 strains in Taiwan can be separated into three groups based on the hybridization patterns (fig. 3). Biovar 4 strains from Taiwan showed the same pattern except one strain (PSS 43) which was similar to one group of Taiwan biovar 3 strains. However, the Taiwan biovar 4 pattern is different from the Australian one (strain 092, fig. 3). This polymorphism is probably caused by the great variation among the Ps strains themselves. Thus, it is difficult for us to use this probe as a biovar 3 specific indicator. However, this probe cannot hybridize with DNA from other plant pathogenic bacteria (fig. 4).

Based on the results described above, it is possible to use the biovar nonspecific probe to identify and detect Ps from plant and soil samples. Specific primers can be developed from the DNA sequence of this probe. Thus, PCR amplification, a more sensitive method, can be applied. However, methods for preparation of samples need to be developed since some compounds in the crude samples may inhibit the polymerase activity in the application of PCR.

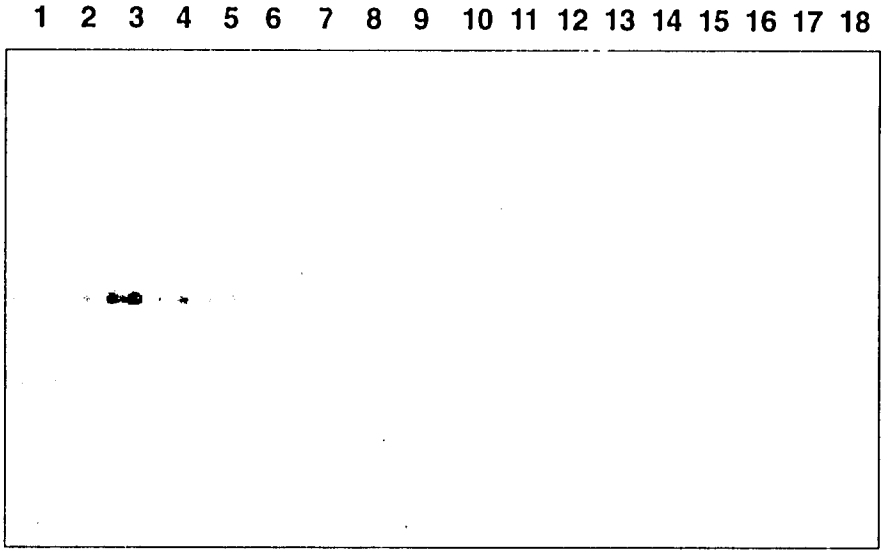

Fig. 1. Southern blot analysis of genomic DNA of various strains digested with EcoR I and hybridized with biovar nonspecific probe (092-03B col. 5). Lanes 1:PSS 4 (bv. 3); 2:0171 (bv. 3); 3: 092 (bv. 4); 4:PSS 52 (bv. 4); 5:PSS 43 (bv. 4); 6:XVT 28; 7:XVT 48; 8:XVT 77; 9:XVP 41; 10:XVP 64; 11:Xcc 10; 12:Xcg 7; 13:Ecc; 14:Ech; 15:TSR 1; 16:TSR 5; 17:Pc 5; 18:Pc 10

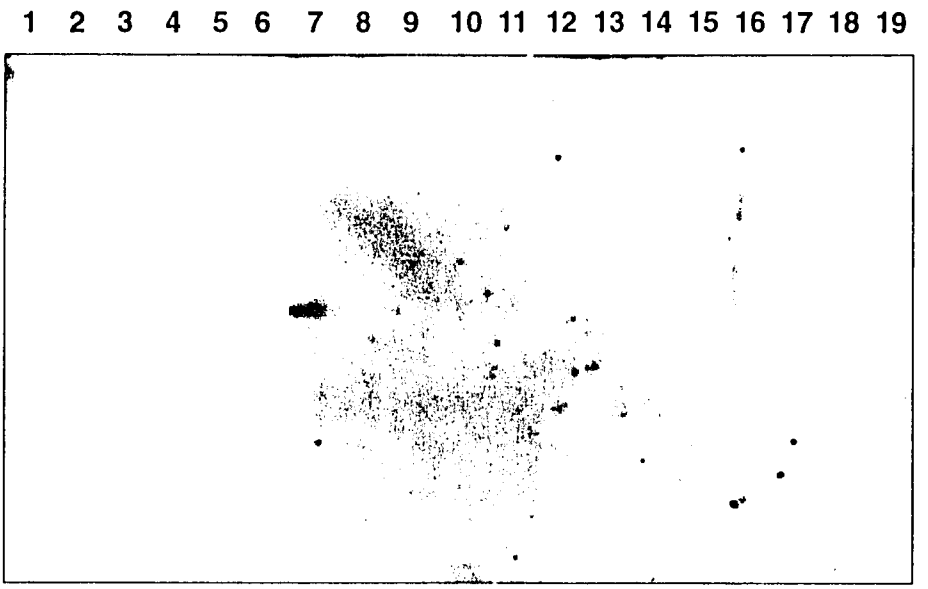

Fig. 2. Southern blot analysis of genomic DNA of various strains digested with EcoR I and hybridized with biovar 4 specific probe (092-03A col.18). Lanes 1-3 are Ps biovar 3 strains and 4-6 are biovar 4. 1:0171; 2:PSS 4; 3:PSS 97; 4:092; 5:PSS 43; 6:PSS 71; 7:XVT 28; 8:XVT 48; 9:XVT 77; 10:XVP 25; 11:XVP 59; 12:Xcc 4; 13:Xcc 10; 14:Xcg 3; 15:Xcg 7; 16:Ecc; 17:Ech; 18:Pc 5; 19:Pc 10

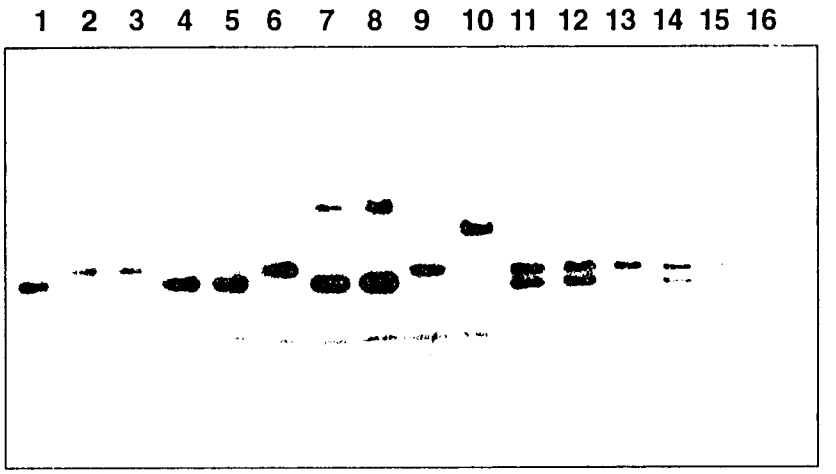

Fig.3. Southern blot analysis of genomic DNA of various Ps strains digested with EcoRI and hybridized with biovar 3 specific probe (0171-10 no. 9). Lanes 1-9 are biovar 3 and 10-16 are biovar 4. 1:0171; 2:PSS 4; 3:PSS 5; 4:PSS 37; 5:PSS 60; 6:PSS 97; 7:PSS 21; 8:PSS 22; 9:PSS 25; 10:092; 11:PSS 27; 12:PSS 36; 13:PSS 43; 14:PSS 70; 15:PSS 71; 16:PSS 114

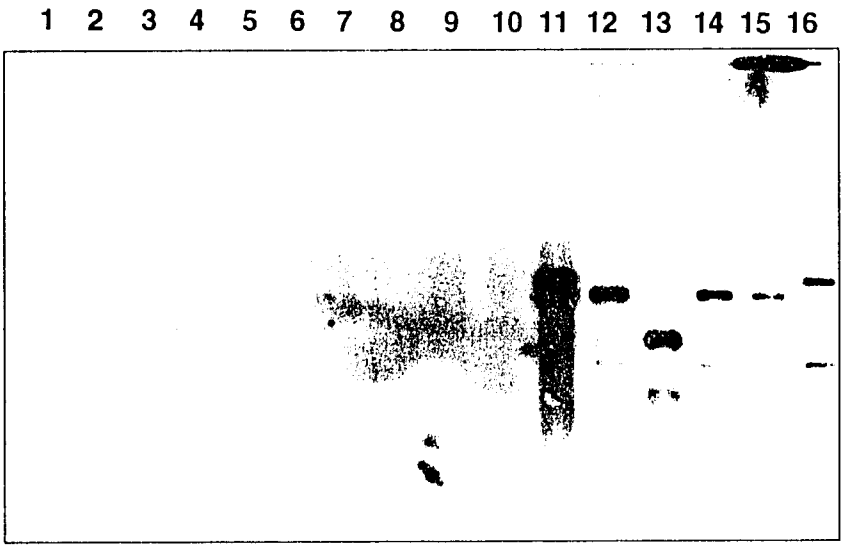

Fig.4. Southern blot analysis of genomic DNA of various strains digested with EcoRI and hybridized with biovar 3 specific probe (0171-10 no. 9). Lanes 1-3 are Ps biovar 3 strains and 4-6 are biovar 4. 1:0171; 2:PSS 4; 3:PSS 97; 4:092; 5:PSS 43; 6:PSS 71; 7:XVT 28; 8:XVT 48; 9:XVT 77; 10:Xcc 4; 11:Xcc 10; 12:Xcg 7; 13:Ecc; 14:Ech; 15:Pc 5; 16:Pc 10

Studies on Cucumber Mosaic Virus, Leaf Curl Virus, and Tomato Spotted Wilt Virus and Network Support

Summary

Cucumber mosaic virus (CMV), leaf curl viruses, and tospoviruses are considered the most important viruses of tomato in the tropics and subtropics. Commercial lines with resistance to CMV or tospoviruses are not available, and only recently lines with resistance to one of the many different leaf curl viruses, namely, TYLCV, have become available. In the past, screening for leaf curl virus and tospovirus has been difficult because specific diagnostics have not been available. Using the newly developed nonradioactive DNA probe and an improved hybridization method, we were able to screen this year (76) new accessions and identify several lines with resistance to leaf curl virus. These are already being used by our breeders. Resistance/tolerance to CMV could also be identified in several wild species. Three lines with reported tomato spotted wilt virus resistance in the USA were found susceptible to the Asian tomato tospovirus, and peanut bud necrosis virus (PBNV). This finding is important in that other resistance sources need to be sought to develop tomato lines resistant to the Asian tospovirus.

Virus surveys conducted in Tanzania indicated that potato virus Y (PVY), tomato mosaic virus (ToMV), and CMV were the most important viruses on tomato. Leaf curl virus was also found. Preliminary hybridization tests showed that the leaf curl cirus is similar to or the same as the tomato yellow leaf curl virus (TYLCV) that is predominant in the Mediterranean region.

Introduction

Cucumber mosaic virus (CMV), leaf curl virus, and tospoviruses are considered the most devastating viruses of tomato in the tropics and subtropics. While CMV usually affects tomato year-round, the other two cause epidemics at certain times of the year, coinciding with abundance of the vectors. Despite intensive screening efforts, resistance to these viruses has not been easy to identify. In the past we reported a high number of CMV-resistant plants in one line of *L. hirsutum*. This line has in the meantime undergone purification for CMV resistance and it has been used for making crosses. Progress on resistance to the Taiwan tomato leaf curl virus (TTLCV) was slow in the past because of the absence of reliable diagnostics. Screening was done by double-sandwich grafting and visual symptom observation. However, this year, screening could be stepped up because we have developed a TTLCV-specific nucleic acid probe. This probe, as well as others specific to other geminiviruses of tomato, is also being used in virus surveys that are conducted as part of the network activities in South Asia and Africa. Screening for resistance to peanut bud necrosis (formerly called tomato/watermelon strain of TSWV) was not possible in the past because of difficulty in maintaining the virus in pure culture and the nonavailability of specific diagnostics. These bottlenecks have in the meantime been overcome; the virus is maintained in a growth room and PBNC-specific polyclonal antiserum and nucleic acid probes have become available.

Materials and Methods

CMV resistance screening

Fifty *L. chilense*, 54 pureline selections of *L. hirsutum* VL 262, and 17 F_1 generations of *L. hirsutum* VL 262 x FM 54 were screened using an inoculum of one part infected leaves in nine

parts 0.01 M. phosphate buffer. The first inoculation was at the second-leaf stage with Peet's isolate. One week thereafter plants were inoculated with strain NT9 and 1 wk later with a mixture of Peet and NT9. Resistant plants were transplanted to the field where they were exposed to natural infection. Three ELISA tests were conducted, the first 1 wk after the second inoculation, the second 2 wk after the inoculation with the virus mixture, the third 8 wk after transplanting to the field.

TSWV resistance screening

Two *L. esculentum* lines (VL 362, VL 364) and one *L. hirsutum* line (PI 247087) with reported resistance to the TSWV-type strain (formerly TSWV-lettuce strain) were tested for resistance to PBNV. Test plants (12 plants per line) were mechanically inoculated at the second-leaf stage with PBNV propagated on *N. benthamiana*. The virus was originally isolated from tomato in the Tainan (Taiwan) area. A homogenate of 1:10 in phosphate buffer (plus 0.01 M Na_2SO_3) (pH 7.0) served as the inoculum. Symptoms were recorded visually at 20-30 DAI. At the same time, an indirect dot ELISA on NC membranes was conducted on the uninoculated leaves.

LCV resistance screening

Fifty new *Lycopersicon chilense* accessions and 26 various other materials (breeding lines and commercial lines) with reported resistance/tolerance to TYLCV were screened. One stem tip per plant of the lines to be tested were cleft-grafted on TTLCV-infected *L. esculentum* stock plants. Of each line, 20-25 plants were tested. At 3-4 wk after grafting, the grafted stem tips were tested for the presence of TTLCV by nucleic acid hybridization as follows:

A 1.5kb TTLCV DNA fragment (pAL1v1979-pAR1c715) cloned in KS+Bluescript plasmid was used to make a DNA probe (AVRDC 1993[2]). Linear plasmid fragments were generated by using random primers with Klenow polymerase. Nonradioactive labeling was by digoxigenin, using dioxy uridine-triphosphate (DIG-dUTP at 37°C/16-24 h) of the Boehringer Mannheim Biochemical Kit.

Detection of gemini viral DNA used the squash blot method. Leaf disks of 0.8 cm diameter were excised with a corkborer from 4-wk-old grafted stem tips. The disks were placed on a Hybond-N nylon membrane (Amersham) covered with a small piece of clear plastic sheet, and gently squashed with the aid of a pestle. The membranes were placed on filter paper, saturated with 0.5 N. NaOH for 5 min for lysis of plant cells and denaturation of DNA. After washing in 1 M Tris pH 7.5 (5 min) followed by incubation in 2 x SSC (5 min) and rinsing in 95% ethanol, the membranes were air-dried. DNA was bound to the membrane by UV crosslinking (5 min) at 254 mm. Prehybridization (1 h) and hybridization (16-24 h) were carried out at 60°C in hybridization buffer (5 X SSC - 2% blocking reagent, 0.1% [w/v] N-lauroylsarcosine, 0.02% [w/v]SDS). Unbound labeled DNA was removed by washing twice in 2 X SSC-0.1% (w/v) SDS for 5 min at room temperature and in 0.1% SSC - 0.1% (w/v) SDS at 60°C. For luminescent detection the membrane was soaked for 3 min in buffer 1 (0.1 M maleic acid, 0.5 M NaCl, 0.3% [w/v] Tween 20 pH 7.5). After addition of 1% blocking solution, the membrane was placed in anti-digoxygenin alkaline phosphatase Fab' (1:10,000) in 1% blocking solution. Unbound conjugate was removed by washing twice in washing buffer. After 2 min equilibration in buffer 3 (0.1 M Tris HCL, 0.1 M NaCl, 0.05 M $MgCL_2$, pH 9.5), the membranes were incubated for 5 min at 37°C in lumigen PPD (1:100) in buffer 3. The membranes were exposed for 16-24 h at room temperature to x-ray film (Fuji). Films were developed in D-19 solution (Eastman Kodak).

[2]AVRDC. 1993. AVRDC 1992 Progress Report. Shanhua, Tainan, Taiwan.

Optimization of sample selection for leaf curl virus detection

Four leaves, the newest fully expanded leaf, and three other leaves below (each at 15-cm distance from the other) of the main stem of 10 naturally infected tomato plants (of approximately 60-cm height) were tested individually by nucleic acid hybridization to determine which leaf position contained the highest virus titer and would be most suitable for reliable virus diagnosis in field surveys of naturally infected plants. Two sample application methods were tested: squashing of leaf disks (see above) and spotting of centrifuged plant sap (one leaf disk of 8 mm diam was excised, ground in 10 µl TE buffer, and centrifuged at 10,000 rpm/5 min, 5 µl of the supernate was used to apply to the membrane).

The recommended hybridization procedure requires the use of formamide at a hybridization temperature of 42°C. However, since formamide which prevents reannealing of DNA is very toxic, an adjustment of the procedure that did not necessitate the use of this chemical was sought.

Network support: survey for tomato viruses

One hundred and eighty-seven tomato leaf samples, squashed on NC membranes, were received from the Africa Regional Program, Tanzania. The samples originated from plants showing various types of virus symptoms and were collected from several tomato-growing regions in the country. They were tested by indirect ELISA for presence of ToMV, CMV, PVY, PVMV, TSWV, and PBNV.

In addition, three nylon membranes each containing 30 spotted leaf squash samples of plants suspected to be infected with leaf curl virus were tested for the presence of leaf curl virus. They were probed with DIG labeled cloned DNAs from TYLCV-Egypt, the Indian tomato leaf curl virus (ITmLCV), and the Taiwan tomato leaf curl virus. The following clones were used: ITmLCV: PI 16 PCR amplified fragment using the degenerate primer pAL1v1979 and pAR1c715; TYLCV-Egypt; and TTLCV: PCR amplified fragment using the degenerate primer pAL1v1979 and pAR1c715.

The hybridization was done at low stringency for 18 h; cross linking and film exposure were as described earlier.

Results and Discussion

CMV resistance screening

Four out of the 50 *L. chilense* lines screened were resistant to CMV (LA 1969, LA 2731, LA 2737, and LA 2746) in a first resistance screening using two CMV isolates (Peet and NT-9). All other lines were susceptible. Thirty-seven of the 54 pureline *L. hirsutum* selections were still resistant after 8 wks in the field. All other lines had a very low percentage (35%) of susceptible plants. Among the F_1 cross combinations, the percentage of susceptible plants was low and ranged from 0 to 30%. F_1 combinations with fewer than 10% susceptible plants were FM54 x VL262-6-12-1-1, FM54 x VL262-6-12-1-5, and FM54 x VL262-6-11-1-1. All F_1 plants of the cross FM54 x LV262-19-16-3-10 were resistant. The potential of *L. hirsutum* for CMV tolerance is obvious. However, multilocational tests are necessary to confirm whether this resistance is strain specific or not. The resistance of *L. chilense* needs to be reconfirmed.

LCV resistance screening

Thirty-seven of the 48 *L. chilense* lines screened were resistant to TTLCV. Thirty-one did not show any symptoms and TTLCV DNA was not detected by DNA hybridization (LA 1969, 2731, 2737, 2764, 2765, 2774, 2779, 2780, 2755, 2762, 2879, 2884, 2891, 2930, 2946, 2949, 2952, 2955, 2980, 2981A, 3111, 3112, 3113, 3114, 3115, 295, 130, 458, 1917, 1968, 1970). Lines LA 2750 and 1958 were moderately susceptible, with only 75 and 60% susceptible plants, respectively. The remaining lines contained fewer than 60% resistant plants. Of the lines with reported resistance/tolerance, only one, namely, TY-King, a commercial F_1 hybrid, was found resistant. None of its plants showed any symptoms, and TTLCV-DNA was not detected (fig. 5a-c). Seven lines had more than 50% resistant individuals (Fiona F_1, Roza, BI, T 146, KWR, BII, T2AA), and three lines had 40-50% resistant individuals (Hirseptyle, Lignon C 8-6, TY-20). Seven of the lines were found susceptible (Heatwave, P-11, Columbian 1988, Ratan, Progress 7 S68, BT 15-1, T-245. The remaining lines had 4-36% resistant individuals (Chepertyle C-92, Colonial, Pertyle, Octotyle, Pimhirtyle, Duotyle, P-2, Early Cascade, CL-1131-0-0-43-8-1, Lignon C20-5, Tm 126, Manik, Ty-Gold, Big Strike, Chepertyle).

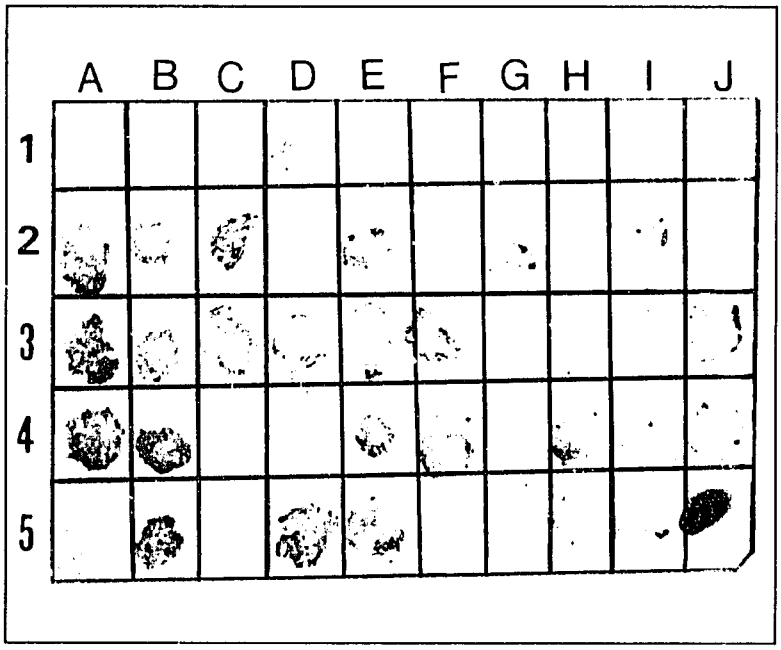

Fig. 5a. DNA hybrization leaf squash tests of lines with suspected tolerance/resistance to leafcurl virus. A1-C5, TY-20; D1-F5, Octotylc; G1-I5, CL 1131-0043-8-1; J1, J2, healthy check; J3, J4, diseased check; J5 diseased check dot blot, using plant sap centrifuged with TE buffer 10,000 rpm

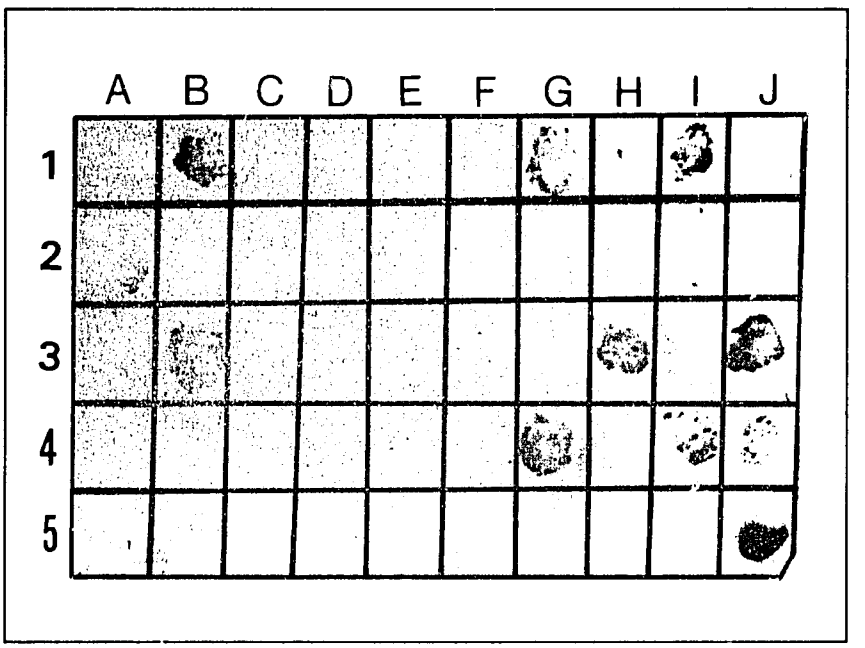

Fig. 5b. DNA hybrization leaf squash tests of lines with suspected tolerance/resistance to leafcurl virus. A1-C5, LA 1969; D1-F5, TY King; G1-I5, Fiona; J1, J2, healthy check; J3, J4, diseased check; J5 diseased check dot blot, using plant sap centrifuged with TE buffer 10,000 rpm

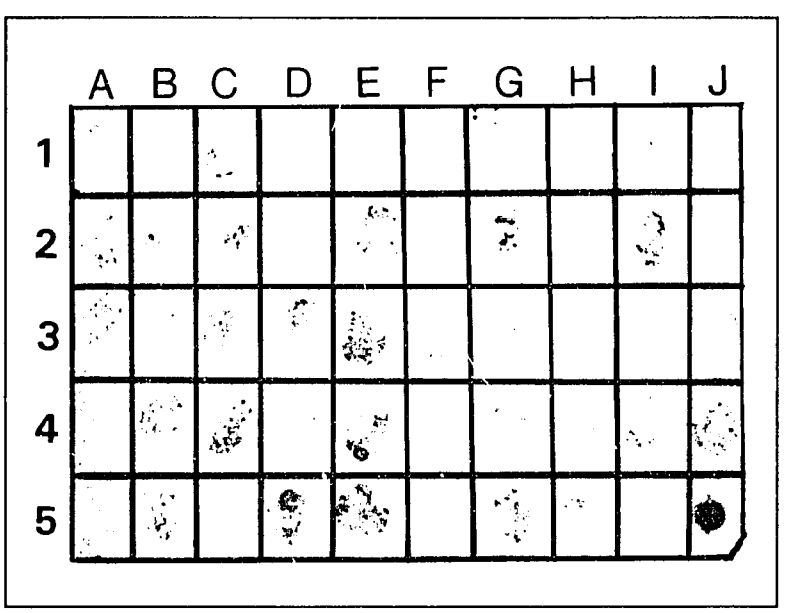

Fig. 5c. DNA hybrization leaf squash tests of lines with suspected tolerance/resistance to leafcurl virus. A1-C5, Pertylc; D1-F5, Hirseptylc; G1-J5, Chepertylc; J1, J2, healthy check; J3, J4, diseased check; J5 diseased check dot blot, using plant sap centrifuged with TE buffer 10,000 rpm

Optimization of sample selection for leaf curl virus detection

Results indicate that the squash test is generally more sensitive for field samples than the dot blot test and that leaf position 2 is the most optimal for use in hybridization tests (table 8). The use of formamide was found to be not essential. When the hybridization temperature was raised to 60°C, equally good results were obtained without the addition of formamide than with the use of formamide at 42°C.

Table 8. Virus titer in squashes and dot blots of leaves of naturally LCV-infected plants

	Plant no.																			
Leaf	1		2		3		4		5		6		7		8		9		10	
position[a]	S[b]	D[c]	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
1	++	-	++	-	+/-	-	+	-	+/-	+/-	++	+	+	-	-	-	+	-	+	--
2	++	-	++	-	++	+	++	+	+/-	+	++	++	++	++	++	++	++	-	++	+
3	++	+	+/-	-	+/-	+	+	-	+/-	+	-	-	++	++	+	++	+	+/-	+	+/-
4	++	+	+	-	+/-	+	+	+	+/-	+	-	-	+	+	+	+	+	+/-	+	-

[a] Leaf 1 = topmost fully expanded leaf; leaf 2 = leaf at 15 cm below the top most leaf; leaf 3 = leaf at 15 cm below leaf 2; leaf 4 = leaf at 15 cm below leaf 3.
[b] S = squash.
[c] D = dot blot.

Network support survey for tomato viruses

PVY was the most frequently detected virus in the samples with 86 of the 180 samples giving a strong positive reaction. Sixteen samples reacted with ToMV, 12 with CMV. None of the samples reacted with TSWV, PBNV, or PVMV. One of the suspected leaf curl samples gave a positive reaction with the TYLCV-Egypt probe; 11 samples reacted weakly with that probe, and all other samples were negative. Six samples reacted weakly with the ITmLCV probe. None of the samples reacted with the TTLCV probe. This suggests that the virus causing leaf curl symptoms in Tanzania is closely related to or identical to TYLCV-Egypt. The weak reaction of some samples with ITmLCV probe needs to be further investigated. The possibility exists that two different geminiviruses infect tomato in Tanzania. However, the weak reaction may also be caused by cross-reaction of the TYLCV-Egypt with ITmLCV.

Conclusions

Line VC 262 has shown a high level of field tolerance to CMV under southern Taiwan conditions. However, since many strains of the virus are known to occur worldwide, it is important to conduct multilocational testing in other Asian countries to determine stability of resistance. The resistance to CMV in *L. chilense* needs to be reconfirmed.

Our finding that genes which confer resistance to the tomato spotted wilt type strain do not necessarily confer resistance to the closely related peanut bud necrosis virus is important for developing resistance breeding programs in the Asian region, where PBNV, not TSWV seems to be the predominant tospovirus.

With the newly developed nucleic acid probe of the Taiwan tomato leaf curl virus and after optimization of the hybridization test procedure, we have been able to conduct resistance screening more effectively and were able to identify several new sources of resistance to TTLCV which may be useful in the AVRDC breeding program.

Preliminary surveys in Tanzania have shown that PVY, ToMV, and CMV are the most important viruses of tomato. Leaf curl virus has also been detected. Based on nucleic acid hybridization tests, the virus is similar or identical to the tomato yellow leaf curl virus of Egypt and Israel. The importance of this virus in the country needs to be established. The results of this survey will help to determine the most suitable tomato and pepper lines for Tanzanian conditions. Since AVRDC headquarters focuses on CMV, PVY, and leaf curl virus, any resistant lines that will become available at headquarters should also be tested for usefulness in Tanzania or other cooperating countries where leaf curl virus problems exist.

For seed cloning, mature fruit from each of the crosses listed in table 1 were harvested. Seeds were then extracted and sterilized before planting in 90 x 15-mm petri dishes containing 20 ml of half-strength MS basal medium. Petri dishes were maintained at room temperature under total darkness, and observed for seed germination throughout the experimental period.

For embryo cloning, fruit from each of the crosses listed in table 2 were harvested 3-4 wk after pollination and surface sterilized. Fruits were dissected under sterile conditions and the immature seeds excised. Immature seed coats were removed and embryos at the heart stage were transferred to 125 ml Erlenmeyer flasks containing 20 ml of the MS basal medium supplemented with IAA, BA, GA_3, NAA, kinetin, zeatin, 2 ip, or 2,4-D. Flasks containing the immature embryos were maintained at room temperature under 12 h of light. Regenerated plantlets were dissected into various segments and cultured in the MS basal medium without hormones for multiplication.

After multiplication, plantlets were transferred from flasks to 250 cm^3 plastic boxes filled with sterilized vermiculite and grown in the culture room. When the plants showed shoot elongation and leaf expansion, they were transferred to a growth chamber and maintained at 25/20°C (day/night temperatures) and 75% RH.

Table 1. Comparison between *L. esculentum* x *L. chilense* hybrids of number of mature seeds cultured and plants regenerated

Crosses	No. seeds cultured	No. plants regenerated
CL 5915-93 x 1L	20	0
CL 5915-93 x 10LC	37	0
CLN 698 x Bulk of 1L, 2L & 4L	2	0
CLN 399 x 10LC	3	0
L 3957 x Bulk of 1L, 2L & 4L	13	0
CLN 399 x LA 1990-4	7	0
CL 5915-93 x 8LC	37	0
CL 5915-93 x 2L	10	0
L3957 x 1LC	10	0
CL 5915-93 x L 1964	10	0
L 3957 x 9IC	5	0
CLN 65 x 4L	11	0
L 3957 x 10 LC	5	0
CLN 698 x 1L	12	0

Table 2. Comparison between *L. esculentum* x *L. chilense* hybrids of number of embryos cultured, embryos that produced plantlets, and plants regenerated

Crosses	No. embryos cultured	No. plantlets regenerated	No. plants regenerated
CL 5915-93 x 1L	78	4	0
CL 5915-93 x 10LC	40	37	96
CL 5915-93 x 2L	64	0	-
CL 5915-93 x 8LC	111	4	10
CLN 399 x Bulk of L & LC	80	0	-
CL 5915-206 x Bulk of L	109	0	-
CL 5915-93 x Bulk of L & LC	122	0	-
CL 5915-93 x Bulk of L	156	0	-
CLN 65 x Bulk of L & LC	66	0	-
CLN 65 x Bulk of L	25	0	-
CL 5915-93 x (CL 5915-93 & bulk of L)	80	0	-

Tomato Physiology

Embryo Culture of *Lycopersicon esculentum* x *L. chilense* Hybrid Genotypes Possessing Resistance to Tomato Yellow Leaf Curl Virus

Summary

Genotypes of *Lycopersicon chilense* LA 1969 siblings selected from accessions that possess resistance to tomato yellow leaf curl virus (TYLCV), a geminivirus transmitted by the *Bemisia tabaci* whitefly, were used as male parents in crosses with TYLCV-susceptible *L. esculentum* breeding lines CL 5915-93D_4-1-0-3, CL 5915-206D_4-2-2-0-4, CLN 399BCF_2-2-6-0, CLN 65-309D_5-2-0, CLN 698BCF_2-358-4-13, and L 3957 (BL 6807 from Canada), respectively. The incongruity barrier between the two plant species was overcome by an embryo cloning technique but not seed rescuing. Hybridity of the F_1 progeny obtained from the crosses of CL 5915-93 x LA 1969 10LC, and CL 5915-93 x LA 1969 8LC was confirmed by differences in leaf morphology and growth habit. Research is still in progress to improve the technique and investigate the weakness, fertility, and virus resistance of F_1 plants.

Introduction

Resistance to many pests and diseases have been found in wild tomato genotypes, especially in the *peruvianum* group (which consists of *L. peruvianum* and *L. chilense*). Self-incompatible *L. chilense* is known to possess resistance to tomato yellow leaf curl virus (TYLCV), a gemini virus transmitted by the *Bemisia tabaci* whitefly and drought stress. However, incompatibility barriers between plants of the *peruvianum* and *esculentum* complexes have made the routine transfer of these desirable traits from the *peruvianum* complex to the *esculentum* complex, including esculent tomato, difficult. The objective of this work was to introgress the TYLCV resistance gene(s) from *L. chilense* to *L. esculentum* germplasm via embryo culture.

Materials and Methods

Genotypes used in these experiments were *L. chilense* LA 1969 (85L8760m sibs) selections resistant to TYLCV and cucumber mosaic virus, 2LC, 8LC, 9LC and 10LC, and resistant to TYLCV only, 1L, 2L and 4L, and LA 1990-4 and L 1964. These genotypes were maintained by artificial selfing. TYLCV-susceptible *L. esculentum* lines CL 5915-93D_4-1-0-3, CL 5915-206D_4-2-2-0-4, CLN 399BCF_2-2-6-0, CLN 65-309D_5-2-0, CLN698BCF_2-358-4-13, and L 3957 (BL 6807 from Canada) were used as female plants in crosses with the resistant *L. chilense* clones.

Crosses between various genotypes of *L. esculentum* and *L. chilense* were made in an open field in spring 1993. Plants were grown in the fertilized soil mixture. *L. chilense* genotypes were used as male parents in all crosses. Two days before anthesis, flowers of *L. esculentum* plants were emasculated and hand-pollinated.

Results and Discussion

The number of seeds in each cross was highly variable (table 1). A total of 182 seeds were planted. After one month of culture, most of the seeds became brownish and no germination was observed.

Most of the immature seeds produced small, brownish, globular-stage embryos. Several hundred immature embryos were isolated from these immature seeds and cultured, but none of the crosses involving the bulked pollens from selections of LA 1969 were rescued. About 45 immature embryos from the crosses of CL 5915-93 x LA 1969 1L, CL 5915-93 x LA 1969 10LC, and CL 5915-93 x LA 1969 8LC at the heart stage were rescued (table 2). No somatic embryogenesis was observed on the callus, but adventitious shoots were obtained. Subsequently, the shoots were rooted, and plantlets were dissected for multiplication. Regenerated plantlets were transferred to culture boxes for stem elongation and leaf expansion. Several F_1 plantlets were transferred to pots after conditioning. However, many of them did not survive the transfer from tissue culture to soil growing conditions. The leaf morphological characters and growth habit of those F_1 plants from the crosses of CL 5915-93 x LA 1969 10LC and CL 5915-93 x LA 1969 8LC which survived, more closely resembled the male parent or were between the two parents. This indicates the dominance of morphological attributes of wild *L. chilense* over *L. esculentum*.

Research is still in progress to test other cross combinations, improve the technique of embryo rescuing, and investigate the weakness, floral structure, fertility, and virus resistance of those F_1 plants that survived.

Expressions of Heat Shock Proteins in Tomato

Summary

The expression of heat shock proteins (HSPs) in leaf tissue of heat-tolerant tomato breeding line CL 5919-153 and its double-crossed parents (CL 1131-38, L 127, CL 9, and CL 949) was analyzed by using SDS-polyacrylamide gel electrophoresis and 2-D electrophoresis. Three proteins, ranging from 17kD to 27kD in CL 1131-38, two proteins in CL 9, and four proteins in CL 949 were newly synthesized after heat treatment. No newly synthesized protein showed in L 127 and CL 5915-153 by 2-D electrophoresis.

Introduction

Heat shock proteins induced by heat stress are known to have a protective role in heat stress. These stress proteins are arbitrarily divided into two groups: high molecular weight (68 to 110 kD) and low molecular weight (15 to 27 kD). In plants, low molecular weight HSPs play a dominant role in the determination of heat tolerance. Although the kinetics of HSP synthesis, electrophoretic prolifes, and intracellullar localization have been characterized in several plants, little is known about their physiological roles in heat tolerance of plants. This study investigated the expression of HSP in heat-tolerant and -susceptible tomatoes to lay the groundwork for the potential application of HSPs in conventional or modern improvement of heat tolerance in tomato.

Materials and Methods

Plant materials and growth conditions. A heat-tolerant tomato breeding line (CL 5915-153) and its double-crossed parents (CL 1131-38, L 127, CL 9, and CL 949) were used in this study. All plants for analysis of the heat shock response were grown in growth chambers at 25°C on a 12-h day/night cycle for 4 wk. For heat treatment, plants were subjected to 40°C for 4 h.

Protein extraction. Five grams of leaf tissue were dry crushed in a mortar with liquid N. The powder was resuspended in 5 ml of 30 mM Tris-Cl buffer (pH 8.7) with 1 mM DTT, 1 mM ascorbic acid, 1 mM EDTA, 1 mM phenylmethylsulfonyl fluoride, 5 mM magnesium chloride and 30 mM of insoluble PVP. After centrifugation at 37,000 g for 40 min, an equal volume of SDS solution containing 4% SDS, 5% 2-mercaptoethanol, and 5% sucrose was added to the supernatant. The mixture was heated in 37°C for 1 h and centrifuged at 37,000 g for 40 min. Four volumes of ice-cold acetone with 10 mM 2-mercaptoethanol was added to the supernatant to precipitate for at least 1 h at -20°C. After 15 min of centrifugation at 10,000 g, the pellet was air-dried. Protein samples were run on SDS-PAGE and 2-D electrophoresis.

Isoelectrofocusing (IEF). The proteins were loaded on 3 x 130 mm tube gels containing 4% (w/v) acrylamide, 0.36% bis-acylamide, 9.5 M urea, 2% Nonidet NP-40, 1.6% Ampholyte 5/7 (40%), 0.4% Ampholyte 3.5/10 (40%), 0.01% (w/w) ammonium persulfate and 0.001% (v/v) TEMED. The cathodic solution was 10 mM histidine, and the anodic solution was 10 mM phosphoric acid. Pre-electrophoresis was run at 200 V for 15 min, then 300 V for 30 min, and 400 V for 30 min. Isoelectrofocusing was carried out at 300 V for 17 h, then 800 V for 1 h. Just before electrophoresis, 250 µg of the protein samples were solubilized in 50 µl sample solution containing 9.5 M urea, 2% NP-40, 1.6% Ampholyte 5/7, 0.4% Ampholyte 3.5/10, and 5% 2-mercaptoethanol.

SDS slab gel electrophoresis. The second-dimensional SDS gels were run with the running buffer containing 0.025 M Tris-base, 0.192 M glycine and 0.1% SDS. A 1.5-mm thick 11% polyacrylamide slab gel with a 4% polyacrylamide stacking gel, both 0.1% in SDS, was poured and run in a vertical slab system. The IEF gels run in the second dimension were equilibrated in 10-ml 2.3% SDS-equilibrate buffer containing 62.5 mM Tris-base (pH 8.0), 10% glycerol, 5% 2-mercaptoethanol for at least 2 h with two changes to remove most of the ampholyte, urea, and the Nonidet NP-40. Then 2.3% SDS-equilibrate buffer/0.75% agarose sealer was pipetted into the trough and the tube gels were quickly loaded on top of the hot agarose solution. The low (12-77 kD) and high (43-200 kD) molecular weight markers were layered on either edge of the slab before the running buffer was added to the upper chamber. The buffer in the lower reservoir was cooled with a cooling coil connected to a refrigerating water bath set at 12°C. Electrophoresis was started with an initial current of 17 mA, which gave a voltage of 31 V, and performed overnight (about 17 h). The conditions of SDS-PAGE for 1-D electrophoresis were the same as for 2-D electrophoresis but only differed in solubilizing of sample solution (containing 62.5 mM Tris-base, pH 6.8, 3% SDS, 10% glycerol, and 5% 2-mercaptoethanol) and heating sample at boiling water for 5 min.

Staining. The SDS-PAGE gels were stained with 0.1% Coomassie blue R-250 which contained 30% methanol, 3.6% sulfisalicylic acid and 12% trichloroacetic acid, and destained with 5% methanol, containing 10% acetic acid. The 2-D gels were silver stained by Bio-Rad silver

stain kit. Gels were oxidized with potassium dichrimate and nitric acid, reacted with silver nitrate, and developed by sodium carbonate and para-formaldehyde under room temperature.

Results and Discussion

Tomato leaf tissue exhibited a small change in the protein synthesis with or without heat treatment (fig. 1). No significant qualitative differences between heat and nonheat treatments were observed in the protein pattern of the low molecular weight by 1-D SDS-PAGE analysis. The 2-D IEF-SDS-PAGE electrophoresis, on the contrary, revealed production of low molecular weight HSPs in heat-tolerant, double-crossed parent, CL 1131-38, and heat-susceptible parents, CL 9 and CL 949. CL 1131-38 had two proteins — 20 kD and 25 kD — CL 9, two proteins, 22 kD and 24 kD, and CL 949, four proteins from 19 kD to 25 kD after heat treatment (fig. 2).

Among the molecular factors involved in the development of heat tolerance, HSPs are considered the most important. In general the low molecular weight HSPs are the major HSPs in plants. In our study, 1-D SDS-PAGE analysis failed to detect the correlation between low-molecular HSPs and heat treatment (fig. 1). This may be because heat tolerance is a quantitative rather than qualitative expression of the genes controlling HSP synthesis.

Analysis of 2-D electrophoresis showed that low-molecular HSPs were generated not only by heat-tolerant CL 1131-38 but also by heat-susceptible CL 9 and CL 949. However, their double-crossed progeny, CL 5915-153, did not show any HSP synthesis after heat treatment. (fig. 2). It seemed that there was no relationship between HSPs and heat tolerance. We believe that HSPs have a function in heat tolerance based on the results of studies on other plants by some scientists. Heat tolerance, a complex character, needs further investigation. We also need to ascertain whether HSPs work in heat tolerance and how.

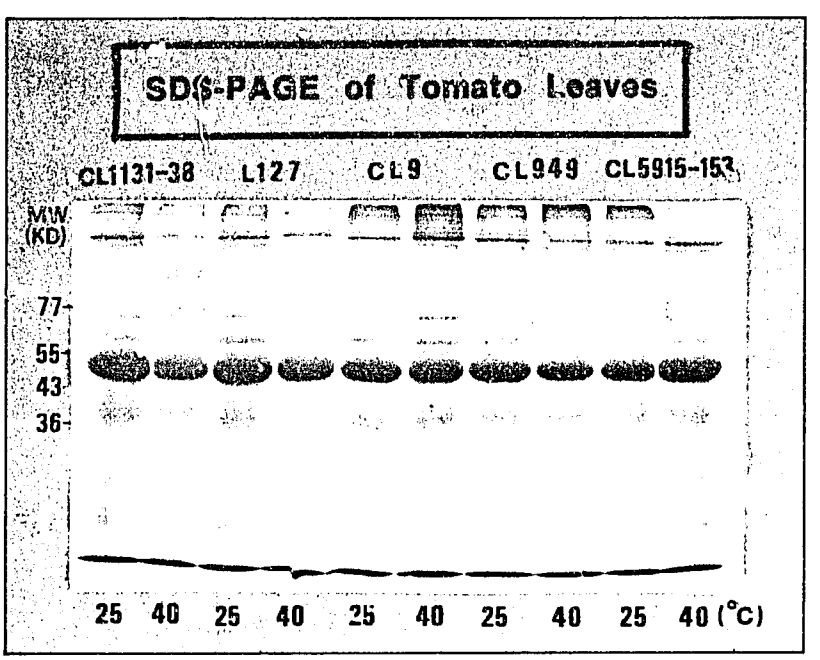

Fig. 1. SDS-PAGE of total protein from leaf tissue of CL 5915-153, and its double-crossed parents, CL 1131-38 (P1), L 127 (P2), CL 9 (P3), and CL 949 (P4) with or without 40°C treatment for 4 h

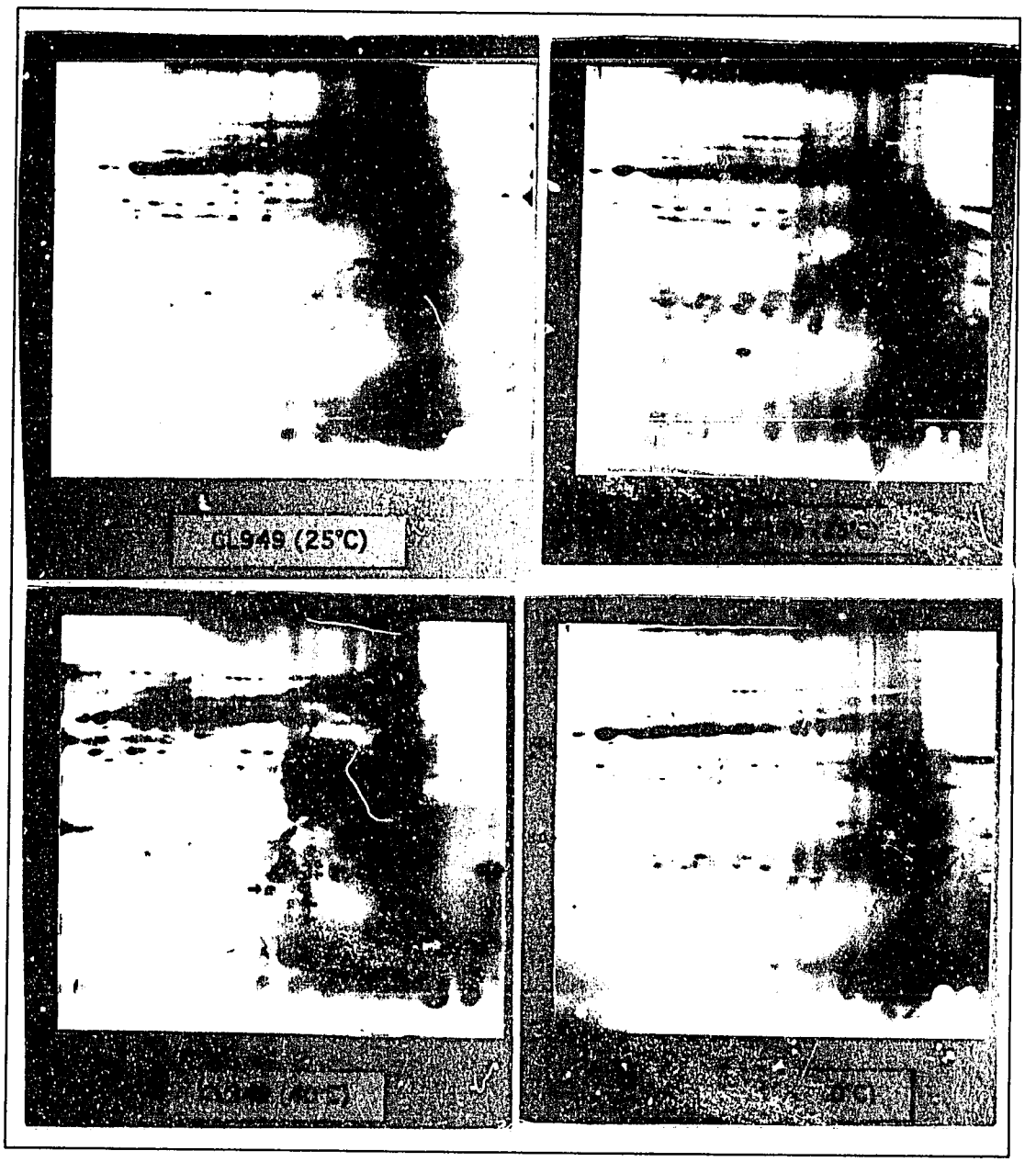

Fig. 2. Comparison of 2-D protein patterns of leaf tissue of CL 949 and CL 5915-153 with or without 40°C treatment for 4 h

A Rapid Transformation Method for Tomato and Pepper

Summary

Plasmid pBI 121 carrying NPT II and GUS genes was introduced into genomes of tomato and pepper via pollen-tube pathway. Seedlings from three tomato cultivars, L 123, CL 5915-153, and CL 5915-206, and two pepper cultivars, Early Calwonder (ECW) and Szechwan, were selected on medium containing kanamycin after pBI 121 DNA application. About 0.25% of the seeds were transformed and 4.48% of the treated florets produced transgenic tomato plants. The transgenic plants were confirmed by Southern or dot analysis. Sweet pepper ECW was screened by spraying kanamycin solution to growing plantlets. The transformation efficiency was about 14.6% of the plants from ECW seeds. Hot pepper Szechwan had a problem with flower abscission. This problem needs further exploration. The pollen-tube pathway method seems simpler and can avoid the problem of regeneration from callus.

Introduction

Since pollen-tube pathway method was introduced in 1981 for gene transformation of plants, more reports show that this method can be applied not only on various crops, but also in developing stable nereditary cultivars in F_3-F_4 generations. In comparison to Agrobacterium-mediated system based on explant transformation, the pollen-tube pathway method seems simpler because it avoids the use of time-consuming tissue culture steps. In this study, the gene transformation system of tomato and pepper via pollen-tube pathway was investigated.

Materials and Methods

Plant materials

Three tomato cultivars (L 123, CL 5915-153, CL 5915-206) and two pepper cultivars, ECW and Szechwan, were used in exogenous transformation via pollen-tube pathway.

Plasmid

The plasmid pBI 121 (Clontech Co.) carries neomycin phosphotransferase II (NPT II, which confers kanamycin resistance) and ß-glucuronidase (GUS) genes. JM 109 harbors pBI 121 cultures in LB medium containing 50 µg/ml kanamycin for overnight application at 37°C. Plasmid was isolated by the protocol of Birnboim et al. (1980).

Plant transformation

Foreign DNA transformation via pollen-tube pathway. Tomato and pepper plants were grown in the greenhouse for three months. Floral buds at one day before anthesis were artificially pollinated with their own pollens. One day later, the top 1/3 to 2/3 of the stigma was cut away with a pair of scissors. Some 5-8 µl of the DNA solution (pBI 121 50 µg/ml in TE buffer) was placed on the cut surface using a pipetman. The floret was covered by a paper bag. Mature seeds were harvested about 30 days after the DNA treatment. Seeds were germinated on 1/2 MS medium containing 100 µg/ml kanamycin at 25°C for selection. An alternative method of screening for transformed seeds was to spray 100 µg/ml of kanamycin on growing plantlets with normal looking green leaves.

Southern analysis

Total DNA was prepared from tomato and pepper leaves by the modified method of Dellaporta et al. (1983). The DNA was digested with EcoR I or EcoR V, and 8 µg samples of digested DNA was electrophoresed in 0.8% agarose and blotted onto Hybond-N membrane (Amersham) by neutralization blotting procedure. The membrane was hybridized to DIG-dUTP labeled pBI 121.

GUS assay

Leaves were homogenized for GUS assays in extraction buffer, the buffer consisting of 50 mM $NaPO_4$ pH7.0, 10 mM EDTA, 0.1% TritonX-100, 0.1% Sarkosyl, 10 mMß-mercaptoethanol. Samples were centrifuged at 10,000 rpm for 20 min. The supernatant solution was transferred to the fresh eppendrof. For each sample, 200 µl of GUS extraction buffer containing 1 mM methyl umbelliferyl glucuronide was pre-incubated at 37°C for 2 h to 1 day. Samples were observed under long-wave UV(360 nm) transillumination.

Results and Discussion

Twenty-four hours after florets were pollinated, the top 1/3 to 2/3 of the stigma was cut and applied with pBI121 DNA. Mature seeds were harvested about 30 days after the DNA treatment. Seeds were germinated on 1/2 medium containing 100 µg/ml kanamycin for selection. About 0.25% of the seeds were transformed and 4.48% of the treated florets produced transgenic tomato plants (table 3). Table 3 shows the results of exogenous transformation for three tomato cultivars. F_1 seeds derived from transformed plants were screened. Among the three tomato cultivars, L123 has a lower seed production, hence it needs more treated florets to get better transformation result. CL5915-206 has higher seed production, therefore its transformation ratio is higher. The transgenic plants were confirmed by Southern analysis (fig. 3).

Sweet pepper is a very good material for the pollen-tube pathway method because it has bigger flowers and stigma, and a large quantity of seeds for DNA application. However, its stigma is shorter and very close to the ovary, so it is advisable not to cut the stigma so as not to injure the ovary. Seedlings of Early Calwonder after DNA treatment were directly sprayed with kanamycin for screening of transformed plants. About 14.6% of total seeds was resistant to kanamycin and confirmed by dot-blot analysis.

Hot pepper is more difficult to use in DNA treatment because its stigma is very slender and flower abscission tends to occur after treatment, which makes fruit setting impossible. This problem requires further examination.

Table 3. Transformation ratios of tomato plants after exogenous application of pBI 121 DNA (carrying NPT II and GUS genes) via pollen-tube pathway

Entry	Transformed plants/ treated florets		Transformed plants/ collected seeds	
	No.	%	No.	%
Tomato				
CL 5915-153	5/216	2.30	5/4957	0.10
CL 5915-206	12/96	12.50	12/2600	0.46
L 123	2/112	1.80	2/184	1.09
Pepper				
ECW	-	-	19/133	14.29

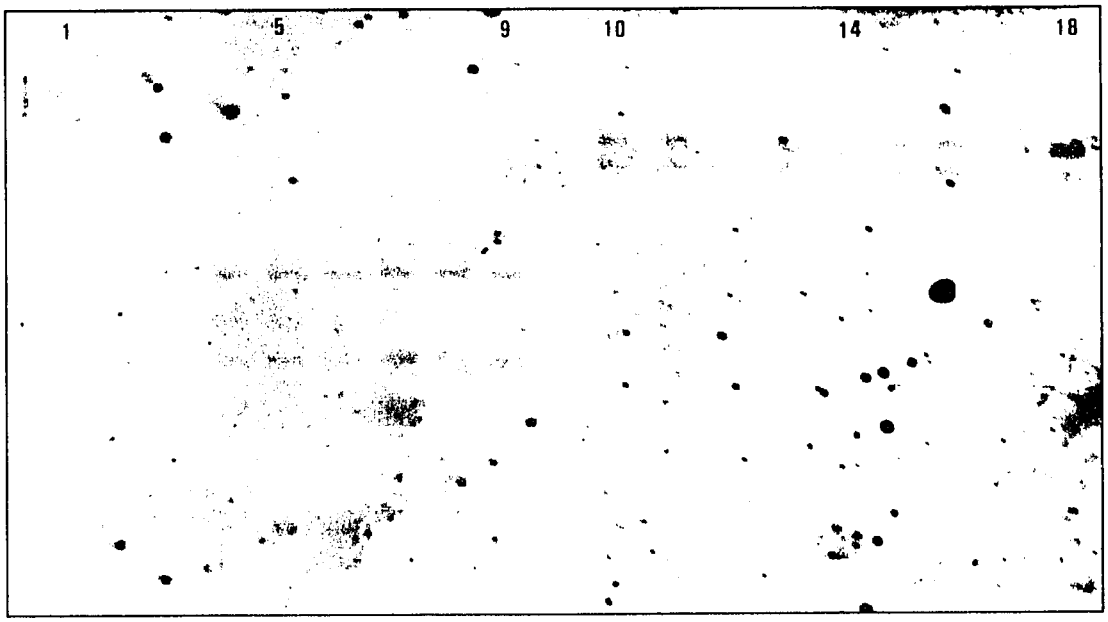

Fig. 3. Southern analysis of transformed tomato plants via pollen-tube pathway transformation. pBI 121 labeled with DIG-dUTP was used as a probe. Lanes 1-9: EcoR I digested DNA of transformed plants. Lanes 10-18: EcoR V digested DNA of transformed plants

Genetic Resources and Seeds

Status of the AVRDC Germplasm Collection

As of 30 September 1993, the total number of registered accessions in the AVRDC collection was 39,329 (table 1). This represents an increase of 3379 over that reported last year (AVRDC 1993). The greatest acquisition was 931 accessions of *Glycine soja* from USDA-ARS, followed by 429 accessions of pepper, 370 accessions of newly collected eggplants, and 205 alliums which included newly collected material and donations from the Natural Resources Institute/Horticulture Research International, United Kingdom.

Table 1. The AVRDC germplasm collection as of 30 September 1993

Crop	No. of accessions
Priority crops:	
Soybean	13,603
Tomato	6,629
Pepper	6,363
Mungbean	5,737
Brassica spp.	1,421
Eggplant	564
Allium spp.	327
Subtotal	34,644
Other crops:	
Yard-long bean and cowpea	1,600
Black gram	452
Phaseolus beans	450
Luffa spp.	229
Pea	207
Cucumis	206
Abelmoschus	187
Lablab bean	161
Cucurbita spp.	148
Benincasa spp.	126
Others	919
Subtotal	4,685
Total	39,329

From the collecting expeditions in the Philippines and Thailand, 1299 accessions of other crop species were added. The tomato collection includes Dr. Charles M. Rick's (Tomato Genetics Resource Center) standard set of core collection which provide representative collections of the different races, varieties, forms and other subspecific groups.

The transfer of the sweet potato germplasm collection to CIP, Lima, has been completed.

Multiplication and Characterization of the Germplasm Collection

Summary

A total of 4606 accessions were multiplied and characterized in 1993 at headquarters, Philippines, and Thailand. Based on demand, the priority for multiplication are pepper, wild species of tomato that are potential sources of resistance to diseases, and the new crop species *Allium* and eggplant. Another priority is accessions with low viability. New strategies for faster and more efficient methods of multiplication are being developed and tested to cope with increasing requirement for special materials. In vitro conservation of garlic and shallot has been started.

Introduction

One of the objectives of GRSU is to build up base and active collections of vegetable species popular in the tropics. To have enough seeds for preservation and distribution, newly acquired materials are planted for seed increase. During seed increase, characterization is routinely done.

Changing needs for germplasm and conditions of newly received as well as stored materials require that yearly prioritization for multiplication be done. The increasing demand for wild species which require special cultural management and seed production techniques necessitate the development of new strategies for their multiplication.

Materials and Methods

Before the start of the planting season, GRSU sends out a reminder to center scientists to submit a list of germplasm material that they would like to be multiplied. GRSU considers the list in the schedule of multiplication. Accessions observed to have low viability and low quantity of seeds for distribution are also included in the priority list.

The number of accessions planted for multiplication in 1993 are shown in table 2.

Table 2. Number of accessions multiplied in 1993

Crop species	Site			Total
	Taiwan	Philippines	Thailand	
Soybean	1,000	-	2,000	3,000
Pepper	341	541	-	882
Tomato	66	-	-	-66
Eggplant	36		-	36
Allium	36	-	-	-36
Brassica	36		-	36
Others	-	396	154	550
Total	1,515	937	2,154	4,606

Headquarters

All of the priority crops were represented in the multiplication. To save on cost, 36 net cages, 4 x 24 x 2.1 m in length, width, and height, respectively, were constructed. Inside each cage, two 1.5-m-wide beds were formed and covered with plastic mulches. One accession each of five crop species was enclosed in one net cage: *Allium*, pepper, tomato, eggplant, and *Brassica*. The number of plants per species equals 60 for *Brassica*, 30 for the solanaceous species, and 40 for *Allium*.

Management practices included furrow irrigation, fertilization, spraying against pests, staking, and pruning. To increase pollination, bees were released inside the cages. Bees were kept inside their boxes for 48 h before release to prevent their bringing into the net cages pollen from outside.

Due to increasing requests for wild species, three more species of wild tomatoes were planted inside the screenhouse. Supplementary hand-pollination was done to increase seed set. Using an improvised collector, dehiscing pollen from all plants in one accession were collected, mixed, and stored inside the freezer (0°C) until pollination time. Pollen was brushed onto receptive stigma of the same accession.

An additional 25 net cages were constructed to accommodate 305 accessions of pepper.

Soybeans were sown in the field.

In vitro conservation of garlic and shallot was started.

All characterization was based on a standardized set of descriptors. For pepper, a 200-g sample of each accession was sent to AVRDC's Analytical Laboratory for NIRS analysis of dry matter, sugar, fat, and color value.

Philippines

A total of 402 accessions of pepper were sent to the National Plant Genetic Resources Laboratory, University of the Philippines Los Baños for multiplication and characterization. An additional 13 accessions from locally collected material were included.

As part of the project "Conservation, Evaluation, and Utilization of Vegetable Genetic Resources: a Collaborative Network Project for Southeast Asia", accessions multiplied last year but which did not produce the required 20,000 seeds were again planted. These include 71 accessions of lima beans, 54 winged beans, 53 yard-long beans, 34 *Luffa* spp., 17 *Cucurbita moschata*, 15 *Cajanus cajan*, 9 bottle gourds, and 4 wax gourds.

Thailand

At Kamphaengsaen, 2000 accessions of soybeans and 154 yard-long beans were planted. The decision to multiply soybeans in Thailand is based on the need to quickly multiply a large number of accessions that have deteriorating viability and the transfer of the soybean breeding program to the regional center where consequently the soybean and mungbean active collection will be located.

Results and Discussion

Allium

Only 17 of the 36 accessions germinated. All 17 had circular cross-section of leaf. All accessions had light green leaf color except one which had medium-dark green leaves. Leaf surface was covered with wax. In one accession (TA 103), five of 40 plants flowered. However, no seeds were recovered. The quality of bulbs produced was poor. Surviving bulbs were vernalized and planted in autumn 1993.

There are now 13 accessions of garlic and 7 shallot maintained in vitro.

Crucifer

The majority of the accessions multiplied this year belong to the *toria* and *sarson* group from Nepal. No vernalization treatment was needed. Although these accessions were thought to have a high degree of incompatibility, seed setting for most of them was high possibly due to the presence of bees as pollinator and the favorable growing conditions. Seed yield ranged from 486

to 1549 g per accession of 30 plants or an average of about 700 g per accession. Only one accession (TB0001) proved to be a mixture of two types based on vegetative traits, days to maturity, and seed color.

Pepper

Tables 3 and 4 show the flower and fruit characteristics of the accessions multiplied.

Tomato

Due to the increasing demand for wild species, multiplication of tomato germplasm was concentrated on the wild species. Inflorescence and fruit traits observed are summarized in tables 5 and 6.

Eggplant

Except for TS 113 (*S. melongena*) from the Philippines, all the other 35 accessions produced at least 140 g of seeds, enough for the base and the active collections,

Conclusions and Recommendations

Seed production in net cages with a single crop and net cages with mixed crops were the same. Supplementary hand-pollination in eggplants and wild tomatoes increased fruit/seed set. If growth of onions is not improved, they will have to be moved out of the net cages.

Mixed cropping inside one net cage did not pose a problem on irrigation, weeding, and fertilization. However, the planting schedule for each crop should be adjusted so that most of them will flower at the same time.

The rate of multiplication of wild species as well as the new crop species still cannot meet the demands of center scientists. New strategies to increase the number of accessions that can be multiplied yearly need to be considered.

Distribution of Vegetable Germplasm

Summary

In 1993, various AVRDC research units requested a total of 4142 seed samples most of which were used in screening for resistance to pests and diseases. Externally, a total of 14,245 samples of germplasm and breeding lines were distributed to 67 countries and territories. The Asian Regional Center (ARC) received the most number of samples. A large quantity of germplasm also went to the Africa Regional Program (ARP) and to countries with which the center has formal collaborative activities.

The Zambian collection of *Capsicum* has been multiplied and is ready for repatriation as requested by the Zambian national program on assembly of all germplasm originating from their country.

Distribution of mungbean breeding lines is now done through the Asian Regional Center in Thailand.

Table 3. Diversity in inflorescence characters of pepper germplasm from different sources characterized in 1992-1993

Country	Species	No. of acc.	Fruit pungency	Days to flower	No. of pedicels per axil	Corolla color	Calyx margin shape	Corolla spot	Anther color	Filament color	Stigma position in relation to anther at full anthesis
Guatemala	*annuum*	20	Mixture	62-133	1	White	Intermediate/ Dentate	Absent	Blue	White	Exserted
	frutescens	1	High	73	1	White	Intermediate	Absent	Blue	White	Exserted
Honduras	*annuum*	41	Mixture	56-120	1	White	Dentate	Absent	Blue	White	Same level/ Exserted
	frutescens	5	High	120-179	2	Yellow-green	Intermediate	Absent	Blue	Light purple	Exserted
Belize	*annuum*	5	Sweet/ Intermediate/ High	76-100	1	White	Dentate	Absent	Blue	White	Exserted
	chinense	2	Intermediate/ High	92-111	2/3	Yellow-green	Intermediate/	Absent	Blue	Light purple	Exserted
Zambia	*annuum*	24	High	73-120	1	White	Intermediate/ Dentate	Absent	Blue	White/ Purple	Exserted
	baccatum	2	Low/ Intermediate	244	1	White	Dentate	Green	Yellow	White	Inserted
	chinense	4	Low/High	92-111	2	Yellow-green	Intermediate	Absent	Blue	Light purple	Exserted
	frutescens	24	High	92-100	2	Yellow-green	Intermediate	Absent	Blue	Light purple	Exserted
Mexico	*annuum*	69	Mixture	62-144	1	White	Intermediate/ Dentate	Absent	Blue	White	Exserted
	baccatum	5	Low/High	83-133	1	White/ Light yellow	Dentate	Green-yellow	Yellow	White	Exserted
	chinense	9	Intermediate/ High	92-111	2/3	Yellow-green	Intermediate/ Dentate	Absent	Pale blue/ Blue	Light purple	Same level/ Exserted
	frutescens	6	High	92-133	2	Yellow green	Intermediate	Absent	Blue	Light purple	Exserted

Table 4. Diversity in fruit characters of pepper germplasm from different sources characterized in 1992-1993

Country	Species	Fruit length (cm)	Fruit width (cm)	Fruit wall thickness (mm)	Fruit weight (g)	Fruit color at immature stage	Fruit color at intermediate stage between immature and mature stage	Fruit color at mature stage	Fruit shape	Duration to fruiting
Guatemala	*annuum*	1.5-10.4	1.0-5.6	0.7-5.1	0.7-70.8	Green	Brown	Red	Elongate/ Conical	Early-Late
	frutescens	1.1	0.4	0.4	0.2	Green	Orange	Red	Elongate	Late
Honduras	*annuum*	3.0-9.2	1.3-5.2	0.8-6.0	3.2-68.0	Green/ Yellow	Brown	Red	Elongate Conical/ Blocky	Early-Late
	frutescens	1.1-2.5	0.8-1.0	0.6-0.9	0.4-1.0	Green	Brown/ Orange	Red/ Orange-red	Elongate/ Oblate/ Conical	Early-Late
Belize	*annuum*	3.6-8.3	1.6-2.8	0.8-2.2	1.9-13.7	Green	Brown/ Orange	Red/ Orange-red	Elongate/ Conical	Intermediate-Late
	chinense	1.4-1.9	1.7-2.0	1.4-1.7	2.0-3.0	Green	Brown/ Yellow	Red/ Yellow	Conical	Intermediate
Zambia	*annuum*	1.7-10.5	1.0-1.6	0.4-1.5	0.7-6.4	Green	Brown	Red	Elongate/ Oblate/ Conical	Intermediate-Late
	baccatum	2.7-3.0	2.6-2.8	1.4-1.7	4.8-8.5	Green	Orange	Red	Campanulate	Late
	chinense	1.2-3.3	1.0-2.2	1.1-1.8	1.0-4.9	Green	Brown	Red Orange	Oblate/ Campanulate	Intermediate-Late
	frutescens	1.2-1.8	0.3-0.4	0.3-0.4	0.1-0.2	Green	Brown	Red	Elongate	Intermediate-Late
Mexico	*annuum*	1.4-12.5	0.7-5.7	0.3-3.9	1.6-66.4	Green	Brown	Red	Elongate/ Conical	Early-Late
	baccatum	1.0-3.4	1.4-1.8	1.0-2.2	1.3-3.8	Green	Brown	Red	Elongate/ Oblate/ Round/ Campanulate	Intermediate-Late
	chinense	1.0-3.8	1.3-2.6	0.6-2.8	1.4-5.7	Green	Brown/ Orange	Red/ Orange-red/ Orange	Elongate/ Round/ Campanulate	Intermediate-Late
	frutescens	1.0-1.4	0.4-0.8	0.4-0.7	0.1-0.3	Green	Brown/ Orange	Red/ Orange-red	Elongate Round	Late

Table 5. Diversity in inflorescence and fruit characters of tomato germplasm from different species in 1992-1993

Species	Days to flower	Inflorescence type	No. of flower/ inflorescence	Days to fruit	Exterior color of immature	Intensity of greenback fruit	No. of fruit/ inflorescence
chmielewskii	53-61	uniparous	6-11	110	light	slight	3-11
cheesmanii	59-87	uniparous	7-13	110-157	light / medium	mixture	3-13
chilense	61-76	multiparous	15-49	110-157	light	none/ slight	11-40
hirsutum	68-81	multiparous	12-13	142	light	none medium	1-2
peruvianum	46-84	uniparous	8-14	79-93	light	slight/ medium	4-11
pimpinellifolium	46-68	uniparous	9-29	57-93	light	slight/ medium	2-14

Table 6. Diversity in fruit characters of tomato germplasm from different species in 1992-1993

Species	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Thickness of fruit wall (mm)	Soluble solids (brix)	Ease of peeling	Exterior color of mature fruit	Interior flesh color intensity	Predominant fruit shape
chmielewskii	1.2-1.6	1.4-2.1	1.4-3.8	0.7-1.1	6.1-10.4	fair/ good	green	light	slightly flattened/ round
cheesmanii	0.9-1.3	0.9-1.5	0.4-1.6	0.7-1.5	5.4-18.5	fair	orange	light	slightly flattened/ round/high-round
chilense	1.1-1.5	1.4-1.9	1.2-2.7	0.8-1.3	7.7-9.1	fair/ good	green	light	slightly flattened/ round/high-round
hirsutum	1.3-1.6	1.5-1.9	1.4-2.4	1.3-1.4	7.9-8.1	poor	green	light	slightly flattened
peruvianum	1.5-2.6	1.5-3.0	2.0-14.6	1.1-2.5	4.2-6.6	fair/ good	red	medium	round
pimpinellifolium	0.9-2.7	1.0-2.9	0.6-13.5	0.6-2.4	4.5-10.3	fair/ good	red	light/ medium	round

Introduction

To complement conservation with utilization, GRSU maintains a large active collection for distribution purposes. Most of the materials go to national breeding programs, research at center headquarters, and regional activities.

Materials and Methods

Requests for germplasm are regularly received by AVRDC. Depending on the nature of material required, the request is either served by GRSU or channeled to the other units of AVRDC.

This year, materials for distribution were pre-packed in laminated aluminum foil envelopes immediately after seed processing and drying priority crops at 50 seeds/pack, nonpriority crops at 25 seeds/pack, and wild species at 15 seeds/pack.

The 2000 accessions of soybean multiplied at ARC in Thailand are being processed to be part of the active collection that will be distributed through ARC.

Results and Discussion

External seed distribution

Table 7 shows the recipients of AVRDC germplasm including breeding lines and in vitro materials. Thailand received the greatest number of samples, followed by Taiwan. The large number of samples received by Taiwan is due to the duplication at the National Plant Genetic Resources Center, Taiwan Agricultural Research Institute of 500 accessions of tomato, 300 of pepper and 200 of *Brassica*. Table 8 shows the major institutions that received AVRDC germplasm in 1993. Thailand is the location of the AVRDC Asian Regional Center and Tanzania of the AVRDC Africa Regional Program. About 400 of the samples sent to the Philippines were for

Table 7. External distribution of germplasm and breeding lines in 1993 (as of 30 September)

	No. of samples[a]									
Country	A	B	C	G	I	L	O	S	V	Total
Thailand	0	5	259	51	703	135	0	0	1,493	2,652
Taiwan	0	204	218	574	0	500	20	0	0	1,516
Korea	0	30	62	620	408	45	166	0	74	1,405
Philippines	0	85	348	190	15	134	17	7	426	1,222
Tanzania	6	0	23	0	0	1082	0	0	0	1,111
India	7	37	535	82	0	328	35	14	2	1,040
Indonesia	0	0	96	61	42	75	27	0	385	686
Peru	0	0	0	0	443	0	0	0	0	443
USA	0	2	182	52	0	81	31	0	78	426
Sri Lanka	7	0	250	0	0	62	2	14	0	335
Others[b]	21	258	1,333	383	107	1,055	64	46	142	3,409
Total (67)	41	621	3,306	2,013	1,718	3,497	368	81	2,600	14,245

[a]A = *Allium*; B = *Brassica*; C = *Capsicum*; G = *Glycine*; I = *Ipomoea*; L = *Lycopersicon*; O = Others; S = *Solanum* and V = *Vigna*.

[b]Includes 57 countries and territories: Australia, Austria, Bangladesh, Bhutan, Botswana, Brazil, Canada, Central Africa, China, Colombia, Egypt, Ethiopia, Fiji, France, Gabon, Gambia, Germany, Ghana, Grenada, Guadeloupe, Guam, Hong Kong, Hungary, Israel, Italy, Ivory Coast, Japan, Kuwait, Lesotho, Madagascar, Malawi, Malaysia, Mauritius, Mexico, Nepal, Netherlands, New Zealand, Nicaragua, Nigeria, Oman, Pakistan, Panama, Samoa (American), Samoa (Western), Seychelles, Sierra Leone, Singapore, South Africa, St. Christopher and Nevis, Granada, St. Lucia, Togo, Uganda, Ukraine, United Kingdom, Venezuela, Vietnam, and Zimbabwe.

Table 8. Recipients of AVRDC vegetable germplasm in 1993

Australia
Cunningham Laboratory

Austria
University of Vienna

Bangladesh
AVRDC/USAID/Bangladesh Project
Crop Diversification Programme - Dutch Executing Agency
Grameen Krishi Foundation
Mennonite Central Committee (MCC)

Bhutan
Center for Agricultural Research and Development
Department of Agriculture
Integrated Horticulture Development Project
Ministry of Agriculture
Royal Government of Bhutan
UNDP/FAO

Botswana
SACCAR

Brazil
EMBRAPA-CENARGEN
University de Brasilia
Universidade Estadual Paulista-UNESP

Central Africa
Department of Research

China
Chiangsu Provincial Agricultural Sciences
Chinese Academy of Agricultural Sciences
Guangxi Academy of Agricultural Sciences

Colombia
Centro International de Agricultural Tropical
Frutera de la Costa S.A.

Egypt
Assiut University
FAO Protected Cultivation Project
Minufiya University
Vegetable Research Sections

Ethiopia
FAO Office
Nazareth Research Center

Fiji
Sigatoka Research Station

France
CIRD/C.A. Martinique
Royal Sluis

Gabon
Organisation des Jeunes du Village pour le Development Rural (OJVDR)

Germany
Biogische Bundesanstalt fur Land-und Forstwirtschaft
Bundesangstalt für Zuchtungsforschung an Kulturpflanzen
Humboldt-Universitat Zu Berlin
Technical University Berlin

Ghana
Universal Pest Control and Agric. Ventures Ltd.

Grenada
The Agricultural Technical Mission of the ROC

Guadeloupe
Institut National de la Recherche Agronomique

Guam
University of Guam

Hong Kong
Ellerman & Company, Ltd.

Hungary
Bartok B. UT 41
Budakert KFT
Vegetable Crops Research Institute

India
Agricultural University Ludhiana
Annamalai University
C.R.S., Punjabrao Krishi Vidyapeeth
Central Agricultural Research Institute
E.I.D. Parry (India) Ltd.
G.B. Pant University of Agriculture
Harrisons Malayalam Ltd.
Indian Institute of Horticultural Research
ITC Limited
Khatau Junker Limited
National Agricultural Research Center

Table 8. Continued.

Nuziveedu Seeds Pvt. Ltd.
Punjab Agricultural University
Tamil Nadu Agricultural University
University of Agricultural Sciences
University of Agricultural Sciences & Technology
Vijay Seeds Co. Pvt. Ltd.

Indonesia
Bogor Research Institute for Food Crops
Central Research Institute for Horticulture
International Potato Center/Indonesia
Lembang Horticultural Research Institute
Malang Research Institute for Food Crops
Mitra Tani Terpadu, pt.
PT. Selektani
Sukmandi Research Institute for Food Crops
Ualan Pajajaran Bogor
Universitas Nusa Cendana

Israel
Agecotec, Agricultural & Biotechnologies Ltd.
Hazera (1939) Ltd.
The Israel Genebank for Agricultural Crops

Italy
National Agency for Atomic Energy (ENEA)

Ivory Coast
IDESSA-DCV

Japan
Kagawa University
Kogome Food Company
Kobaysahi Seed Co., Ltd.
Sumitomo Chemical Co., Ltd.
Tokyo University of Agriculture

Korea
Agri. Biotechnology Institute
Crop Experiment Station
Horticultural Experiment Station
Hung Nong Seed Co., Ltd.
International Technical Cooperation Center
Kangwon Provincial Rural Development Administration
Korea Atomic Energy Research Institute
Korea Seed International Co., Ltd.
Korea University
Mokpo Branch Station, CES
Seoul National University
Young Nam Crop Experiment Station

Kuwait
Kuwait University

Lesotho
Agricultural Research Division

Madagascar
FOFIFA/CENRADERU

Malawi
Bvumbwe Agricultural Research Station
Chitedze Agricultural Research Station

Malaysia
Dip Agr. (M) Agr. Sc. (Hons) (M)
Instant Garden Industries
Malaysian Agricultural Research and Development Institute (MARDI)
Pusat Penyelidikan Pertanian
Universiti Pertanian Malaysian

Mauritius
Mauritius Sugar Industry Research Institute

Mexico
ICRISAT - CIMMYT
Instituto Nacional de Investigaciones Forestales Y Agropecuarias

Nepal
Center for Environmental and Agri. Policy Res. Extension and Development
GCP/NEP/043/SWI
Lumle Regional Agricultural Research Center
Nepal Agricultural Research Council
Tribhuvan University

Netherlands
Enza Zaden de Enkhuizer Zaadhandel B. V.
Nunhems Zaden B.V.

New Zealand
Crop and Food Research

Nicaragua
Mision Tecnica Agropecuaria de la Republica de China

Nigeria
Jigawa State Polytechnic
Ministry of Agriculture and Natural Resources
Samaru Ahmadu Bello University

Table 8. Continued.

Oman
Sultan Qaboos University

Pakistan
Agricultural Research Station (North)
AYUB Agricultural Research Institute
National Agricultural Research Center
Pakistan Agricultural Research Council
Pakistan Organic Farmers Association

Panama
Nestle Panama S.A.

Peru
International Potato Center (CIP)

Philippines
Asian Development Bank
AVRDC/POP
Benguet State University
Bohol Agricultural Promotion Center
Central Luzon State University
Department of Agriculture
Institute of Plant Breeding, UPLB
Isabela State University
National Plant Genetic Resources Laboratory
Northern Philippines Root Crops Research and Training Center
OIC, Central Post Entry Station
University of the Philippines Los Baños (UPLB)
University of San Carlos
Xavier University

Samoa (American)
American Samoa Community College

Samoa (Western)
University of the South Pacific

Seychelles
Ministry of Agriculture and Fisheries

Sierra Leone
CTA-GCP/SIL/015/NOR
Rice Research Station

Singapore
Eastreco (Pte.) Ltd.
First Grade Agency Ptd.

South Africa
May Ford Seeds (Pty.) Ltd.

Sri Lanka
Central Agricultural Research Institute (CARI)
Department of Agriculture
Eastern University BPI-LANCRDC (Economic Garden)
Eastern University Sri Lanka
Regional Agricultural Research Center

St. Christopher and Nevis
Agricultural Technical Mission of the ROC

St. Lucia
ROC Agricultural Technical Mission

Taiwan (ROC)
Council of Agriculture, Executive Yuan
National Chiayi Institute of Agriculture
National Pingtung Polytechnic Institute
National Plant Genetic Resources Center
Taiwan Agricultural Research Institute

Tanzania
Kimango Farm Enterprises Ltd.
SADCC/AVRDC-CONVERDS

Thailand
Asian Regional Center-AVRDC
Chiang Mai Field Crops Research
Church World Service
Department of Agriculture
Faculty of Agricultural Technology, KMITL
Kasetsart University
Sluis Vegetable B.V.

Togo
Universite du Benin - Ecole Superieure D'Agronomie

USA
BHN Research, Richfield Packing Co., Inc.
Cornell University
Louisiana State University
Mahyco American, Inc.
Northern Mariana College, Asterlaje Campus
North Carolina Sate University
Pepper Research Inc.
Peto Seed Company
Texas A & M University
Tropical Rural and Island/Atoll Development Experimental Station
University of Agricultural Sciences, Dharwad
University of Arkanasa at Pine Bluff

Table 8. Continued.

University of Hawaii	Center Rothamsted Experimental Station
University of Minnesota	University College of North Wales
University of Wisconsin	University of Leeds
	University of Wales
Uganda	
FAO UGA/87/003 "Development of the Horticulture Industry"	**Venezuela**
Namulonge Horticulture Farmers' Group	Universidad Central de Venezuela
	Vietnam
Ukraine	University of Cantho
Plant Breeding and Genetics Institute	
	Zimbabwe
United Kingdom	Agricultural Development Authority
Natural Resources Institute	Horticultural Research Center

the joint AVRDC-NPGRL multiplication of pepper germplasm project. The materials sent to Peru consisted of the sweet potato germplasm that was transferred to CIP, Lima.

The 36 accessions of *Capsicum* originating from Zambia are now ready for repatriation as requested by Zambia through IBPGR as part of the country's effort to assemble its germplasm material.

As in 1992, the majority of the seeds distributed outside of AVRDC were breeding lines, including sets involved in variety trials (e.g., IMN, INTHOPE, ASET, AVNET).

Since the legume breeding activity has been transferred to ARC, distribution of mungbean breeding lines is now done through the mungbean breeder stationed there. Requests received at headquarters are transmitted to the regional center except for materials that are maintained at GRSU. The 2000 accessions of soybean multiplied at ARC are being processed to be part of the active collection that will be distributed through ARC. However, the lack of an efficient seed drying facility is impeding the rate of processing.

Internal seed distribution

Table 9 shows utilization of germplasm collection by the center's researchers. Most of the materials went to the Pathology and Entomology units: 738 accessions of tomato for screening for resistance to late blight and 500 accessions of pepper for screening for resistance to broadmites. Table 10 shows how the requested materials were used by the center scientists.

Conclusions and Recommendations

Distribution of germplasm is one of the heaviest loads in the operation of GRSU. The transfer of the legume breeding program to ARC provides another route for germplasm distribution. From hereon, breeding lines of mungbean will be distributed through ARC. Efforts to transfer the active collection of soybean to ARC have also started. However, there is a need to improve seed-drying facilities at ARC to accomodate the large amount of material that needs to be processed.

Table 9. Internal seed distribution of germplasm as of 30 September 1993

Unit	A[a]	B	C	G	L	O	S	V	Total
Pathology	50	51	640	0	1,472	0	0	0	2,213
Entomology	0	0	799	0	0	0	50	0	849
GRSU	0	0	345	0	0	0	4	6	355
Country Programs	0	129	0	0	12	84	106	0	331
Plant Breeding	103	0	74	33	1	0	0	19	230
Crop Management	0	0	0	0	0	0	113	0	113
Training	0	11	6	0	12	0	0	0	29
Physiology	0	0	0	0	18	0	0	0	18
Analytical Lab	0	0	0	4	0	0	0	0	4
Total	153	191	1,864	37	1,515	84	273	25	4,142

[a]A = *Allium*; B = *Brassica*; C = *Capsicum*; G = *Glycine*; L = *Lycopersicon*; O = Others; S = *Solanum*; and V = *Vigna*.

Table 10. Utilization of AVRDC germplasm by center scientists in 1993

Crop species	Purpose
Allium	Evaluation trial
	Meristem culture
	Inoculation experiment
Crucifer	TuMV
	SO_2 resistance/sensitivity
Eggplant	Bacterial wilt
	Fruit borer
	Shoot borer
	Thrips
	Heat tolerance
	Waterlogging trial
	Grafting trial
	Development of management practices
Pepper	Virus
	Anthracnose
	Black leaf mold
	Broadmites
	SO_2 resistance/sensitivity
	SDS-PAGE
	INTHOPE seed distribution
Soybean	Summer trial
	Lipoxygenase isozyme activity assay
Tomato	Virus
	PVY
	TSWV
	Bacterial wilt
	Late blight (greenhouse and field)
	Bacterial spot
	Black leaf mold
	Development of management practices
Mungbean	Seed protein SDS-PAGE
Others	Heat tolerance
(*Amaranthus*, celery, lettuce, kangkong, basil, *Basella*, kailan, mustard, and yard-long bean)	Evaluation as leafy vegetable

Diversity in the Philippine Mungbean Germplasm Collection

Summary

Initial results revealed five protein profiles, two of which shared low Jaccard similarity values with respect to the predominant profile. Re-examination of the accessions and their passport data showed that the latter belonged to a misidentified *V. glabrescens* accession and to Red Mungbean accessions which were re-identified to be non-*V. radiata* based on plant and seed morphology.

Three mungbean profiles remained for analysis. Profile 1 was exhibited by 98% of the accessions, Profile 2 by three accessions, and Profile 3 by two accessions. It was composed of all the Profile 1 bands plus Band 8 (26.9 kD). The predominance of Profile 1 among the 271 accessions examined indicated a low degree of variation with respect to seed protein profiles. All the bands exhibited a relative frequency of 1.00; except for Band 8 which exhibited 0.01 and Band 9 which exhibited 0.99. The bands were thus monomorphic with respect to a 0.99/0.01 polymorphism criterion, indicating low genetic variation with respect to seed protein polypeptides.

Low genetic diversity of seed proteins among the Philippine mungbean populations represented in the study was hypothesized to be due to a genetically homogeneous progenitor population that reached the Philippines from India. Given the apparently short historical duration of mungbean cultivation in the country, variation in seed proteins did not arise in significant proportions, maybe because of a slow rate of emergence of successful mutations, or an absence of environmental selection pressure for variant seed proteins.

SDS-PAGE of seed proteins was demonstrated to be useful in rapid identification of different species in a germplasm collection. It was able to identify non-*V. radiata* species that have been mistakenly assigned to the *V. radiata* collection. Characterization of the mungbean accessions based on seed protein profile was also demonstrated to be useful as an adjunct to established morphological cluster analysis. Thus, SDS-PAGE may be used to characterize genetic diversity of mungbean accessions with the final objective of nominating accessions to a core collection.

Introduction

The genetic resources of crop species have been conserved by means of genebanks. These genebanks store the seeds of the various populations of the crop species to preserve the diverse genotypes that have evolved through thousands of years (Yndgaard and Kjellqvist 1984[1]). The germplasm collections of many genebanks have become very large and thus need to be organized in a manner that will facilitate their use. One approach to organization is to set up a core collection: a small subset of the collection that is easy for breeders to access for the desired genotypes and yet representative of the entire range of genetic diversity present in the whole collection. The genetic diversity that is represented by the different entries, or accessions, of a genebank collection thus have to be characterized to allow its ample representation in a core collection (Brown 1989[2]).

A worldwide collection of mungbean has been assembled at AVRDC. The collection had grown to 5737 accessions and so research activities were launched with the ultimate objective of

[1]Yndgaard, F. and Kjellqvist, E. 1984. Economic aspects of genebank conservation. Plant Genetic Resources Newsletter. 58: 34-36.

[2]Brown, A.H.D. 1989. The case for core collections. *In* Brown, A, Frankel, O., Marshall, D., and Williams, J. (eds.). The Use of Plant Genetic Resources. Cambridge Univ. Press. pp. 136-156.

establishing a core collection. The strategy used was to form country cores from which nomination to a global core will be based. The present study was conducted in line with that objective and characterized the genetic diversity of a subset of the mungbean collection which originated from the Philippines. The genetic diversity of the Philippine collection had been previously characterized based on morphological characters (Cababasay 1991[3]). The data was used in the formation of clusters from which a country core was developed (Cababasay et al. 1993[4]; Engle et al. 1993[5]).

The concept of genetic diversity, in its broadest sense, encompasses the total variation within all living organisms and their habitats or biodiversity (IBPGR 1992[6]). In a narrower sense, the presence of observable differences between different populations of the same species, e.g., the mungbean species *Vigna radiata*, also reflects genetic diversity. By observing the differences in the phenotypes of the individuals from different populations, the differences in their genotypes — their genetic diversity — can be observed.

This study characterized genetic diversity in mungbean with respect to one particular phenotype: the seed storage proteins. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) which separates the different polypeptide components of the seed proteins according to molecular weight was used. Any differences between the seed proteins were thus detected by the presence or absence of different molecular weight polypeptides in the proteins of seeds from different populations.

This study was designed to test the hypothesis that genetic diversity in seed proteins exists in the mungbean germplasm that had been collected from the Philippines. Its objectives were: (1) to determine the SDS-PAGE band pattern distribution in the collection, (2) to calculate the frequency of occurrence of specific bands in the collection, and (3) to determine how SDS-PAGE can be used in the management of germplasm collections.

Materials and Methods

Preparation of seed materials

A total of 315 accessions from the Philippines were listed as *V. radiata* var. *radiata* in the GRSU germplasm catalog (Tay et al. 1989[7]). Only 263 of these accessions were used in this study; 13 accessions were unavailable and 32 accessions were culled out because they were traced to have originated from other countries. Ninety-six of the 263 accessions were subdivided in the catalog into two or more subaccessions due to the recognition of morphologically distinct populations after plant multiplication procedures. Only 11 pairs of these subaccessions were examined; and the seeds of the remaining 85 accessions were obtained from the mixed premultiplication populations.

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[3]Cababasay, M.P. 1991. Classification of mungbean (*Vigna radiata*) using cluster analysis. B.S. Statistics Special Problem. UPLB, Philippines.

[4]Cababasay, M.P., Engle, L.M., and Gironella, A.I.N. 1993. A biometrical clustering of mungbean (*Vigna radiata*) accessions from the Philippines. Phil J Crop Sci 18 (Supl 1): 4.

[5]Engle, L.M., Cababasay, M.P., Gironella, A.I.N., and Kim, D.H. 1993. Establishing a country core collection in mungbean. Phil J Crop Sci 18 (Supl 1):44.

[6]IBPGR. 1992. Geneflow. IBPGR. R. 1992. Geneflow. IBPGR.

[7]Tay, D.C.S., Huang, Y.K., and Chen, Y.L. 1989. Germplasm Catalog of Mungbean [*Vigna radiata* (L.) Wilczek] and other *Vigna* species. AVRDC, Shanhua, Tainan, Taiwan.

Extraction of seed proteins

About 100 mg of seeds were placed inside small paper envelopes, immersed in liquid nitrogen, and pounded to form a fine meal. The seed meal was transferred to a microfuge tube, to which 1.0 ml of extraction buffer (0.05 m Tris-HCl with 0.2% SDS and 5 m urea at pH 8.0) was then added. Twenty microliters of 2-mercaptoethanol was added and the tube was vigorously shaken for about 2 min to mix the seed meal with the buffer. The resulting slurry was centrifuged at 3000 rpm for 5 min, and the protein extract was transferred to a new microfuge tube which was subsequently immersed in a boiling water bath for 90 sec.

Electrophoresis

Electrophoresis was carried out according to the system of Laemmli with a 12% resolving gel and 5% stacking gel. Two BIO-RAD Mini-PROTEAN II vertical slab cells, connected to a BIO-RAD Model 200/2.0 power supply unit, were employed.

The seed protein extracts were diluted in a fourfold volume of extraction buffer and 15 µl of the dilutions were loaded in the gel. Sigma MW-SDS-70L molecular weight standards were used. Electrophoresis was carried out with a constant voltage of 100 v in the stacking gel for about 20 min, and 150 v in the resolving gel for about 45 min. The gels were stained with the general purpose protein stain, Coomassie Brilliant Blue R-250, and destained with an aqueous solution of 40% methanol and 10% acetic acid.

Each protein extract was subjected to two separate runs to confirm the consistency of its banding pattern.

Analysis of bands and banding patterns

The relative mobility (Rf) of each band was calculated by taking the quotient of the distance it migrated over the distance traveled by the fastest marker protein, alpha-lactalbumin. The average Rf value of each band was calculated over all gels and then used to estimate its molecular weight from a standard curve. The standard curve was drawn by plotting the base-10 logarithm of molecular weight in kilodaltons (kD) of the marker proteins against the average of their Rf values relative to alpha-lactalbumin.

The banding patterns of the different accessions were compared to each other on the basis of repeatable bands. A band was considered to be repeatable when it consistently appeared on the duplicate gels for each accession. The different accessions were classified according to the type of banding pattern or protein profile, and the different protein profiles were compared to each other by calculating the Jaccard coefficient for each pair of profiles.

The relative frequency of each repeatable band was calculated by taking the quotient of its occurrence among the different accessions over the total number of accessions.

Results and Discussion

Estimation of molecular weight

The marker proteins exhibited the following average Rf values relative to alpha-lactalbumin: bovine albumin = 0.25, ovalbumin = 0.44, glyceraldehyde-3-phosphate dehydrogenase = 0.51, carbonic anhydrase = 0.58, trypsinogen = 0.73, trypsin inhibitor = 0.82, and alpha-lactalbumin = 1.00. A standard curve was constructed from a plot of the base-10 logarithm of molecular weight against the Rf values. The best-fit line was obtained from linear regression as $y = 2.022 - 0.884x$, where y is the logarithm of molecular weight in kilodaltons (kD) and x is the Rf value. The molecular weight of the sample polypeptides was calculated from the logarithm values

obtained from this standard curve. The low standard deviation values of each band indicate a high degree of precision in relative mobility between the gels (table 11).

Table 11. Band composition of the five profiles exhibited by mungbean populations originating from the Philippines

Rf value[a]	SD[b]	M.W. (kD)[c]	Profile 1	Profile 2	Profile 3	Profile 4[d]	Profile 5[e]
0.190	0.04	71.5	0	0	0	1	1
0.262	0.05	61.8	0	0	0	1	0
0.270	0.02	60.8	1	1	1	0	0
0.296	0.02	57.6	1	1	1	0	0
0.300	0.03	57.2	0	0	0	1	1
0.332	0.04	53.5	0	0	0	1	0
0.350	0.02	51.6	0	0	0	0	1
0.373	0.02	49.2	1	1	1	1	0
0.410	0.02	45.6	0	0	0	0	1
0.432	0.02	43.7	1	1	1	1	0
0.503	0.02	37.8	1	1	1	1	1
0.555	0.02	34.0	1	1	1	1	0
0.575	0.03	32.7	0	0	0	0	1
0.627	0.03	29.4	1	1	1	1	1
0.671	0.02	26.9	0	0	1	0	0
0.699	0.04	25.4	0	0	0	1	0
0.718	0.12	24.4	0	0	0	0	1
0.733	0.02	23.7	1	0	1	0	0
0.824	0.02	19.7	1	1	1	0	1
0.835	0.02	19.2	0	0	0	1	0
0.920	0	16.2	0	0	0	1	0
0.946	0.02	15.4	1	1	1	0	1

[a]Mean value of relative mobility with respect to alpha-lactalbumin.
[b]Standard deviation of the Rf values.
[c]Estimated molecular weight in kilodaltons.
[d]Profile of *V. glabrescens*.
[e]Profile of Red Mungbean, an unidentified non-*Vigna radiata* var. *radiata* species.

Banding patterns

Five banding patterns were observed from the 274 accessions included in the study. These banding patterns were designated as profile 1 through profile 5 (table 11, fig. 1). Profile 1 was exhibited by 263 accessions, while Profile 2 was exhibited by 3 accessions, and Profile 3 by 2 accessions; Profile 4 was exhibited by accession V1160, and Profile 5 by the two Red Mungbean accessions. The Jaccard similarity coefficients for each pair of profiles showed that Profiles 1, 2, and 3 were very similar; and that Profiles 4 and 5 were very dissimilar, both to each other and to the other three profiles (table 12). The three accessions exhibiting Profiles 4 and 5 were, therefore, re-examined. Seeds were retrieved and planted for observation. Passport data was also studied in detail. Accession V1160 was found to be PI 207655 which has been previously reported as *V. glabrescens* (Poehlman 1991[8]). The Red Mungbean accessions also turned out to be different from mungbean with respect to the following characteristics: (1) red seed coat, (2) concave hilum, (3) glabrous pod, stems, and leaves, (4) squarish leaf base, and (5) purple flowers. The purple flowers of Red Mungbean indicate that they do not belong to the subgenus *Ceratotropis*, which has characteristic yellow flowers. Therefore, this accession is not a member of *Vigna radiata* var. *radiata* or mungbean which is included in subgenus *Ceratotropis*.

[8]Poehlman, J.M. 1991. The Mungbean. Oxford and IBH Pub. C. Pvt. Ltd.

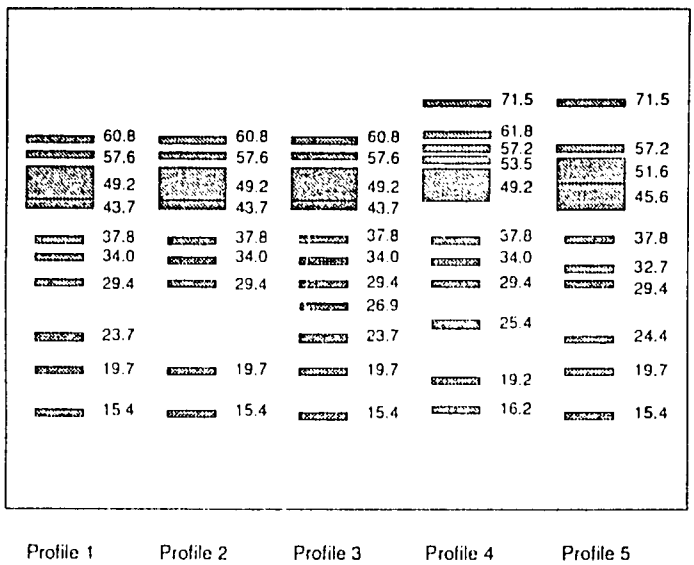

Fig. 1. Band composition of the five profiles exhibited by mungbean populations originating from the Philippines (Profile 4 is for *V. glabrescens* and Profile 5 is for *Vigna* sp.)

Table 12. Jaccard similarity coefficients of the protein profiles

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5
Profile 1	1.00				
Profile 2	0.90	1.00			
Profile 3	0.91	0.82	1.00		
Profile 4	0.24	0.29	0.22	1.00	
Profile 5	0.25	0.27	0.24	0.25	1.00

The subsequent analysis, therefore, considered only the 271 accessions that exhibited profiles 1, 2, or 3, which from hereon will be referred to collectively as 'mungbean profiles.' The band composition and relative frequency of these mungbean profiles and the different bands are shown in Table 13. An analysis of variance showed that the differences in Rf values between different bands in the same gel were highly significant compared to the error variance between identical bands in separate gels. The mean square between gels, indicative of the error variance, was only 0.06% of the mean square between the Rf values. This means that the experimental procedure used in the study accurately resolved the different bands of the mungbean seed proteins according to their relative mobilities, and that experimental error had an insignificant effect on the resolution of the proteins into bands.

The bands exhibited by the predominant profile 1 were compared to previous studies on mungbean seed proteins that presented SDS-PAGE gel photographs. Jose (1992)[9] reported the genetic segregation of seed protein bands in a mungbean-blackgram cross. Reference to her data indicates that Bands 2 and 10 in this study may be under the control of codominant alleles, and Band 5, of dominant allele. Rao et al. (1992)[10] reported seed protein bands that are characteristic of mungbean among 10 *Vigna* species. These may be Bands 2, 3, 4, 5, 6, and 7. Thakare et al. (1988)[11] reported four bands that were characteristic to mungbean, which may be Bands 2, 3, 6, and 7. Bands 6 and 7 may correspond to the cleavage products of a large vicilin molecule as they reported. Lastly, Tomooka et al. (1992)[12] reported the polymorphic bands among different Asian populations of mungbean. Bands 5 and 6 may correspond to their albumin bands, while Bands 7, 9, and 10 may correspond to their globulin bands. This inference was supported when the bands were fractionated accordingly in the laboratory using their procedure. The Protein Type 1 of Tomooka et al. (1992) seems to correspond with Profile 1 in this study, much more so because they reported that Protein Type 1 was exhibited by 84% of the Philippine populations they studied. They reported that 15% of the Philippine populations exhibited Protein Type 3, in which A1 (37 kD) was substituted with A3 (34.4 kD); although in an earlier publication of the same study (Tomooka et al. 1991[13]) this was Protein Type 2, in which A1 was substituted with A4 (36.3 kD). The present study was unable to distinguish these protein types from Protein Type 1, probably due to a lower resolution of the minigel apparatus or the concentration of the resolving gel. This inference is plausible because 36.3 kD was very close to 37 kD and the two bands may have appeared identical in the minigels used for this study. Tomooka et al. (1992) further reported a Protein Type 7 which was rare in the Philippines and which seems to correspond to Profile 2 in this study. They reported no protein type which corresponds to Profile 3, even among the other Asian populations.

Genetic diversity in seed proteins

The relative frequencies of the SDS-PAGE bands indicate a monomorphic composition for the Philippine population of mungbean (table 13). All the values are monomorphic with respect to even a 0.99/0.01 polymorphism criterion. Thus, there is no genetic diversity of seed proteins in the Philippine mungbean population.

An examination of the classification of the accessions used in the study showed that 30% were breeder lines and 54% were accessions donated from other collections (table 14). All the breeder lines exhibited Profile 1 except for DES M-2 which exhibited Profile 2. The pedigree of these lines were ultimately traceable to a few ancestral varieties; because the nationwide selection program

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[9] Jose, D.S.R. 1992. Variation and inheritance of seed proteins in mungbean *Vigna radiata* (L.) Wilczek (NCM 53) x blackgram *Vigna mungo* (L.) Hepper (ACC 25). B.S. Biology Thesis. UPLB, Philippines.

[10] Rao, R., del Vaglio, M., Paino d'Urzo, M., and Monti, L. 1992. Identification of *Vigna* spp. through specific seed storage polypeptides. Euphytica 62: 39-43.

[11] Thakare, R.G., Gadgil, J.D., and Mitra, R. 1988. Origin and evolution of seed protein genes in *Vigna mungo* and *V. radiata*. *In* Mungbean: Proc. 2nd Intl. Symposium. Bangkok, Thailand. p. 47.

[12] Tomooka, N., Lairungreang, C., Nakeeraks, P., Egawa, Y., and Thawarasook, C. 1992. Center of genetic diversity and dissemination pathways in mungbean deduced from seed protein electrophoresis. Theor. Appli. Genet. 83: 289-293.

[13] Tomooka, N., Lairungreang, C., Nakeeraks, P., Egawa, Y., and Thavarasook, C. 1991. Center of genetic diversity and dissemination pathways in mungbean deduced from seed protein electrophoresis. *In* Mungbean and the Genetic Resources: the Subgenus *Ceratotropis*. TARC, Japan and Chainat Field Crops Research Center. Thailand. pp. 59-66.

conducted by the Bureau of Plant Industry (BPI) came up with only a few parent varieties (Catipon et al. 1988[14]). Furthermore, CES 14 and MG 50-10A, which were ancestors of most of the breeder lines (table 11), both exhibited Profile 1. Hence, it can be hypothesized that the lack of genetic diversity in seed proteins among the breeder lines was due to the lack of genetic diversity in seed proteins among its ancestors. The selection program conducted by BPI seems unfortunate in retrospect, because the local varieties not used in the breeding program were apparently not systematically conserved as a collection. These local varieties may have exhibited genetic diversity — in seed proteins and in other characters — which are lost today.

Table 13. Relative frequency of electrophoretic bands among the mungbean accessions

Band no.[a]	M.W. (kD)[b]	Profile 1	Profile 2	Profile 3	Frequency[c]
1	60.8	1	1	1	1.00
2	57.6	1	1	1	1.00
3	49.4	1	1	1	1.00
4	43.7	1	1	1	1.00
5	37.8	1	1	1	1.00
6	34.0	1	1	1	1.00
7	29.4	1	1	1	1.00
8	26.9	0	0	1	0.01
9	23.7	1	0	1	0.99
10	19.7	1	1	1	1.00
11	15.4	1	1	1	1.00
Frequency of protein profile:		0.98	0.01	0.01	

[a]Arbitrarily assigned band identification number.
[b]Approximate molecular weight in kilodaltons.
[c]Relative frequency over 271 mungbean accessions.

Table 14. Classification of the Philippine mungbean collection

Classification	Name of accession	Source	Number	Percentage
Unclassified	'21-'	Unknown	4	2
	'STB'	Unknown	4	2
	Unnamed	Unknown	35	13
		Subtotal	43	17
Breeder lines	'CES' and 'Pag-asa'	IPB, UPLB	38	14
	'DES' and 'EG'	BPI	23	8
	Other BPI lines	BPI	12	4
	'PAEC' and 'PARC'	PAEC, Quezon City	10	4
		Subtotal	83	30
Donated collections	'48-'	RPIP collection	45	17
	'OSU'	OSU collection	4	2
	'Phil. Coll.'	SEARCA collection	47	17
'PHLV'	Unknown		49	18
		Subtotal	145	54
		Total	271	100

[14]Catipon, E.M., Legaspi, B.M., and Jarilla, F.A. Development of mungbean varieties from AVRDC lines for the Philippines. *In* Mungbean: Proc. 2nd Intl. Symp. Bangkok, Thailand. p. 88.

It is interesting to note that BPI Mg4 and BPI Mg5 had PHLV 18 as a parent. PHLV 18 exhibited Profile 2, but the effect of this on BPI Mg4 and BPI Mg5 is unfortunately unknown because these two varieties were absent in the GRSU collection. Another interesting fact was that the PAEC lines all exhibited Profile 1. This may mean that either their mutant ancestor also exhibited Profile 1 because the seed protein genes were not mutant, or that the PAEC lines did not inherit a mutant profile. It is unfortunate that the mutant ancestor was absent from the GRSU collection and its native yellow mungbean progenitor was unidentifiable.

The other fraction of the collection consisted of accessions donated from other collections. Since no varietal names were given for these accessions, it may be assumed that they were obtained from field collections and not from breeding institutions. Of course, some of these accessions may be breeder lines, which were either undocumented in the transfer, or unidentified in the field collections. However, given the emphasis of most collectors on local varieties to avert genetic erosion, it is plausible to assume that most of these accessions were local varieties or landraces. For this group of accessions, Profile 1 again predominated, excepting 48-071-00963 which had Profile 2; and PHLV 18 and PHLV 170 which had Profile 3. Thus, it appears that even the local varieties exhibited low genetic diversity in seed proteins.

The low diversity in seed proteins of the mungbean populations in the Philippines may be explained by the origin of the earliest mungbean populations in the Philippines. Mungbean was domesticated in India and then disseminated to the other parts of Asia. The mungbean populations that first reached the Philippines were hypothesized to be of simple genetic composition (Tomooka et al. 1992; Dela Viña and Tomooka 1993[15]). This means that a few populations with low genetic diversity ultimately gave rise to the different accessions in this study. The historical duration of its cultivation in the islands has also been relatively short — compared to India, the center of genetic diversity — as evidenced by the observation of San Miguel (1916)[16] that its intensive culture was limited to Pangasinan even in 1916. However, genetic diversity in morphological types and isozymes had evolved from the simple progenitor population during this short period of history. Why no parallel genetic diversity of seed proteins had evolved may be explained by the nature of genetic variation in seed proteins.

Nevo and Payne (1987)[17] presented another hypothesis to explain the origin of seed protein variation: through natural selection the geographical distribution patterns of seed protein types were correlated with ecological factors and must have been due in part to natural selection. However, cultivated mungbean populations in the Philippines have been grown under a relatively more favorable and uniform environment — the farm — and consequently were not subjected to selection for different adaptive variants of seed proteins. Hence, lack of selection pressure for variant protein forms maintained the homogeneity of the populations with respect to seed proteins.

Application of seed protein SDS-PAGE to genebank management

SDS-PAGE of seed proteins is useful in rapid identification of different species in a germplasm collection. The rapidity of SDS-PAGE analysis was evident in this study, considering that 274 accessions were analyzed in duplicate runs for only about 25 working days. SDS-PAGE was able to identify V 1160 and Red Mungbean as non-*V. radiata* species, as confirmed by literature

[15] Dela Viña, A.C. and Tomooka, N. 1993. Isozyme variation and geographic distribution of mungbean, *Vigna radiata* (L.) Wilczek. Phil J Crop Sci 18 (Sup 1):3.

[16] San Miguel, L.A. 1916. Tests and selections of mungo beans. Phil Agric and Forester 5: 164-179.

[17] Nevo, E. and Payne, P.I. 1987. Wheat storage proteins: diversity of HMW glutenin subunits in wild emmer from Israel. 1. Geographical patterns and ecological predictability. Theor Appl Genet 74: 827-836.

and observation of morphological characteristics. Thus, SDS-PAGE analysis was demonstrably useful in screening for accessions that have been mistakenly assigned to the *V. radiata* collection. Since only a few seeds are needed the procedure can be used to quickly confirm species identity of incoming seeds.

SDS-PAGE profiles also provide useful characters which can be used in conjunction with morphological characterization in establishing a core collection. To demonstrate this point, the rare protein profiles exhibited by the mungbean accessions were compared to the results of the cluster analysis based on morphological characteristics (Cababasay 1991).

(1) Accession V 1390, which exhibited Profile 2, was placed in Cluster 123 along with 35 other accessions which exhibited Profile 1. All the accessions in Cluster 123 are morphologically similar, but the different seed profile exhibited by V 1390 means that it can be assigned to a separate cluster. The seed protein profile may thus be used as another character in cluster analyses.

(2) Accession V 2303A, which exhibited profile 2, was placed in Cluster 44 alone, while V 2303B, which exhibited Profile 1, was placed in Cluster 126. It may be recalled here that V 2303A and V 2303B were varieties of accession V 2303. This means that the original accession V2303 was mixed and contained two populations with distinct morphology and seed protein characteristics.

(3) Accession V 3168, which exhibited Profile 2, was placed in Cluster 132 along with five other accessions which all exhibited Profile 1. Based on seed protein profile, it can be separated from the five accessions and assigned to a separate cluster.

(4) Accession 1397, which exhibited Profile 3, was placed in Cluster 16 along with V1066, which exhibited Profile 1. This means that Cluster 16 must be divided into two clusters. It may be recalled that Tomooka et al. (1992) and other researchers were not able to detect Profile 3 in their studies. This may mean that Profile 3 is unique to the Philippines, and that it may be a mutant of V 1066-type mungbean.

(5) Accession 1404, which exhibited Profile 3, was subdivided into V 1404A and V 1404B and placed in separate clusters. V 1404A was assigned to Cluster 49 with seven Profile 1 accessions. It may now be assigned to its own cluster based on seed protein profile. V 1404B, on the other hand, was assigned to Cluster 130 by itself. This means that it was morphologically different from V 1404A and all other accessions. Unfortunately, 1404A and 1404B were not analyzed separately in this study, and so it is not known whether or not they both exhibit Profile 3.

Conclusions and Recommendations

SDS-PAGE using minigels proved to be a rapid and effective method of analyzing seed protein in mungbean. It was demonstrated that it can confirm species identity of accessions. It, therefore, can be used to quickly verify species identity of new introductions even before they are multiplied. It can also be used to detect mixtures and variants in an accession.

The Philippine mungbean accessions at GRSU predominantly exhibited one seed protein SDS-PAGE profile. Profile 1 was exhibited by 98% of the accessions, while Profiles 2 and 3 were exhibited by 1% each of the accessions.

The polypeptide bands of Profiles 1,2, and 3 all exhibited 1.00 relative frequency, except for two bands which exhibit 0.99 and 0.01, respectively. All bands are, thus, monomorphic based on a 0.99/0.01 polymorphism criterion.

Based on the predominance of one SDS-PAGE profile and the monomorphic distribution of bands, the Philippine mungbean collection at GRSU does not exhibit appreciable genetic diversity with respect to seed proteins.

The seed protein SDS-PAGE profiles are, however, still useful as an additional trait to be considered in nominating accessions to a core collection. Accessions that exhibited the rare profiles could be separated from the other accessions with which it had been grouped based on morphology, and assigned to new clusters. The SDS-PAGE profile can thus be used as an adjunct to morphological characteristics in cluster analyses of the collection.

It is recommended that the study be extended to other populations in the mungbean collection and that the collection be further studied with respect to other characters; such as resistance to pests, diseases, and environmental stress.

Diversity in Seed Proteins in the White-flowered *Capsicum*

Summary

Two hundred one accessions belonging to five species of *Capsicum* were analyzed for their seed protein banding patterns using SDS-PAGE. Partial results indicated the possibility of identifying both *C. annuum* which lacks Band 1 and *C. chacoense* which exhibits band pattern 2. The likelihood of occurrence of *C. baccatum* when both Bands 1 and 2 are present is suggested by high frequency of occurrence of both bands. The highest intraspecific similarity was observed to be in *C. annuum*. This resulted from less variation in its banding pattern. The highest interspecific similarity was between *C. annuum* and *C. chinense*, followed by *C. annuum* and *C. frutescens*. The three species are the closely related domesticated forms of *Capsicum*.

Introduction

Seed proteins have been used as genetic markers for surveying the genetic variation in a crop and knowing its probable site of domestication, for cultivar and hybrid identification in grass, cotton, and pepper, and to characterize durum wheat, rye, and triticale, maize, mungbean, and barley (Gepts 1989[18], Rao et al. 1992, and He et al. 1993[19]). In the study of genetic diversity, seed proteins may give better results compared to enzymes as they undergo a slower process of evolution due to their 'nonessential' nature.

This study utilized the white-flowered species of chili peppers. The seed protein profiles of each were analyzed using SDS-PAGE. The data that were gathered from different populations represent gene homologies and thus were used in interpreting species relationships and also in determining the pattern of genetic diversity among the species. This study was conducted from March to April 1993.

The general objective of the study was to determine the genetic diversity among populations of *C. annuum*, *C. baccatum* (with *C. baccatum* var. *baccatum* and *C. baccatum* var. *pendulum*), *C. chinense*, *C. chacoense*, and *C. frutescens*. The specific objectives were (1) to compare the seed protein band patterns of five species of *Capsicum*, (2) to compute for the percentage similarities within and between populations of the five species, and (3) to determine the geographic distibution of the band patterns.

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[18]Gepts, P. 1989. Genetic diversity of seed storage proteins in plants. *In* Brown, A.H.D. , Clegg, M. T., Kahler, A.L., and Weir, B.S. (eds.) Plant Population, Genetics, Breeding, and Genetic Resources. Sinauer Ass. Inc. pp. 64-82.

[19]He, K., Yoshida, K.H., Soutome, K., Kajiwara, K., Komatsu, S., and Hirano, H. 1993. Relations between seed storage proteins and malting quality in two rowed barley (*Hordeum vulgare* L.). Jap. J. Breed. 43: 81-90.

Materials and Methods

Eighty seeds of 201 accessions of *C. annuum*, *C. baccatum*, *C. chacoense*, and *C. frutescens* were used in this study. For each accession, 250 mg of seeds were immersed in liquid nitrogen ground and seed proteins extracted. The protein stain solution used was 0.125% Coomassie Brilliant Blue R-250. Destaining was done with 50% methanol and 10% acetic acid.

The number of protein bands resolved per accession were counted and drawn. Band numbers were assigned beginning from the slow migrating down to the fast migrating bands. Banding patterns were identified and the total number of accessions that exhibited a particular band pattern was tabulated. The similarity index (S values) among the different accessions within and between species were computed using the formula of Sokal and Sneath (1973)[20].

The similarity indices among the band patterns observed and among the accessions of the different species were plotted in a matrix.

Geographic distribution of band patterns and specific bands was tabulated and analyzed.

Results and Discussion

Band pattern distribution

Seven types of banding patterns were recognized (fig. 2). The frequency distribution for banding pattern is shown in table 15. Pattern 4 was the most common in the whole population followed by Pattern 7. Patterns 2 and 3 may be considered rare band patterns. These two appeared to be species-specific. They were found only in *C. chacoense* and *C. baccatum*, respectively. Only Pattern 4 was common to all species. Pattern 1 was not found in *C. annuum* and *C. frutescens*; Pattern 5 in *C. chacoense* and *C. chinense*; Pattern 6 in *C. chinense*; and Pattern 7 in *C. chacoense*. Pattern 1 was most common in *C. baccatum*, Pattern 4 in *C. annuum* and *C. chacoense*, and Pattern 7 in *C. frutescens*. Patterns 4 and 7 occur in equal frequency in *C. chinense*.

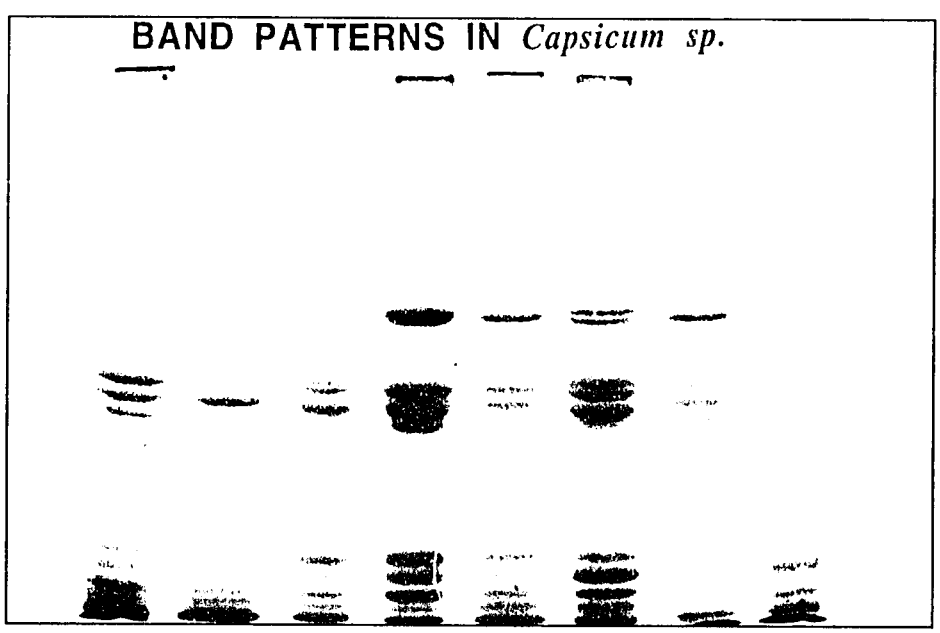

Fig. 2. SDS-PAGE seed storage protein band patterns observed among five *Capsicum* species

[20]Sokal, R. and Sneath, P. 1973. Principle of Numberical Taxonomy. W.H. Freeman Co.

Table 15. Distribution of protein band patterns observed in different species of *Capsicum*

Species	Band patterns 1	2	3	4	5	6	7	No. of acc. observed
C. annuum	- (52.9)[a]	- (2.3)	- (1.1)	46 (43.7)	2	1	38	87
C. baccatum	28 (68.3)	-	1 (2.4)	1 (2.4)	1 (19.5)	8 (4.9)	2	41
C. chacoense	1 (16.7)	1 (16.7)	-	3 (50.0)	-	1 (16.7)	-	6
C. chinense	1 (4.3)	-	-	11 (47.8)	-	-	11 (47.8)	23
C. frutescens	-	-	-	10 (37.0)	2 (7.4)	1 (3.7)	14 (51.8)	27
Uncertain	-	1 (5.9)	-	4 (23.5)	3 (17.6)	4 (23.5)	5 (29.4)	17
Total (%)[b]	30 (14.9)	2 (1.0)	1 (0.5)	75 (37.3)	8 (4.0)	15 (7.5)	70 (34.8)	201

[a]Percentage of the species population exhibiting the band pattern.
[b]Percentage of the total population studied exhibiting the band pattern.

Specific band distribution

The percentage of the population of each species showing a particular band is shown in table 16. The bands that were always present in all the species were Bands 2, 4, 5, 8, 9, 10, 11, and 12. Variation was observed only for bands 1, 3, 6, and 7.

Table 16. Band position distribution in five *Capsicum* species

Band no.	*C. annuum*	*C. baccatum*	*C. chacoense*	*C. chinense*	*C. frutescens*
1	1 (1)	37 (90)	2 (33)	1 (4)	1 (4)
2	87 (100)[a]	41 (100)	6 (100)	23 (100)	27 (100)
3	39 (45)	11 (27)	2 (33)	11 (48)	15 (56)
4	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
5	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
6	87 (100)	40 (98)	5 (83)	23 (100)	27 (100)
7	2 (2)	1 (2)	-	-	2 (7)
8	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
9	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
10	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
11	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)
12	87 (100)	41 (100)	6 (100)	23 (100)	27 (100)

[a]Number of accessions with the particular band. Values in parentheses are percentages of the population for each species studied.

Only one in 87 accessions of *C. annuum* exhibited Band 1. Thus, it can be forwarded that in a collection of *C. annuum*, screening for the absence of Band 1 can be done to check the identity of the accessions. Similarly, *C. chacoense* and *C. chinense* lacked Band 7, thus, the possibility of identifying an accession as belonging to either of these two. However, one cannot say to which of the two species an accession lacking Band 7 belongs to since the two are similar for presence of all other bands. *C. baccatum* was observed to exhibit Band 1 at a very high frequency (90.2%). Thus, the probability that an accession that exhibits Band 1 is *C. baccatum* is high.

Similarity index

Index of similarity for the seven band patterns ranged from 66.7 to 100 (table 17). The noticeably high values for the similarity index resulted because of variation present only for a few bands. A similarity index of 66.7 means that the accessions compared differed only in four bands.

Table 17. Range and average of similarity index values observed in five species of *Capsicum*

Species	*C. annuum*	*C. chinense*	*C. frutescens*	*C. chacoense*	*C. baccatum*
C. annuum	75.0-100 (95.3)	83.3-100 (95.2)	75.0-100 (94.6)	75.0-100 (91.6)	66.7-100 (88.0)[a]
C. chinense		83.3-100 (94.9)	83.3-100 (94.6)	75.0-100 (91.6)	75.0-100 (88.3)
C. frutescens			75.0-100 (93.9)	75.0-100 (90.4)	66.7-100 (87.4)
C. chacoense				75.0-100 (88.3)	75.0-100 (88.2)
C. baccatum					66.7-100 (94.0)

[a]Mean similarity between all the accessions in the species combination.

Intraspecific comparisons. Accessions within *C. annuum* and *C. chinense* gave the highest average similarity index value of 95. The second highest value observed was in *C. frutescens* and *C. baccatum*. However, the range was wider in *C. baccatum*. This indicates that variation in *C. baccatum* was greater than in *C. frutescens*. *C. chacoense* showed the lowest average similarity index. In terms of degree in intraspecific variation, the species may be ranked as follows: *C. annuum* = *C. chinense* > *C. frutescens* > *C. baccatum* > *C. chacoense*. However, due to the much smaller number of accessions observed in *C. chacoense*, any conclusion regarding this species should be taken with reservation.

Gepts (1989) suggested the loss of genetic diversity upon domestication of a crop species. From the five species of *Capsicum* studied, those with high average similarity index are considered domesticated and widely cultivated, e.g., *C. annuum*, *C. chinense*, and *C. frutescens* (Pickersgill 1991[21]). *C. chacoense* is a wild species, and its lower average similarity index means that it exhibited more variable seed protein patterns. This suggests that diversity in the polypeptides of seed proteins was greater in *C. chacoense*. *C. baccatum* includes both the cultivated form var. *pendulum* and the wild form var. *baccatum* which probably explains why the range observed was very wide. True enough, when the accessions known to belong to the cultivated form were analyzed separately from those known to belong to the wild form, the range and average for var. *pendulum* was 83.3-100 and 91.7, respectively and for var. *baccatum* was 83.3-100 and 86.1.

[21]Pickersgill, B. 1991. Cytogenetics and Evolution of *Capsicum* L. *In* Tsuchiya, T. and Gupta, D. K. (eds.). Chromosome Engineering in Plants: Genetics, Breeding, Evolution. Elsevier. pp. 139-160.

Interspecific comparisons. When interspecific comparison was done, *C. annuum* vs. *C. chinense* showed values similar to those obtained in intraspecific comparison. This suggests that interspecific variation for seed proteins was no greater than intraspecific variation for these two species. The same thing may be said of *C. chinense* and *C. frutescens*. *C. chacoense* was less similar to the three previously mentioned species than the three were to each other.

The lowest index of similarity was observed between a cultivated and wild form of *C. baccatum*, accessions C04229 and C00739, respectively.

Since SDS separates the protein into their polypeptide subunits, it may be assumed that when two accessions exhibit the same band, they have the same form of the gene coding for the polypeptide. Therefore, accessions with similar banding pattern are genotypically similar. It also follows that since similarity indices for the different species was high the species of *Capsicum* studied do not vary much genotypically based on their seed proteins.

All of the species used in this study belong to the white-flowered group. Pickersgill (1991) and IBPGR (1983)[22] gave a crossability polygon for the white- and purple-flowered species. *C. annuum, C. baccatum, C. chinense, C. chacoense, and C. frutescens* produced F_1 hybrids. All crosses produced normal and viable hybrids except when *C. chacoense* was crossed to *C. frutescens* with the latter used as the male parent and when *C. chacoense* was crossed with *C. baccatum* with the latter used as the female parent. This cross compatibility may be supported by the observations of this study. The species compared did not vary very much genotypically.

Geographic distribution and dissemination pathways

The geographic distribution of each band is shown in table 18. The 48 countries of origin of the 210 accessions were grouped into 10 regions: North America, Mexico, Central America and the West Indies, South America, East Asia, Southeast Asia, South and Southwest Asia, Russia and the Balkan States, Western and Central Europe, and Africa.

The number of representative accessions from each region was not constant, thus the frequencies of the band patterns were computed by dividing the number of accessions exhibiting the particular band pattern by the total number of accessions that were observed in the particular region. Patterns 4 and 7, the two most frequent band patterns were present in all regions varying in frequency from region to region but showing no obvious clinal pattern (fig. 3). Pattern 1 which was associated with *C. baccatum* was found mostly in the New World with only three accessions in the Old World exhibiting it. On the other hand, Patterns 2 and 3 were found only in Europe and Southeast Asia. Patterns 5 and 6 were found in Central America and the West Indies, South America, Europe, Southeast Asia, and Africa.

The frequency distribution for specific bands is shown in table 19. Bands 2, 4, 5, and 8-12 were not included in the table since they were present in all accessions and may be considered monomorphic. Only the polymorphic Bands 1, 3, 6, and 7 were considered in the analysis of geographic distribution. Band 1 is distributed in decreasing order of frequency in South America > Europe > North America > Mexico > Central America and the West Indies > Russia and the Balkan States > Southeast Asia > South and Southwest Asia > Africa and absent in East Asia. For Band 3, Mexico = Russia and the Balkan States > Africa > Central America and the West Indies > East Asia = Southeast Asia > South and Southwest Asia > South America > North America. Band 6 exhibited variation only in Southeast Asia and Europe and Band 7 only in Southeast Asia, Central America and the West Indies, South America, and Africa. The absence of Band 7 in all the other regions may be due to the loss of the gene for the said band or the fixation of the gene that fails to produce the corresponding polypeptide.

[22]IBPGR. 1983. Genetic Resources of *Capsicum*. International Board for Plant Genetic Resources. Rome, Italy. 49 pp.

Table 18. Geographic distribution of SDS-PAGE band patterns in *Capsicum*

Region	No. of acc.	Band pattern 1	2	3	4	5	6	7
North America	17	5 (0.3)[a]	-	-	10 (0.6)	-	-	2 (0.1)
Mexico	12	3 (0.2)	-	-	1 (0.1)	-	-	8 (0.7)
Central America and West Indies	18	3 (0.2)	-	-	5 (0.3)	1 (0.1)	1 (0.1)	8 (0.4)
South America	43	16 (0.4)	-	-	12 (0.3)	2 (0.05)	8 (0.2)	5 (0.1)
East Asia	11	-	-	-	6 (0.5)	-	-	5 (0.5)
Southeast Asia	20	-	1 (0.05)	-	7 (0.4)	4 (0.2)	2 (0.1)	6 (0.3)
South Asia and Southwest Asia	13	1 (0.1)	-	-	8 (0.6)	-	-	4 (0.2)
USSR and the Balkans	9	1 (0.1)	-	-	2 (0.2)	-	-	6 (0.7)
					1			
West and Central Europe	31	1 (0.03)	1 (0.03)	1 (0.03)	3 (0.4)	-	3 (0.1)	12 (0.4)
Africa	27	-	-	-	11 (0.4)	1 (0.04)	1 (0.04)	14 (0.5)
Total	201	30	2	1	75	8	15	70
Percent		14.9	1.0	0.5	37.3	4.0	7.5	34.8

[a]Values in parentheses are frequencies.

The dissemination pathways of the banding patterns for the white-flowered group of *Capsicum*, represented by the accessions examined, can hypothetically be reconstructed. History of the spread of the genus has been reviewed by Somos (1984)[23]. Peppers were introduced by early European voyagers who carried the plant from South America to Europe via Spain sometime in 1493. The plant was then introduced to Central Europe in 1585 and taken to India and Southeastern Asia in the 17th century by the Portuguese. The distribution of SDS-PAGE band patterns and specific bands partly support these hypotheses. The greatest variation was found in South and Central America. Variation was gradually lost as the species moved up north. The original variation was represented in Europe but gradually decreased as the species moved eastward. The high degree of variation in Southeast Asia may mean a direct route from Central America. The African population may have come from both Central and South America as well as Southeast Asia.

More gene combinations are found in Europe compared to South and Central America or Southeast Asia. However, considering the frequencies of specific bands, South and Central America contain a greater amount of diversity. Based on the degree of polymorphism in these regions, most of the genes are far from either fixation or extinction.

Thus, considering total seed proteins in the white-flowered group of *Capsicum*, it appears that the South American region is where the greatest amount of genetic diversity can be found. There are two other secondary centers of diversity: Europe and Southeast Asia.

[23]Somos, A. 1984. The Paprika. Academiae Kindo.

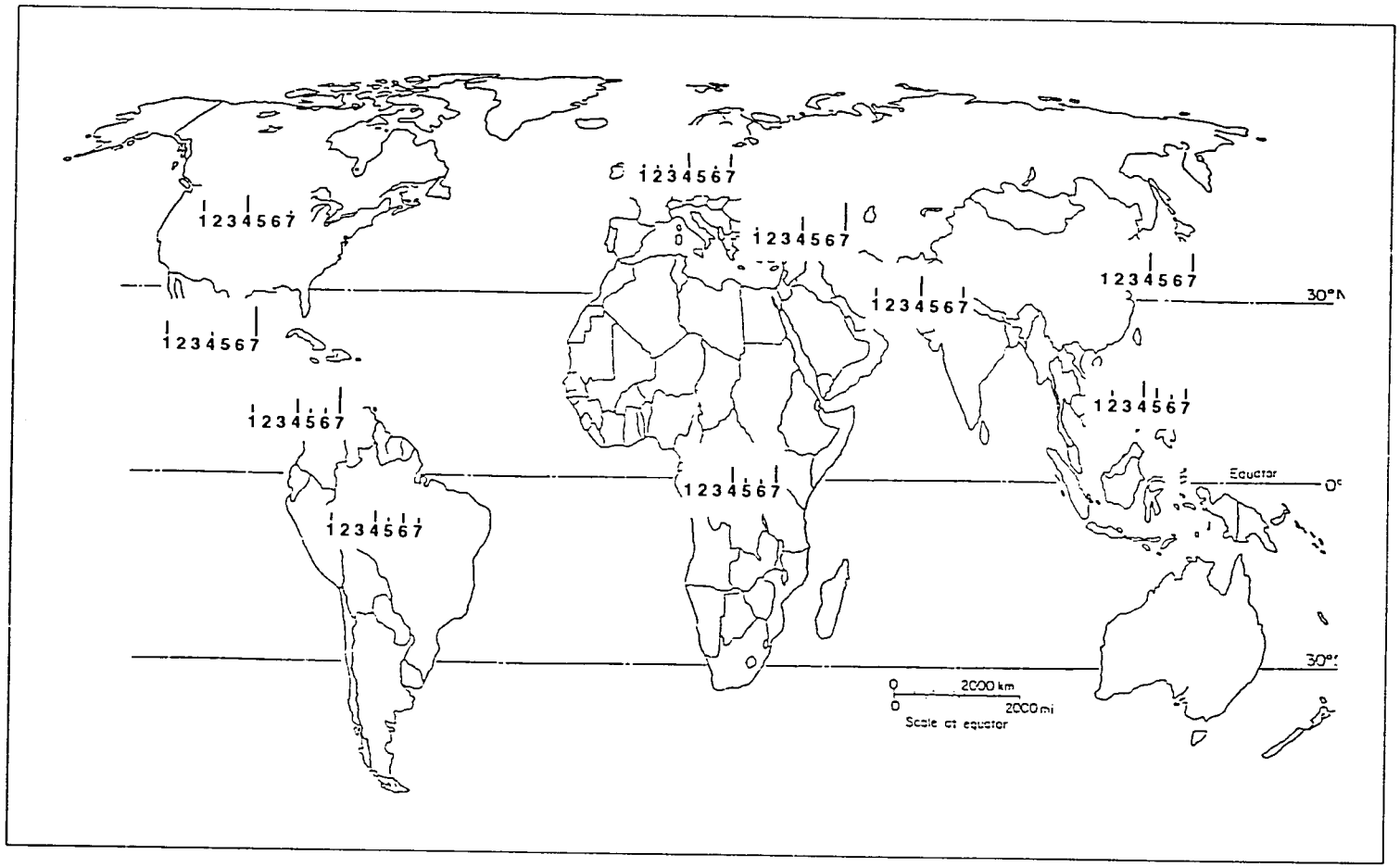

Fig. 3. Clinal distribution of SDS-protein bands in *Capsicum*

Table 19. Geographic distribution of specific SDS-PAGE bands in *Capsicum*

Region	No. of acc.	Band number			
		1	3	6	7
North America	17	5 (0.3)	2 (0.1)	17 (1.0)	-
Mexico	12	3 (0.2)	8 (0.7)	12 (1.0)	-
Central America and West Indies	18	4 (0.2)	7 (0.5)	15 (1.0)	-
South America	43	24 (0.6)	13 (0.3)	43 (1.0)	2 (0.05)
East Asia	11	-	5	11	-
Southeast Asia	20	2 (0.1)	9 (0.4)	19 (1.0)	4 (0.2)
South and Southwest Asia	13	1 (0.1)	2 (0.7)	8 (1.0)	
West and Central Europe	31	5 (0.3)	17 (0.6)	29 (0.9)	-
Africa	27	1 (0.04)	15 (0.6)	27 (1.0)	1 (0.04)
Total	201	46	88	195	8
Percent		22.9	43.8	97.0	4.0

Values in parentheses are frequencies.

Conclusions and Recommendations

Partial results indicated the possibility of identifying both *C. annuum* which lacks Band 1 and *C. chacoense* which exhibits band Pattern 2. The likelihood of occurrence of *C. baccatum* when both Bands 1 and 2 are present is suggested by high frequency of occurrence of both bands. SDS-PAGE on minigels can thus be used as a rapid means to confirm species identity of accessions.

The procedure can also be used to characterize the degree of genetic diversity in a population and thus aid in the formation of homogeneous clusters from which nominations to a core collection can be based.

The highest intraspecific similarity was observed to be in *C. annuum*. This resulted from less variation in its banding pattern. The highest interspecific similarity was between *C. annuum* and *C. chinense*, followed by *C. annuum* and *C. frutescens*. The three species are the closely related domesticated forms of *Capsicum*.

Conservation, Evaluation, and Utilization of Vegetable Genetic Resources: A Collaborative Network Project for Southeast Asia

Summary

The focus for the year was seed increase and characterization of the collected germplasm. Diversity in the material posed a problem. To meet the required amount of seeds a second planting was sometimes necessary. In the Philippines, 257 accessions of eight species were planted for a second time. In Thailand, the whole collection of yard-long bean was multiplied and characterized. Meanwhile, collecting is ongoing in Indonesia and plans are being finalized for Vietnam. A special collecting expedition for garlic yielded 41 samples from the Philippines.

One national program staff member from Thailand finished her 6 months' internship at GRSU. Three came from the Philippines with partial support from the project to do specific research work, and one from Indonesia came for a 3-month internship. Another from Vietnam started a 6-month internship in genetic resources management.

Introduction

In 1989, GRSU, in collaboration with the Japan International Cooperation Agency (JICA), started implementing a project to extensively collect vegetable germplasm from the Southeast Asian countries of Malaysia, Philippines, Thailand, and Indonesia. The materials collected are to be multiplied to get enough seeds for long-term storage, distribution, characterization, evaluation, and documentation. The project also aims to provide for training in genetic resources of national program personnel from the countries involved.

The diversity in the materials collected will provide a broader genetic base for vegetable breeding programs and safety back-ups to the dangers of a limited and highly uniform gene pool.

The nationals trained through the project will 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.

Activities in the Philippines were coordinated by the National Plant Genetic Resources Laboratory (NPGRL), in Thailand by AVRDC-ARC and Kasetsart University, in Indonesia by the Lembang Horticultural Research Institute (LEHRI), and in Vietnam by the Vietnam Agricultural Science Institute (INSA).

Materials and Methods

Collecting

Based on a previously mapped collecting route, an expedition was launched by collaborating staff from LEHRI and GRSU on the island of Java. A special collecting expedition for garlic was done in the Philippines.

Seed increase and characterization

Of the 1071 accessions collected from the Philippines and multiplied last year, 257 were replanted to produce enough seeds for preservation and distribution. In Thailand, 154 accessions of yard-long bean were multiplied and characterized. Seed increase and characterization were done in the country of origin by national program staff who received training at GRSU.

Characterization data are being compiled for transfer to a central database.

Training

Special-purpose trainees and research interns were accepted. Based on the needs of the national programs, the priorities of GRSU, and the interest of the trainee, a training program for each was developed.

Results and Discussion

Collecting

Collection is still in progress in Indonesia. The special collecting expedition for garlic in the Philippines yielded 41 samples.

Seed increase and characterization

Of the 1071 accessions collected from the Philippines and multiplied last year, 257 were replanted to produce enough seeds for preservation and distribution.

Characterization data for the yard-long beans from Thailand showed variation in almost all the traits considered (table 20). The biggest variation was in the number of pods/plant and seed yield. One accession did not flower, probably due to photoperiod sensitivity; while 36 failed to germinate. Table 21 shows correlation between some quantitative traits. Highly significant correlations were found between pod length and mean fresh pod weight; pod length and 100-seed weight; fresh pod weight and 100-seed weight; number of pods/plant and seed yield; days to flowering and days to first harvest. The following were negatively correlated: days to 50% flowering or days to first harvest and pod length, mean fresh pod weight, number of pods/plant, and seed yield.

Table 20. Variation in quantitative traits observed in yard-long bean from Thailand

Trait	Range	Mean	S.D.	c.v.
Days to 50% flowering	36 - 62	44	4.9	11.1
Days to 1st harvest	41 - 69	50	5.8	11.5
Pod length (cm)	12.4 - 61.8	36.6	9.4	25.6
Mean fresh pod weight (g)	3.3 - 24.2	12.6	3.9	30.1
No. of pod/plant	2 - 132	43	22.5	52.4
No. of seed/pod	4 - 18	12	3.1	25.3
100-seed weight (g)	10 - 24	17.3	2.6	15.1
Seed yield (kg/ha)	97.2 - 2,902.8	1,198.7	583.6	48.7

Table 21. Correlation coefficient between some quantitative traits in yard-long bean

	Days to harvest	Pod length	Pod weight	No. of pods/ plant	No. of seeds/ pod	100-seed weight	Seed yield
Days to flowering	0.92[b]	-0.36[b]	-0.31[b]	-0.33[b]	0.12	-0.002	-0.35[b]
Days to harvest	1.00	-0.36[b]	-0.30[b]	-0.35[b]	0.14	-0.002	-0.40[b]
Pod length	1.00	0.77[b]	-0.10	-0.15	0.41[b]	0.01	
Pod weight			1.00	-0.04	-0.01	0.36[b]	0.03
No. of pods/plant				1.00	0.01	0.07	0.83[b]
No. of seeds/pod					1.00	-0.13	-0.01
100-seed weight						1.00	0.23[a]

[a]Significant at 1% level.
[b]Significant at 5% level.

Training

One trainee from Thailand finished a 6-month internship. She participated in routine genebank operations and trained in some research methodologies (e.g., cytology of pepper, germination behavior in pepper, and computer use). The three students from the Philippines received training in diversity analysis in pepper and mungbean using electrophoretic procedures. One staff of LEHRI, Indonesia, stayed for 3 months to observe genebank operations at GRSU.

Production Systems Program

Agricultural Economics

Economic Analysis of Mungbean Cultivation in Java, Indonesia

Summary

A farm-level survey was carried out in February/March 1993 involving 179 farm households located in seven districts in Java, Indonesia. The study represents a collaborative effort between AVRDC, the Central Research Institute for Food Crops (CRIFC) in Bogor, the Sukamandi Research Institute for Food Crops (SURIF), and the Malang Research Institute for Food Crops (MARIF). The main aims of the survey are to provide a detailed input-output characterization of mungbean cultivation in Java, analyze its profitability, assess the adoption of AVRDC-related mungbean technologies, and determine the major biotic and abiotic constraints in mungbean cultivation in Java. The survey data are being analyzed for the sample as a whole as well as for each of the different cropping systems in which mungbean is being grown. The results of the study are expected to provide useful indications for the direction of future mungbean research aimed at increasing the productivity and profitability of mungbean in Indonesia.

Introduction

Mungbean (*Vigna radiata*) constitutes an important source of protein in the cereal-based diet of large numbers of people in Indonesia. Its production has shown dramatic increases over the past 20 years, from just over 40,000 t in 1969 to nearly 270,000 t in 1989 (Jansen and Dumsday 1991[1]). Although area has increased about fourfold during the period (from some 80,000 ha in the late 1960s to over 340,000 ha in 1989), yield increases have also contributed significantly to production increases, particularly after 1983 with the release of several improved cultivars developed at AVRDC. Yields increased from less than 500 kg/ha in the 1960s to nearly 800 kg/ha by the end of the 1980s (Jansen 1992[2]).

Area expansion has been responsible for 70% of past production increases, with yield gains contributing 30%. Increasingly limited availability of land makes a continuation of past area increases highly unlikely. This implies that future production advances have to come from yield gains, emphasizing the need for a continuing supply of yield-increasing technologies which can be profitably adopted by farmers.

The standard local mungbean variety in Indonesia is called Bhakti. VC 1089A was the first AVRDC breeding line in Indonesia, released in 1983 under the name Manyar by SURIF. In the same year, a selection from another variety, V 2773, was released as URI. These were followed

[1]Jansen, H.G.P. and Dumsday, R.G. 1991. Preliminary impact assessment for AVRDC-improved mungbean varieties in five countries. AVRDC working paper no. 2. 15 p.

[2]Jansen, H.G.P. 1992. Supply and demand of AVRDC mandate crops in Asia: implications of past trends for future developments. AVRDC working paper no. 4. 84 p.

by VC 1160 and VC 1163A which were released in 1986 as Gelatik and Walet, and VC 2754A which was released in 1991 as Merpati.

The project's overall objectives are to characterize major mungbean-growing farming systems and assess their profitability; identify the major factors responsible for the considerable yield gap in mungbean and hindering further productivity growth; and suggest ways to increase farm-level yields.

Materials and Methods

A pro forma of a production survey questionnaire was developed jointly by CRIFC and AVRDC. Pilot testing of this survey questionnaire was done in January 1993 by AVRDC, CRIFC, SURIF, and MARIF. The main survey was carried out during February/March 1993 among a total of 179 farmers in seven districts in West, Central, and East Java (between 22 and 28 farmers in each district), making sure that the major mungbean cropping systems were adequately represented. Mungbean in Indonesia is grown under different systems during all three seasons, i.e., early dry season (March-June), late dry season (July-September), and the wet season (October-March). The main survey districts included Cirebon and Karawang in West Java where mungbean is grown in the early and late dry seasons on paddy land after rice; Grobogan in Central Java where mungbean is grown in the uplands during the wet season; Pati in Central Java with a mungbean-growing system similar to that in Cirebon; Demak in Central Java where mungbean is planted in the late dry season on rainfed paddy land; Mojokerto in East Java where mungbean is grown in lowlands; and Banyuwangi in East Java where mungbean is grown in uplands after maize.

The main survey was carried out under the general direction and supervision of CRIFC which was also directly responsible for data collection in Grobogan, Pati, and Demak districts, as well as for data entry. SURIF was responsible for the survey's implementation and data entry in Cirebon and Subang districts; whereas, Lamongan and Banyuwangi districts were the responsibility of MARIF.

Analysis of the survey data is done jointly at AVRDC in Taiwan, between an AVRDC economist and an economist from CRIFC.

Results and Discussion

Analysis of the survey data is under way and is being done for the sample as a whole as well as for the different cropping systems. A detailed quantitative and qualitative description of mungbean-growing practices on Java in terms of cultivation methods and input-output coefficients is being generated. Production costs and profitability of mungbean production are being analyzed for the various cropping systems. The survey data also contain information regarding production and sales of other crops and, together with secondary data on their cost structure, will allow some conclusions regarding the competitiveness of mungbean vis-a-vis other crops. The survey data will also allow an analysis of the adoption of AVRDC-related mungbean cultivars. In addition, major biotic and abiotic constraints were identified by the survey and will form the basis for recommendations for future directions of research aimed at improving mungbean production in Indonesia. The study's final results are also expected to result in improved knowledge among researchers and policymakers which can be used in the design of follow-up projects and/or government and extension policies.

Peri-urban Vegetable Production Around Ho Chi Minh City, Vietnam

Summary

AVRDC's production systems program pays increasing research emphasis on peri-urban vegetable production systems. In this context, a study was initiated on economic and agronomic aspects of peri-urban vegetable production near Ho Chi Minh City (HCMC) in Vietnam, in collaboration with the University of Agriculture and Forestry, Thu Duc, HCMC. The objectives of the study are to provide a detailed quantitative and qualitative description of vegetable-growing practices in the peri-urban vegetable growing belt around HCMC in terms of cultivation methods and input-output coefficients; to provide estimates of production costs and profitability of peri-urban vegetable production; to investigate growing constraints faced by peri-urban vegetable growers (including those of an agronomic and soil nature); and to suggest ways to alleviate growing and marketing constraints. A detailed farm-level survey among 98 peri-urban vegetable growers in four districts was carried out. The survey data which are currently being analyzed provided a wealth of information on cropping patterns, growing methods, input use, yields, and cultivation and marketing constraints. One researcher from Vietnam underwent training at AVRDC in data handling and analysis methods. In addition to the economic analysis, detailed agronomic and soil measurements will be taken and analyzed in early 1994.

Introduction

FAO and WHO recommend a daily vegetable intake of 200 g per person. However, with a total vegetable production of just over 3 million t per year (on an area of 250,000 ha), vegetable availability in Vietnam is only just over 130 g/day (FAO 1991[3]). Despite the expected decrease in population growth in Vietnam over the next two decades, growth in demand for vegetables has been projected to significantly exceed supply growth, mainly due to strong expected growth in per capita income (Jansen 1992, World Bank 1991[4]). If historical supply growth patterns would prevail in the future, per capita availability of vegetables may decrease.

While there is a clear need to increase vegetable supplies in Vietnam in general, future demand pressure can be expected to be especially high in and around urban areas. This is because people in urban areas depend to a much larger extent on market supplies for their food consumption than rural people, and urban regions usually have higher incomes and exhibit faster income growth than rural areas. Also, the urban population in Vietnam has grown at an annual rate of nearly 3.5% during the past decade, compared to an overall population growth of just over 2% per year.

The presence of virtually assured markets in urban areas with their high concentrations of people dependent on purchases for most of their food needs is very conducive to intensive vegetable production close to cities. Increased peri-urban vegetable production by small-scale commercial farmers close to the major urban foci of demand could significantly increase the availability of vegetables in urban markets and reduce malnutrition, reduce transportation costs, minimize produce spoilage, while at the same time provide farmers with an assured source of

[3]FAO. 1991. Food Balance Sheets, 1984-86. Average. Rome, Italy.

[4]World Bank. 1991. World Development Report 1991: The Challenge of Development. Oxford University Press, New York. 290 p.

income. These developments would also lead to increased employment for rural and urban people, particularly women (Hayami et al. 1990[5]).

Ho Chi Minh City, the largest in Vietnam, depends to a large extent on small-scale vegetable producers located in the so-called Green Belt around the city (up to 35 km from the city center) for its daily supply of vegetables. The Green Belt around HCMC occupies some 10 to 14 thousand ha, with each farmer cultivating between 0.1 and 2 ha of vegetables. To provide an adequate supply of vegetables to a rapidly growing urban center such as HCMC, reliable information is needed to quantify the demand, supply, and prices of different vegetables on a year-round basis. In addition, there is a need to identify the constraints and opportunities for vegetable production and marketing and to quantify the use of inputs and pinpoint potential sources of horticulturally-generated environmental pollution, to provide the basis for public policy, infrastructure development, horticultural research, and manpower development.

Constraints in peri-urban vegetable cultivation around HCMC may include labor shortages (vegetable growing has to compete with other urban activities requiring labor); land shortages (because of the demand for land by other urban systems); high incidence of pests and diseases, particularly in year-round sequential cultivation of leafy and other vegetables; decreasing soil fertility caused by a lowering of organic matter content of the soil, possibly causing yield decreases over time; pollution of water resources for agriculture, industry, and drinking water caused by the usage of high amounts of fertilizer, especially nitrogen and organic manure; and excessive use of pesticides, particularly insecticides.

Materials and Methods

The main research method consisted of a detailed farm survey among 98 peri-urban vegetable producers carried out in March/April 1993 by a multidisciplinary team of local scientists, after a joint pilot test with AVRDC in January 1993. Secondary sources of information are used to complement the survey data. Most survey analysis takes place at AVRDC in Taiwan, with involvement of one collaborating researcher from Vietnam trained in data handling and analysis methods.

The economic analysis will be followed by a detailed analysis of input and output of mineral nutrients to come up with a crude pollution index (potential), perhaps for pesticides as well. Representative soil samples will be taken to obtain indications of soil types and determine buffer capacity for P and K.

Results and Discussion

The analysis of the survey data is currently under way. A detailed quantitative and qualitative description of vegetable-growing practices in the Green Belt in terms of cultivation methods and input-output coefficients is being generated. Production costs and profitability of vegetable production in the Green Belt are being analyzed for the various cropping systems. The survey data also contain information regarding marketing patterns and this will allow an analysis of prices as well as an approximation of the total quantity of vegetables produced for the HCMC market. This will also enable a comparison of the total quantities of vegetables currently reaching the HCMC market with the supplies needed to meet present and future nutritional requirements. Major biotic and abiotic constraints were also identified during the survey and will form the basis upon which ways will be suggested to develop vegetable delivery and production systems that

[5]Hayami, Y., Kawagoe, T., Yokoyama, S., Bagyo, A.S., and Zakaria, A.K. 1990. Maketing Innovations for Vegetables: Conditions of Diversification in Upland Farming. ESCAP CGPRT Centre and Bogor Research Institute for Food Crop, Indonesia.

closely link farm production capacity with market requirements. A follow-up visit to Vietnam is scheduled in 1994 to carry out the agronomic and soil measurements. The study's final results are expected to contribute to knowledge among researchers and policymakers which can be used in the design of follow-up projects and/or government policies aimed at improving small-scale commercial peri-urban vegetable production.

Peri-urban Vegetable Cultivation Around Bangkok with Emphasis on Pesticide-free Growing of Leafy Vegetables

Summary

AVRDC's production systems program pays increasing research emphasis on peri-urban vegetable production systems. In this context, a study was initiated on the economic and agronomic aspects of vegetable cultivation near metropolitan Bangkok in Thailand, with special emphasis on pesticide-free production of leafy vegetables. The study is being carried out in collaboration with the Department of Agricultural Extension (DOAE) in Bangkok. The objectives of the study are: (1) to identify and review relevant domestic research and development initiatives in the area of peri-urban vegetable growing and marketing; (2) to provide a detailed quantitative and qualitative description of vegetable growing practices in the peri-urban system around Bangkok in terms of cultivation methods and input-output coefficients (both in economic and agronomic terms), including an assessment of differences between pesticide-free, low-pesticide, and conventional farming methods; (3) to provide estimates of production costs and profitability of peri-urban vegetable production around Bangkok; (4) to investigate growing constraints faced by conventional, low-pesticide, and pesticide-free vegetable growers around Bangkok, including a thorough analysis of prices and assessment of price advantages of low-pesticide and pesticide-free produce; (5) to investigate patterns and costs of marketing conventional vs. low-pesticide and pesticide-free produce; and (6) to suggest ways to alleviate growing and marketing constraints.

Introduction

In Thailand, vegetable availability over time has at best stayed constant or may even have decreased, currently standing at less than 100 g/day (FAO 1991). If historical supply growth patterns would prevail in the future, per capita availability of vegetables may decrease further (Jansen 1992). This may hold particularly for leafy vegetables, the Bangkok wholesale prices of which have exhibited rapid increases in the order of 45% over the past decade or so, indicative of an increasing gap between demand and supply. While there is a clear need to increase vegetable supplies in Thailand in general, future demand pressure can be expected to be especially high in and around urban areas. This is because people in urban areas depend to a much larger extent on market supplies for their food consumption than rural people, and urban regions usually have higher incomes and exhibit faster income growth than rural areas. Thailand is a prime example of this, where the urban population has grown at an annual rate of 3.5% during the past decade, compared to an overall population growth of less than 1.5% per year. In most peri-urban systems, vegetables are grown near the major foci of demand, to a large extent irrespective of natural parameters and agroecological factors. Because of the high profitability of vegetable cultivation, producers frequently take extraordinary efforts to grow vegetables under difficult conditions. Thus, peri-urban vegetable production systems can be considered as anthropomorphic (i.e.,

human-made) production environments, rather than as agroecological zones based on natural parameters.

To provide an adequate supply of vegetables to a rapidly growing urban center such as Bangkok, reliable information is needed to quantify cultivation methods, marketing patterns as well as the demand, supply, and prices of leafy and other vegetables on a year-round basis. In addition, there is a need to identify the constraints and opportunities for vegetable production in general, and for low-pesticide and pesticide-free vegetable production and marketing in particular; and to provide improved information for public policy, infrastructure development, horticultural research, and manpower development. Thus, it is important to monitor the conditions under which peri-urban vegetable production around Bangkok takes place, and identify possible ways in which peri-urban vegetable systems could be improved. In particular, it is timely and important to analyze the scope for further increases in environmentally-friendly (in its widest sense to include humans, too) ways of producing vegetables such as pesticide-free farming. In recent years, pesticide-free cultivation of vegetables has received increased attention due to the rising awareness among consumers regarding the adverse impact of excessive use of pesticides on human health. Short season vegetables usually have pesticide residues at harvest since little time exists for pesticide dissipation. Continuing strong economic performance of the Thai national economy and the resultant rapidly growing upper and upper-middle class in cities like Bangkok with matching purchasing power have created a rapidly growing market for low-pesticide and pesticide-free produce.

Constraints in peri-urban vegetable cultivation around Bangkok may include labor shortages (vegetable growing has to compete with other urban activities requiring labor); land shortages (because of the demand for land by other urban systems); high incidence of pests and diseases, particularly in year-round sequential cultivation of leafy and other vegetables (and especially relevant for pesticide-free farming); decreasing soil fertility caused by a lowering of organic matter content of the soil, possibly causing yield decreases over time; and pollution of water resources for agriculture, industry and drinking water, caused by the usage of high amounts of fertilizer, especially nitrogen and organic manure. Vegetable growers in general may not always be sufficiently aware of the adverse impacts on human health of excessive use of chemicals.

Materials and Methods

Extensive use will be made of secondary data sources including both government sources (researchers, extension services, statistical agencies) and the private sector (seed companies, marketing agents, companies involved in contract growing, retailers, exporters).

A detailed farm-level survey using structured questionnaires will be carried out in cooperation with the DOAE among peri-urban vegetable growers around Bangkok. Care will be taken to adequately represent major cropping patterns in the survey, including a sufficiently large number of farmers who practice low-pesticide or pesticide-free vegetable farming. The data collected by the survey will refer to an entire year. Detailed information will be sought on cropping systems, input-output relationships, environmental conditions, agronomic practices, major land use systems, and important farmer constraints.

If data permit, a linear programming (LP) model of a representative peri-urban vegetable farm will be developed incorporating both agronomic and economic relationships. The model will be built in such a way that, given certain constraints, allows for simulation and evaluation of various objectives and scenarios including yield and income maximization, and minimization of negative environmental effects.

Results and Discussion

The research will result in: (1) a detailed quantitative and qualitative synthesis of both conventional, low-pesticide, and pesticide-free peri-urban vegetable cultivation around Bangkok in terms of cultivation methods, production systems, input-output coefficients, and marketing organization; (2) identification of major constraints to, and opportunities for, increased supply of low-pesticide and pesticide-free vegetables for Bangkok linked to a quantification of the demand for, and supply of, pesticide-free vegetables, including projections for the future; and (3) clear-cut policy recommendations regarding the potential of low-pesticide and pesticide-free vegetable farming for improved sustainability of vegetable production and natural resources management.

A Preliminary Analysis of Technical and Economic Aspects of Soil Conservation Among Vegetable Growers in the Cameron Highlands, Malaysia

Summary

A major portion of vegetables in tropical countries is grown in highland areas because lowland vegetable production still succumbs to high temperature and humidity, flooding and typhoons, and pests and diseases. However, highlands are often characterized by their fragile environment of steep slopes, highly dissected topography, and shallow impoverished soils. As a result, highland vegetable production often causes significant negative off-site effects (externalities) which are typically unaccounted for in private producers' decision-making, resulting in sustainability problems. This study, undertaken by AVRDC in cooperation with the Malaysian Agricultural Research and Development Institute (MARDI) and La Trobe University, Australia, and funded by the Australian International Development Assistance Bureau, addresses such problems in the Cameron Highlands (CH), an important highland vegetable-growing area in Malaysia.

The extent of vegetable production in the CH has expanded over the past 25 years, and has been held responsible for most of the increase in sedimentation in tunnels and reservoirs in the region. Recent changes in land use within the CH were quantified by way of Geographic Information Systems (GIS), landsat imagery, a digital elevation model, and a comprehensive on-farm survey representing 10% of farmers undertaken in 1992. The extent of soil exposure, over space and time, was analyzed to determine sources of soil erosion. Broad platform terraces, cut out of the natural slope, are more common than bench terraces. Bench terraces, while reducing erosion (measured in this study as the loss of clay content), are not constructed due to lack of labor and other farmer considerations. Although slopes of cultivated beds on platform terraces rarely exceed 10°, and beds are predominantly positioned across the slope, terraces are resurfaced periodically due to impoverished soil and low yields. With the exception of plastic rainshelters, which induce high erosion control and reduce net farm income, other agronomic practices do not substantially reduce erosion from the cultivated areas. Hence, the traditional concepts of land management do not appear to apply in this production system where the natural environment is so heavily modified (e.g., with mechanical excavations and other earthworks, chicken manure, lime, inorganic fertilizers).

While cognizant that soil erosion exists, and that it will continue in the future, farmers contend that their standard of living will continue to improve. Lack of labor limits adoption of some

practices, e.g., mulching and relay cropping, which could potentially reduce erosion following crop harvest, during preplanting cultivation, and before full canopy cover. However, since evidence suggests that the source of erosion is related to the preparation and periodic resurfacing of platform terraces, recommendations with greater potential impact are made in line with the timing of land clearing and resurfacing of terraces.

Introduction

The Cameron Highlands (CH) represent a textbook example of environmental tradeoff, where sloping lands form the catchment area for a run-off river hydroelectric scheme in an (until recently) undisturbed tropical forest. Clearing of the forest, motivated by horticultural development (largely vegetables, but also flowers and tea), urban expansion, and accommodation for tourists, while generating income for those sectors, has reportedly diminished returns on investment in Tenaga Nasional Berhad (TNB=Electricity Board) infrastructure as a result of accelerated soil erosion with consequent sedimentation in tunnels, waterways, and reservoirs (Omar 1988[6]). While creating a not inconsiderable source of foreign exchange through export of vegetables and providing for farming families within the CH, clearing the forest has the negative effects for the TNB of predisposing soil to erosion, and for tourism through the creation of eyesores (e.g., bare soil particularly after forest clearing and land leveling, and clear plastic rainshelter). These disadvantages should enter into the scenario when considering long- and short-term management of natural resources within the CH.

The main reservoir in the region was constructed in 1965 when some vegetable production was already in force; area estimates for 1968 range from 535 ha to 769 ha (Lim 1970[7], Macken and Ong 1979[8]). With the present-day expansion of vegetable production on newly opened lands, the precise land area under production is not well documented. This study partly aimed to determine, by satellite imagery, the current extent of vegetable (and other crop) production, to relate that to the propensity for erosion given natural slope classes, and by survey of vegetable farmers to determine the level of adoption of erosion control practices, and the variation in net farm income across the CH.

In the present context, the sustainable management of the CH is shown to be unlike that of marginal environments in the tropics where the level of external inputs is often limited by lack of financial resources. Bearing in mind the economic resources of farmers in the CH, a set of recommendations to reduce soil erosion in the CH is outlined.

Materials and Methods

The survey was carried out among vegetable growers in the CH, an area of about 750 km^2, located in the state of Pahang, 250 km from the capital Kuala Lumpur (fig. 1). Most vegetable cultivation in the CH takes place at altitudes of between 900 and 1400 m asl, within the mountainous area which rises to 2100 m asl. The area is highly dissected, with few pockets of broad mountain valleys. Vegetable production is rarely practiced on natural slopes; bench terraces (1-2 m wide) or more generally platform terraces (10-100 m wide) are cut out of the

[6]Omar, Md. F. 1988. Watershed management for Cameron Highlands and Batang Padang hydroelectric scheme. Paper delivered 24 September.

[7]Lim, K.P. 1970. Economics of vegetable market gardening in Cameron Highlands. Master's thesis. Univ. of Malaya, Kuala Lumpur.

[8]Macken, K.P. and Ong, T.S. 1979. Survey of cultural practices and conservation measures performed by maket gardeners in Cameron Highlands. Soil conservation and Reclamation Section Publication no. 15. Dept. of Agric. Peninsular Malaysia. 39 p.

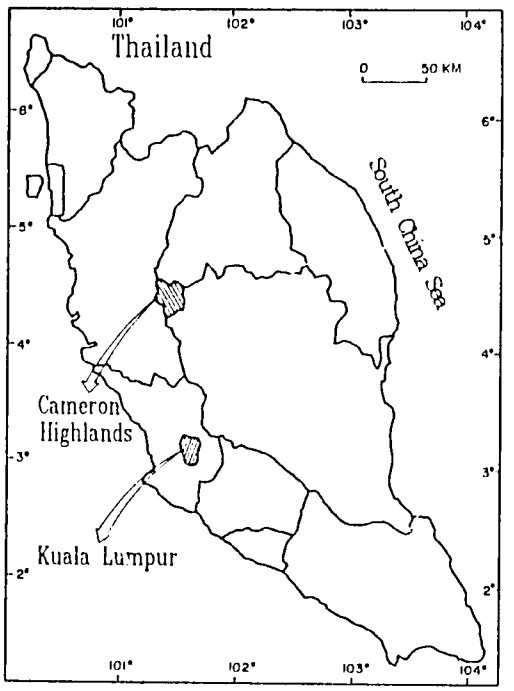

Fig. 1. Location of the study area

natural slope without concern for repositioning of humus or organic matter. Soils are mainly derived from granite, with sandy to sandy clay loam textures, and are classified as paleudults (Paramanathan 1977[9]). Organic matter in the N of CH in virgin soils reaches 80-100 cm in depth (Gunong Brinchang series), falling to 40 cm in the Central Tanah Rata Series and to a negligible layer of humus in the Ringlet Series of the S where altitude is less and temperatures higher. Soil collected from the A1 horizon beneath the organic layer had the following composition: 40% sand; 16% silt; 44% clay; EC 0.13 mS cm^{-1}, and pH 4.2. The cool temperate climate of the CH is ideally suited to the production of temperate vegetables, with maximum monthly mean temperature ranging from 22 to 23.5°C and minimum from 11 to 14°C. Rainfall data for 1981-1991 show an annual bimodal pattern, with peaks in April/May and October/November. No month is without rainfall, although least rainfall is experienced in the months of December and June. Annual rainfall for the past 34 years averaged 2205 mm. Using pluviographic charts for the period 1981-91, erosivity as kinetic energy (KE) was calculated for 30 m/n intensity, and only for storms of > 10 mm as follows:

Daily KE 1-30=$\sum$ (KE x rainfall) x max. 30 min intensity (Dumsday and Huang 1992[10]).

The study on land use was based on the digital landsat TM data (scene no. 127/57) for 23 April 1990, the 1: 50,000 topographic map (sheet no. 3662), and the landuse map for 1986 produced by the Department of Agriculture Malaysia (DOA). To produce a landuse map for 1990, a standard false color composite TM image of bands 7, 4, and 2 with red, green, and blue colors at a scale of 1:50,000 was developed, and visual interpretation, aided by ground-truthing, was done.

[9]Paramanathan, S. 1977. Soil genesis on igneous and metamorphic rocks in Malaysia. D.Sc. thesis. State Univ. of Ghent. Belgium.

[10]Dumsday, R.G. and Huang, J. 1992. Rainfall erosivity in the Cameron Highlands, Malaysia (1981-91). AVRDC. Background paper no. 4.

A digital elevation model (DEM) of the study area was developed, taking 100 m contour lines and peaks from the topographic (1:50,000) map of the area. Landuse information of 1986 and 1990 were drafted onto the model, using 100 m x 100 m grid size (which interpolated altitude of grid cells when they lay between contours), and a slope map with classes <2°, 2-5, 5-10, 10-20, 20-30, 30-40, and > 40° was prepared.

A stratified random sample along a N/S transect consisting of 206 farmers in 13 different locations (between 9 and 28 farmers per location) representing vegetable-producing regions in the CH was interviewed during January 1992. Concurrently, consolidated representative soil samples were collected at each farm, and analyzed for physical composition, pH, and electrical conductivity. Measurements taken with a clinometer enabled assessment of natural land slopes on each farm, and slopes of terraces and beds. Besides the formal interview, observations on the degree of soil erosion on each farm were recorded. From the sample, 194 farmers for which complete data sets were available were retained for analysis, representing approximately 10% of all vegetable farmers in the CH.

Results and Discussion

Land use

Summary statistics (table 1) indicate that >3000 ha were used in vegetable and flower production in 1990. However, compared to other sources (Ko et al. 1987[11]) this is likely an overestimate of about 50% since the areas involved in this class include farm roads, farm buildings and yards, and irrigation channels.

Table 1. Landuse statistics (hectares) for 1990 (by satellite imagery) and for 1986 (landuse map of MARDI) for the Cameron Highlands

Landuse types	1990	1986
1. Vegetables and flowers	3236.8[a]	1453
2. Tea estates	2821.0	2942
3. Cleared tea areas	209.5	n.d.
4. Newly opened forest	1452.5[b]	n.d.
5. Scrub and scattered farms	1859.7[c]	1702
6. Towns	179.0	194
Total	9758.5	6291

[a]Includes farm roads, farmhouses, rainshelters, farmyards, and channels.
[b]Includes dead ferns, cleared forest, barren land, and even landslides.
[c]Includes fruit orchards.
n.d.= no data.

Analysis of distribution of land in the designated slope classes for vegetable production (table 2) indicates that >40% of vegetable production in 1990 was on land with natural slopes >10°, compared to >60% for tea plantations. Although the greatest proportion of farmers cultivate vegetables on land with a natural slope of 10-20°, more than half use beds with a slope of <2°, and only 10% had beds with a slope >5°. Of all newly opened areas only 16% have slopes >20°; not excessive considering that most new lands are peripheral to those already opened within each valley in the CH (fig. 2). From 1986 until 1990, the total developed land area increased from 6097

[11]Ko, W.W., Syed, A.R., N. Mohd. Shukor, Saparuddin, Ho, and Azhar, I.A. 1987. Agriculture in the Cameron Highlands. Proc. Internat'l Conference Steepland Agric. Humid Tropics et al. MARDI, Kuala Lumpur. p. 130-151.

Table 2. Distribution of vegetable production land (%) in the Cameron Highlands by slope classes, according to the digital elevation model (1990 data) and survey analyses (1992 data)

	Slope class						
	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°
Survey	2.1	12.0	29.3	46.1	11.5	0	0
DEM	30.2	9.3	18.4	28.0	11.1	2.7	0.3

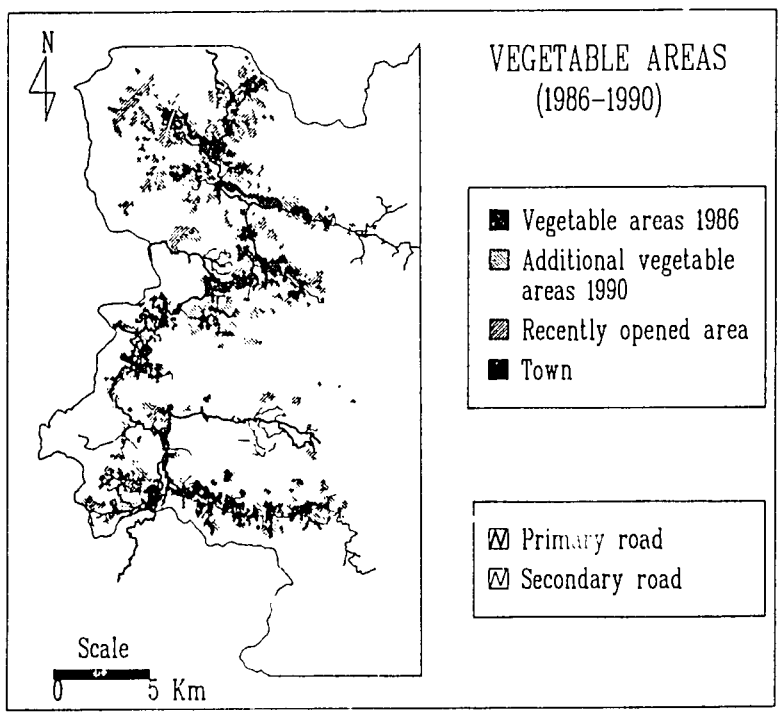

Fig. 2. Change in vegetable areas, 1986-1990

to 9758 ha, at an average annual rate of 732 ha. As long as access is feasible, it seems that expansion of new areas will concentrate on lower angle slopes further up each valley (fig. 2).

Erosivity

Although a close linear fit ($y = 0.86\ [\pm 0.04]\ x - 19.57$; $r^2 = 0.785$ $n = 130$) was observed between monthly rainfall erosivity and rainfall, data for the month of May 1991 was an important outlier, when erosivity was much greater than expected based upon data for the monthly rainfall. It is possible that a large proportion of the erosion for the 11-year period would be accounted for by that month's KEt. Erosion control practices, to be effective, should be implemented in anticipation of extraordinary rainfall events.

Farm size and ownership

Average farm size slightly exceeds 0.8 ha. Most farmers' tenure arrangement consists of a Temporary Ownership License (TOL); 67% of farmers in our study and 75% in another study (Taylor et al. 1993[12]) farmed TOL land. TOLs are a common form of land tenure where land is held for 5-15 years, with nominal fees (about M$ 250-350/ha/year) paid annually or periodically, accompanied by reviews of land use and management practices. About one quarter of all sample farmers make use of plastic shelters; on average, about 0.4 ha of land is covered by farmers who use shelters. All farms have some form of irrigation facility, 90% with sprinkler irrigation. Water is directed from stream flow higher in the watershed, by way of small weirs and plastic pipes, to provide sufficient head to operate sprinklers. Generally, farmers have facilities to irrigate their whole farm area.

Cropping patterns

Most farmers grow between two and five different vegetable species. The 13 most popular vegetable crops in the CH, in decreasing order of frequency, include English cabbage, tomato, Chinese cabbage, lettuce (Indian and head), onion, snowpeas, celery (English and Chinese), spinach, tong ho (garland chrysanth), beans (butter, green, French), mustard (Chinese, kaves, leaves), sweet pepper, and radish.

The popularity of intercropping depends on the species grown, but is often precluded due to labor shortages. Vegetables are grown year-round, although some seasonality is encountered among species. Consideration of harvest time is important in relation to exposure and erosion of soil during presowing cultivation and before groundcover by the succeeding crop. For example, harvests of English and Chinese cabbage (which together account for nearly half of total gross area cultivated) are more predominant during wet periods, with peaks in April and August (when prices are very low).

Costs and returns

Total net farm income (NFI) per year was calculated as the sum (over vegetable species) of net returns per hectare per year, multiplied by the actual area for each individual species, minus the sum of the cost items which could not be attributed to individual vegetable species. The latter include hired labor costs (including permanent labor, but excluding family labor); annualized costs of irrigation, plastic shelters, and terrace construction; recurrent cost of beds (remaking) and terraces (resurfacing); other material costs; land rent and taxes; electricity costs; marketing costs; and any other costs. Annual NFI calculated in this way can be interpreted as net profits or returns to family labor and management (table 3). Expenditures for manure (mostly chicken dung to improve soil fertility) account for the largest part of total material costs for every vegetable except celery and radish, and are particularly high for capsicum. Costs for semipermanent structures such as irrigation facilities, plastic shelters and terraces were annualized using the following formula: $A = P(r/[1-(1+r)^{-t}])$ where A is the annualized capital cost of the structure; P is the current cost of the structure; t is the assumed life span of the structure; and r is the interest rate at which the farmer can obtain a loan. On the basis of the survey data, the life span of irrigation and plastic shelter structures was set at 10 years, with the life span of the plastic itself set at 2 years. Terraces were assumed to last for 15 years, and an annual interest rate of 8% was used.

[12]Taylor, D.C., Mohamed, Z.A., Shamsudin, M.N., Monayidin, M.G., and Chiew, E.F.C. 1993. Sustainability of English cabbage production practices in Cameron Highlands. Mimeo Report. Jabatan Ekonomi Pertanian. Universiti Pertanian Malaysia. 121 p.

Table 3. Mean annual net farm income (M$) (N = 194)

	Mean	c.v.
Total annual gross revenues from vegetable crops	27,714	96
Total annual material costs (vegetable-specific)		
– seed	512	115
– manure	2,454	102
– fertilizer	1,458	125
– pesticides	638	113
– tractor use	79	220
Total annual costs (nonvegetable-specific)		
– hired labor costs	2,418	269
– annualized costs of		
– irrigation		
– sprinkler	1,567	152
– other	92	513
– plastic shelters	1,474	269
– terraces		
– bench	232	254
– platform	9,123	67
– bed costs	279	314
– cost of liming	198	171
– costs of other materials	2,291	71
– land rent	651	306
– land taxes	243	124
– electricity costs	141	154
– marketing costs	603	120
– other costs	46	988
Total input costs	24,496	70
Net annual income per farm	3,218	682

The calculations from which data in table 3 were derived indicate that about half of all sample farmers lose money. While this situation nearly certainly holds for a number of the sample farmers, it should be stressed that these are preliminary results only and that there still remain a few issues which need further clarification.

Soil erosion causes, estimates, and influence of farmers' practices

Soil erosion is a serious problem in the CH, with the average accountable loss of soil estimated at 16.8 t/ha year. Most likely this is an underestimate since the rate of sediment deposition in the reservoir and, therefore, probably the rate of land clearing, has progressively increased (sediment: 1965–0 m^3; 1975–153,000 m^3; 1982–575,000 m^3; 1992–2.382 million m^3) (Omar 1988). Soil becomes exposed following forest clearing, resurfacing of platform terraces, clearing and pruning of tea, and crop harvest.

The physical composition of topsoil was quantified on the assumption that silt and clay fractions would be detached sooner than sand as a consequence of runoff and soil erosion. The percentage of clay in soil from farms with plastic shelters was positively correlated with the proportion of land under plastic. The clay fraction in soil from farms with all land covered by plastic shelters was also greater than that from farms without any plastic shelters (18.0 vs. 15.6%, t=2.319 df 4 to 153). Data for cultivated soils show that much silt and clay has been washed away compared to the virgin soil. However, there were no significant relationships between percentage sand, silt, or clay and the natural slope, the arable slope nor the slope nor length of beds. In fact, although farmers implement a number of agronomic practices which in theory should reduce erosion, their causal effect on sand, silt, and clay composition in soil could not be established. For example, there was no evidence to suggest that at greater application rates of manure the loss of silt or clay particles was limited. Similarly, there was no general reduction in finer particle size with more weeding.

Most farmers construct some type of terrace, with 54 and 187 farmers having constructed bench and wide (i.e., platform) terraces, respectively. The percentage of land under wide terraces greatly exceeds that under bench terraces, with on average 36% of the land of the 54 farmers under bench terraces, while wide terraces on average occupy 92% of farmland. Bench terraces have some disadvantages relative to platform terraces: (1) their construction is entirely done by hand (as opposed to platform terraces which are constructed largely by machine) and labor shortage is a critical concern among farmers; (2) cultivation is more arduous; (3) they are relatively difficult to irrigate; and (4) it is impractical to protect them with plastic shelters. Nevertheless, there did seem to be a benefit in terms of retained silt and less sand as the proportion of bench terrace per farm increased.

Seventy-five percent of all farmers cultivate across the slope on platform terraces, with most of the remaining farmers planting on bench terraces up and down the slope. None of these practices significantly affected sand, silt, and clay composition in soils. Terrace cultivation is considered by farmers to facilitate water control in general and improve drainage in particular, minimize human drudgery, maximize land area, and improve photosynthesis. Very few farmers plant along the contours which is generally viewed as making most farming operations too difficult, particularly irrigation and transportation of inputs and harvested produce. Stagnation of rainwater and flooding are major problems during the heavy rain season. The current cultivation practices are employed because 26% of farmers believe that they create better water flow off the land and 36% are convinced that drainage is improved.

Generally, farmers seem to be well aware of the environmental problems in the CH and expect a future deterioration in most indicators of sustainability such as soil quality, crop yields, and pest and weed infestation. Farmers' perception of soil erosion differs depending on the context, i.e., own fields, local district, or the CH as a whole. Generally, they perceive soil erosion to be an increasingly serious problem the farther away from their own farms. Thus, while only 28% farmers view soil erosion as serious or very serious on their own farm, 61% and 80% indicated similar concerns for their local district and the CH, respectively.

There was a shift in soil quality perceived by sampled farmers; from the past to present assessment the proportion of farmers with very good soil declined while the category of good and fair increased. Many farmers expected their soil quality to decline further in the future, with > 30% of farmers expecting poor or very poor soil compared to about 15% in the past and present. Expectations for crop yields, pests and to a less marked extent weeds, were similar to those for soil quality, but nevertheless, standards of living were predicted to increase for a significant proportion of farmers over the same time frame.

Besides farmers' perception of soil erosion, the survey also asked for the enumerators' field assessment of the extent of soil erosion on each individual farm. Rill erosion is clearly the most serious, with 73% of all sample farms already experiencing at least moderate rill erosion; followed by gully erosion which is reason for concern on nearly half of all sample farms. Even though two-thirds of all sample farms have not yet had land slips, and nearly 60% thus far have been saved from sheet erosion, the situation can be expected to worsen in the near future. During the survey, obvious severe land slips were observed on 10% of the farms, most likely following the heavy rains in May 1991. There was a close correlation between visual assessment of gully erosion and decrease in clay fraction of soil composition ($P \leq 0.017$), but no other visual assessments of erosion were related to soil physical compositions. Rill erosion was more likely to occur when the natural and arable slope was high, but neither bed length nor slope were related to visual estimates of rill erosion. Similarly, no such relations were evident for gully, sheet, nor landslip erosion.

Conclusions and Recommendations

Preliminary analysis suggests that a major portion of soil erosion from vegetable fields in the CH occurs before vegetable crops are in the ground. All developed land in the CH was at one time newly opened, liable to erosion, and probably responsible for a large proportion of the measured sedimentation. In fact, land clearing, together with resurfacing of platform terraces, may well be the most important source of soil erosion. Other significant occurrences of soil erosion are following harvest of vegetables when soil is once again exposed, particularly when coinciding with peak rainfall; and, more generally, when a combination of conditions occurs such that the soil is heavily charged with water followed by long continuous heavy rain causing landslips. Thus, it is not surprising that, even though vegetable farmers within the CH do implement a series of practices which counteract the effects of erosion, their effectiveness is far less than desirable in that none of these factors alone were responsible for maintenance of high clay/silt: sand ratios compared to that of virgin soil. Such practices include limiting the slope of man-made terraces to $< 10°$, a predominance of across the slope as opposed to up-down alignment of beds, minimum tillage through reuse of production beds with reasonably long periods between reconstruction of beds, the use of bryophytes to counteract erosion from sides of beds (and as a weed suppresser), a degree of intercropping, and emphasis on adequate drainage. Even the use of plastic shelters did not prevent loss of silt and clay in absolute terms far beyond that of the unprotected farm lands, and incidentally, led to greater soil EC and was negatively associated with NFI. It almost certainly also leads to increased rate and volume of stream flow. That farmers need to resurface their land is yet another indication that the agronomic practices are uniformly ineffective in controlling erosion. Relationships between the need to resurface terraces and the implementation of erosion control practices were nonexistent. Hence, since little scope apparently exists to increase profitability through traditional agricultural approaches, farmers resurface their fields.

The adoption of soil conservation and other production practices was not apparently constrained by the land tenure of individual farmers. Almost all farmers have overhead sprinkler irrigation systems installed, and the distribution of plastic shelters was not biased towards farms with freehold land access. In this respect, therefore, the condition (financial and access to resources) of farmers in the CH does not limit their ability to implement sound erosion control practices. Therefore, potential solutions to the sources of soil erosion in the CH might take the following form:

- conservation of organic humus and repositioning over newly formed terraces;
- use of organic mulches, and/or relay cropping practices during production to continue to cover soil after harvest (particularly of cabbage which occurs when rains are particularly heavy);
- use of mulches or cover crops on terrace batters;
- avoiding preparation of new lands and resurfacing of old ones during the peak rainfall months; and
- reinforcing the retaining structure for platform terraces to avoid landslips.

The scope for adoption of those requiring large labor inputs will be questionable.

Sustainable Vegetable Supply for Kathmandu with Emphasis on Natural Resources Management in Nepal

Summary

To meet rapidly increasing demand for vegetables in the Kathmandu area and to reduce widespread malnutrition, production of vegetables must be intensified on existing land especially if new marginal land tracts are not to be exploited and environmental degradation is to be avoided. This research is aimed at identifying sustainable ways to guarantee future vegetable supplies to Kathmandu that will match projected demand and meet nutritional requirements. A collaborative effort involving several agencies and a multidisciplinary team of scientists has been initiated, in which diagnostic, rapid rural appraisal (RRA) type field surveys may be followed by formal structured farm surveys in three districts. The results from these surveys, together with already available secondary data and data from other studies will be collated by AVRDC and collaborators, and analyzed in the perspective of Geographical Information Systems together with a set of physico-socio-biological data bases which have been and will continue to be developed by the International Centre for Integrated Mountain Development (ICIMOD) and AVRDC, respectively. The project is expected to result in a detailed quantitative and qualitative synthesis of vegetable production practices, constraints and opportunities for increased supply in areas responsible for Kathmandu's daily vegetable supplies; matching demand for vegetables with the most suitable sites (logistically, climatically, and environmentally); clear-cut policy recommendations for improved sustainability of vegetable production and natural resources management; and an Action Plan to improve upon the sustainability of vegetable production and natural resources management for vegetable supply to Kathmandu.

Introduction

Kathmandu has an estimated population which probably exceeds 1.5 million, and is growing at an astonishing annual rate of 7.3%, dramaticaly exceeding the national population growth of 2.6% per year (World Bank 1992[13]). Current interest in vegetable production is based upon the fact that vegetable consumption, in a country where animal forms of protein and nutrients are minimal, is low at less than 50 kg/capita/year. To ensure vegetable supply which maintains the acceptable level of around 75 kg/capita/year while keeping abreast with predicted population

[13]World Bank. 1992. World Development Report. 1992. Oxford University Press, New York.

growth, production of vegetables must be intensified on existing land especially if new marginal land tracts are not to be exploited. Such an intensification, as has been experienced in a number of Southeast Asian countries in which a demand-led expansion of vegetable production has taken place, must be planned in accord with available national and purchased inputs, and not achieved at the expense of environmental degradation. If historical supply patterns would prevail in the future, per capita availability of vegetables may drastically decrease unless steps are taken to ensure otherwise (Jansen 1992).

Kathmandu receives its supply of vegetables from diverse sources, ranging predominantly from the highlands (i.e., temperate crops such as cabbage) during the summer, with some supplementary leafy vegetables from the peri-urban context (including the true peri-urban zone of Thimi/Bhaktapur in Kathmandu Valley, and Dhading and Kavrepalanchowk districts) and cucurbitaceous vegetables from the Terai; to a winter supply of vegetables dominated by the Terai (Nepal and India), when cool temperatures in the highlands preclude production of most crops.

Given this general description of vegetable supply, for the future it is imperative to plan expansion of production so that it is in line with availability of inputs, especially fertilizer and seed; with marketing potential with concomitant inroads into reduction of postharvest losses; and with development of technology which will ensure equitable increases in production while ensuring environmental protection (in the widest sense to include humans, too).

This recently initiated research is a collaborative effort of the following agencies involved in vegetable research and development in Nepal: Vegetable Development Division, Ministry of Agriculture (VDD), Winrock International Institute for Agricultural Development (Winrock), ICIMOD, Food and Agriculture Organization of the United Nations/Swiss Development Corporation (FAO/SDC), University of British Colombia (UBC), and AVRDC. The main objective of the research is to identify sustainable ways to guarantee future vegetable supplies to Kathmandu that will match projected demand and meet nutritional requirements.

AVRDC has particular interest in involvement with the true peri-urban vegetable production system, since in comparison to the other supply areas of seasonal importance, year-round production and supply of vegetables within the Kathmandu Valley are characterized by a series of problems not yet faced elsewhere in the country, with perhaps the exception of the outskirts of Pokhara. Such problems include high land and labor opportunity costs, urban encroachment, soil erosion, declining land productivity, limits to availability of organic manures, pollution of ground water and pollution by industrial water sources.

Materials and Methods

An interdisciplinary team comprised of personnel from AVRDC and collaborating local and international agencies has been formed to implement the project. Additional expertise will be added to the team on a need basis. Diagnostic methods (i.e., rapid rural appraisal type field surveys) were used by the team in November 1993 in Thimi/Bhaktapur (Kathmandu Valley, about 1,300 m asl), Dhading (outside the Valley, about 600 m asl) and Bara (Terai, less than 200 m asl). In the RRA-type surveys, farmers were interviewed on a pilot basis to understand farmer practices and their level of technical knowledge. Members of the pilot survey team interviewed farmers using informal, open-ended interviews. The results from these surveys, together with already available data from earlier studies (including those conducted by FAO/SDC, UBC, Winrock and VDD), will be collated by AVRDC and collaborators, and analyzed in the perspective of GIS together with a set of physico-socio-biological data bases which have been and will continue to be developed by ICIMOD and AVRDC, respectively. The RRA surveys may be

followed up by a formal baseline survey using structured questionnaires after an exhaustive search for secondary data.

Secondary data will be collected from several sources including ICIMOD's GIS database; climatic data from the Department of Hydrology and Meteorology of the Ministry of Water Resources; and production statistics and information on markets, cropping systems and input use from available government sources (ASD 1992[14], DOH 1992[15], VDD 1992[16]) and foreign-aided projects. In addition the team members will visit various government organizations, NGOs, wholesalers, retailers, as well as national and international research organizations in the study area. The team will characterize and describe the climate, cropping systems, topography, soil, vegetable marketing channels, postharvest handling procedures, environmental conditions, agronomic practices, major landuse systems, land tenure, transportation systems, and demographic features of the study area.

On the basis of primary data obtained from the surveys and the various types of secondary data gathered, a comprehensive database will be established for vegetable production, natural resources, socioeconomic factors, and institutional setting of the supply areas for Kathmandu.

Although commercial-scale vegetable production takes place mostly in roadside areas (and to some extent irrespective of agroclimatic factors), specific combinations of climatic and soil conditions for maximum yields under cost-effective input levels can be identified. Climatic variations are gradual and noticeable only over relatively large distances, while soils show more abrupt and local differences. Regional combinations of climate, soils, topography and land types will be linked to factors which are important for crop performance. They will be organized in a system of agroecological zones, together with the determination of the most suitable crop for each area. To achieve the latter, appropriate use will be made of crop modeling, mostly using and/or adapting existing models. The relative importance of physical and biological factors which determine the extent of vegetable production will be evaluated and scope for research and/or development interventions quantified taking into account the integrated supply of vegetables to Kathmandu. This may result in a better identification of suitable sites for fresh vegetable production within and beyond the peri-urban belt of Kathmandu.

Marketing patterns, price fluctuations, and postharvest handling procedures and losses will be studied to determine major constraints to urban supply of vegetables.

Viable management strategies, based on current knowledge, for achieving sustainability in peri-urban vegetable production and natural resources management will be evaluated for potential implementation.

Based on the results of the diagnostic and formal baseline surveys and the integrated analysis of vegetable production and supply, preliminary key issues will be selected. The order and magnitude of the problems, constraints, and opportunities will be assessed and analyzed. Research, led by VDD, will be initiated in situ on well-defined broad problem areas, particularly related to maintenance of the resource base, while production type on-farm research will further enable identification of production constraints beyond the comprehension of farmers. Solutions to these problems will be sought through research.

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[14]ASD. 1992. Agricultural Indicators of Nepal 1992. His Majesty's Government of Nepal, Ministry of Agriculture, Department of Food and Agricultural Marketing Services, Agricultural Statistics Division, Lalitpur, Nepal.

[15]DOH. 1992. A proposal for eighth five year plan (1993/94-1997/98). His Majesty's Government of Nepal, Ministry of Agriculture, Department of Horticulture, Kirtipur, Nepal (unpublished).

[16]VDD. 1992. Vegetable Development Program — Statistics on area and production of fresh vegetables in 1991/92, Nepal. Vegetable Development Division, Khumaltar, Department of Agriculture, Ministry of Agriculture, Nepal (unpublished).

Results and Discussion

A report on the results of the diagnostic survey is under preparation. The research is expected to result in a detailed quantitative and qualitative synthesis of vegetable growing practices in the major vegetable growing areas responsible for Kathmandu's daily vegetable supplies; identification of major constraints and opportunities for increased supply of fresh vegetables for Kathmandu; matching demand for vegetables with the most suitable sites (logistically, climatically, and environmentally) within the country resulting in increased efficiency of fresh vegetable production; clear-cut policy recommendations for improved sustainability of vegetable production and natural resources management; and an Action Plan to improve upon the sustainability of vegetable production and natural resources management for vegetable supply to Kathmandu.

How to Perform Economic Analysis of Agronomic Field Data: an Example for Hot Pepper

Summary

This research represents a first attempt to economically evaluate the results of two field experiments carried out at the AVRDC experimental farm during 1991-92. The particular field experiments chosen for economic analysis were designed for testing the influence of various management practices on the incidence of viruses on hot pepper (*Capsicum annuum*). The purpose of the research is twofold: (1) to make AVRDC crop improvement scientists familiar with, and increase their appreciation of, the concept of partial budgeting which, it is hoped, will eventually result in a situation where the design of field experiments explicitly allows for the possibility of an ex-post economic analysis of the experimental data, and (2) to assess the relative profitability of alternative management practices to control cucumber mosaic virus (CMV) and chili veinal mottle virus (CVMV) on hot pepper in Taiwan. The results of the first experiment indicate that farmers' current practices, consisting of the use of a locally-produced reflective foil in combination with a weekly application of insecticide, is considerably more profitable than alternative management practices involving various combinations of imported foil, insecticides, alarm pheromone, whitewash, and yellow sticky traps. The results of the second experiment suggest that an investment in a floating net is risky and is a profitable alternative to the use of insecticide only when hot pepper prices rise to improbably high levels of at least NT$56/kg. A number of shortcomings of the analysis are also pointed out.

Introduction

Two hot pepper (*Capsicum annuum*) experiments were carried out during 1991-92 at the AVRDC experimental farm in Shanhua, Taiwan, looking at alternative virus control measures which interfere either with the landing behavior of the aphid vectors or with the virus transmission process (AVRDC 1993)[17]. The two aphid-transmitted viruses causing concern included cucumber mosaic virus (CMV) and chili veinal mottle virus (CVMV). The main variables in the experiments included two kinds of reflective foil (Taiwanese reflective foil commonly used by local farmers and a reflective foil imported from Japan); Tameron insecticide, a biological insecticide, Neem (imported from Germany); an alarm pheromone, farnesene (a whitewash imported from the UK);

[17]AVRDC. 1993. AVRDC 1992 Progress Report. AVRDC, Shanhua, Tainan, Taiwan.

Table 4. Reduction of virus incidence experiment: mulching, insecticides, whitewash, and traps

Treat-ment	Mulch	Tameron	Farnesene	Neem	Whitewash	Yellow sticky traps
1[a]	Taiwan foil	weekly 50% at 1:1000	-	-	-	-
2	Taiwan foil	weekly 50% at 1:3000	-	-	-	-
3	Taiwan foil	weekly 50% at 1:3000	weekly at 0.01 g/l	-	-	-
4	Taiwan foil	-	-	1500 ppm at 1:200 weekly starting 28 DAT and 1:150	-	-
5	Taiwan foil	-	-	-	at 28 DAT	-
6	Japanese foil	-	-	-	-	-
7	Japanese foil	weekly 50% at 1:3000 starting 14 DAT	-	-	-	-
8	Taiwan foil	-	-	-	-	yes

[a]Farmers' practice.

Table 5. Reduction of virus incidence experiment: floating net

Treatment	Mulch	Tameron	Floating net
1[a]	Taiwan foil	weekly 50% at 1:1000	-
2	Taiwan foil	-	up to 35 DAT

[a]Farmers' practice.

and yellow sticky traps (also imported from Germany). In addition, the use of a light floating net (imported from Germany as well) was also evaluated.

In the first experiment, eight different treatments [including farmers' practice which consists of mulching with a locally produced reflective foil in combination with a weekly application of Taiwan insecticide (50%) at 1:1000] were developed using various combinations of reflective mulches, biological insecticides, pheromone, whitewash, and yellow sticky traps (table 4). Sowing occurred in August, transplanting to the field in October, and harvesting during January-March. The use of a floating net was evaluated against farmers' practices in a separate trial (table 5). In the latter experiment, sowing took place in March, transplanting in April, and harvesting during June-August.

Materials and Methods

A partial budget was developed to analyze the results of the experiments from an economic perspective and get an indication as to which management practices may warrant further testing or may be worth recommending to farmers. Subsequently, a marginal analysis was performed to compare the costs that vary with the net benefits. After elimination of dominated treatments, marginal rates of return (MRR) were calculated and compared to the minimum required rate of return (MRRR) based on the opportunity cost of capital. For Taiwan, the latter can approximately be the rates at which farmers can borrow money from cooperative banks. Depending on the purpose and duration of the loan, these rates currently vary between 9.75 and 11.75% per annum.

Results and Discussion

Table 6 shows the partial budget for the first experiment, using a hot pepper price of NT$28/kg which represents the average price during the harvesting months of the experiment (January-March) for the past six years. Yields (fresh weight, total of seven harvests) are averages of three replications. Treatment 4 is dominated (i.e., has higher total costs that vary, but lower net benefits) by treatments 1, 2, and 5; treatment 6 by treatments 1, 2, 4, and 8; and treatment 7 by treatments 1 and 2. Therefore, treatments 4, 6, and 7 were ignored in the marginal analysis (table 7). Of treatments 1, 2, 5, and 8, the farmers' practice (represented by treatment 1 using Tameron foil and Tameron insecticide at full strength) has the highest total costs that vary and also the highest net benefits. Thus, each of treatments 2, 5, and 8 represents a cost saving relative to the farmers' practice but, of course, at a cost in the form of lower net benefits. These decreases in net benefits are substantial and are not justifiable in view of the rather low-cost savings achieved by switching from the farmers' practices to alternative management practices tested in treatments 2, 5, and 8. The marginal returns on the farmers' current practices relative to the practices of treatments 2, 5, and 8 are 2889, 2640, and 1516%, respectively. These marginal rates of return are all exceptionally high, exceeding the opportunity cost of capital manifold.

The two most significant sources of risk for hot pepper farmers in Taiwan are yield risk (e.g., caused by the presence of viruses year-round or by the much more seasonal and, therefore, less important, occurrence of a typhoon) and (related) price risk. Since the experimental data available are only for one year (1991-92) and one location (the AVRDC experimental farm), yield risk was ignored and only price risk was taken into account by varying prices based on historical price data. Price variability considerably exceeds variability in supplies (table 8). Apart from substantial variation in average annual prices (coefficient of variation [c.v.] = 0.32), seasonal price variations are even higher as shown by an average coefficient of variation of 0.49 for the same 6-year period. In addition, hot pepper prices in Taiwan show large variation between years for the same seasons, as evidenced by values exceeding 0.39 for the coefficient of variation of monthly prices for the 6-year period.

Since the profitability of management practices can be expected to depend to a considerable extent on prices, the partial budgeting exercise was carried out for a range of hot pepper prices. Average hot pepper prices during the period January-March were lowest in 1987 (NT$ 16/kg) and 1991 (NT$ 17/kg), and highest in 1992 (NT$ 60/kg). Consequently, two additional partial budgeting calculations were performed under the assumptions that the hot pepper price is NT$ 16 and NT$ 60 per kg, respectively. However, the basic conclusion that the farmers' practice is to be preferred remained unaltered at either NT$16 or NT$60/kg, with marginal rates of return which all exceeded 800%. Simulation analysis showed that prices of hot pepper would have to fall to improbably low levels of less than NT$2/kg for marginal rates of return to fall below 20%.

The use of a floating net up to 35 days after transplanting (DAT) without any insecticides increased hot pepper yields by nearly 20% (table 9).

The second experiment was harvested from June to August when hot pepper prices in Taiwan tend to be slightly higher than during January-March (the harvesting period of the first experiment; see table 8). At a hot pepper price of NT$30/kg, which is the average price for the period June-August over the past 6 years, the treatment involving a floating net was dominated by the treatment representing farmers' practice (table 9). Only when the price of hot pepper exceeds NT$56/kg will the MRR be higher than 20% (table 10). The data in tables show that there is a very low probability that this will actually occur, making the use of a floating net quite a risky investment.

Table 6. Partial budget, first experiment

	Treatment							
	1	2	3	4	5	6	7	8
Reported yield (kg) 7.11	5.15	5.23	4.14	3.82	7.62	9.67	3.3	
Yield per ha (kg)	8,778	6,358	6,457	5,111	4,716	9,407	11,938	4,074
Price per kg (NT$)	28	28	28	28	28	28	28	28
Gross field benefit (NT$/ha)	245,778	178,025	180,790	143,111	132,049	263,407	334,272	114,074
Costs that vary (NT$/ha)								
Taiwan foil	16,500	16,500	16,500	16,500	16,500			16,500
Japanese foil						190,400	190,400	
Tameron insecticide	3,400	1,133	1,133	1,133			1,023	
Labor to apply Tameron	11,250	11,250	11,250				9,643	
Farnesene			na					
Neem				17,000				
Labor to apply Neem				11,250				
Whitewash					2,500			
Labor to apply whitewash					8,000			
Yellow sticky traps								5,000
Labor to install and remove traps								1,500
Total costs that vary (NT$/ha)	31,150	28,883	28,883	44,750	27,000	190,400	201,066	23,000
Net benefits (NT$/ha)	214,628	149,142	151,907	98,361	105,049	73,007	133,206	91,074

Table 7. Marginal analysis, first experiment[a]

Treatment	Total costs that vary (NT$/ha)	Net benefits (NT$/ha)	Marginal rate of return
1	31,150	214,628	
			2,889%
2	28,883	149,142	
			2,640%
5	27,000	105,049	
			1,516%
8	23,000	91,074	

[a]Calculations are based on an average hot pepper price of NT$28/kg.

Table 8. Hot pepper supplies and prices, 1987-92

Year	January		February		March		April		May		June		July	
	supply	price	supply	price	supply	price	supply	price	supply	price	supply	price	supply	price
1987	0.126	17.89	0.133	14.44	0.136	15.38	0.132	16.28	0.157	10.27	0.137	14.09	0.151	13.44
1988	0.128	35.95	0.131	23.49	0.141	22.02	0.160	18.48	0.145	34.30	0.149	35.59	0.170	27.34
1989	0.182	15.34	0.142	15.20	0.169	19.93	0.183	21.74	0.189	23.40	0.199	20.61	0.199	17.62
1990	0.120	48.32	0.153	19.20	0.165	21.60	0.179	21.53	0.168	25.56	0.151	41.49	0.132	53.66
1991	0.181	16.17	0.154	16.20	0.185	17.07	0.189	16.58	0.196	15.10	0.206	16.27	0.183	18.31
1992	0.154	64.88	0.096	58.97	0.119	59.12	0.108	55.86	0.153	36.70	0.163	41.60	0.186	20.84
c.v. (%)	0.17	0.56	0.14	0.64	0.15	0.58	0.19	0.56	0.11	0.39	0.15	0.41	0.13	0.53

Year	August		September		October		November		December		Inter-year cv		Annual average	
	supply	price	supply	price	supply	price	supply	price	supply	price	supply	price	supply	price
1987	0.114	21.65	0.128	20.92	0.106	24.42	0.107	34.33	0.106	43.41	0.13	0.45	0.128	20.54
1988	0.159	30.85	0.148	25.57	0.145	24.29	0.151	24.81	0.163	20.12	0.08	0.21	0.149	26.90
1989	0.171	18.92	0.129	40.04	0.091	116.97	0.082	96.48	0.099	67.41	0.27	0.85	0.153	39.47
1990	0.117	90.03	0.087	87.08	0.078	93.69	0.138	40.38	0.192	18.42	0.24	0.59	0.140	46.75
1991	0.173	33.95	0.170	18.31	0.154	24.86	0.145	58.54	0.177	29.72	0.10	0.52	0.176	23.42
1992	0.137	31.16	0.115	49.32	0.087	73.67	0.108	51.99	0.170	27.79	0.23	0.32	0.133	47.65
c.v. (%)	0.17	0.64	0.20	0.59	0.26	0.63	0.20	0.45	0.24	0.49			0.11	0.32

Note: Data are averages for two Taipei wholesale markets. Prices are in NT$/kg; supplies are in '000 tons.
Source: TAPTC: Monthly Report on Vegetable and Fruit Transportation (Chinese, various issues).

Table 9. Partial budget, second experiment

Treatment	1	2
Reported yield (kg)	4.79	5.72
Yield per ha (kg)	7,096	8,474
Price per kg (NT$)	30	30
Gross field benefit (NT$/ha)	212,889	254,222
Costs that vary (NT$/ha)		
Tameron insecticide	3,400	
Labor to apply Tameron	11,250	
Floating net		70,500
Labor to install and remove floating net		8,000
Total costs that vary (NT$/ha)	14,650	78,500
Net benefits (NT$/ha)	198,239	175,722

Note: treatment 2 is dominated.

Table 10. Marginal analysis, second experiment[a]

Treatment	Total costs that vary (NT$/ha)	Net benefits (NT$/ha)	Marginal rate of return
1	14,650	382,743	
			20.8%
2	78,500	396,048	

[a]Calculations are based on a hypothetical hot pepper price of NT$56/kg.

Conclusions and Recommendations

Current practices among Taiwanese hot pepper farmers to control the incidence of CMV and CVMV consist of mulching with a locally produced reflective foil in combination with a weekly application of Tameron insecticide (50% at 1:1000). A number of alternative control measures were evaluated in two separate field trials. The first trial involved the use of various combinations of foil, Tameron insecticide, biological insecticide, alarm pheromone, whitewash, and yellow sticky traps. The second trial tested the use of a floating net instead of Tameron insecticide.

An economic analysis was performed on the data of both trials. While in the first trial the treatment which reflects farmers' practice involved the highest cost among all nondominated treatments, the results revealed that the extra money invested is well spent, yielding a marginal rate of return exceeding 1500%. In other words, by saving some money in other nondominated treatments the farmer would forego the possibility of earning a return of over 1500% on those savings. Unless there exist alternative investments which yield more than 1500%, the farmers' current practice is preferred.

The data of the second experiment suggest that replacing Tameron insecticide with a floating net increases hot pepper yields by about 20%. However, the results of the economic analysis indicate that investing in a floating net is an attractive proposition only when hot pepper prices exceed the highly improbable level of NT$56/kg. Thus, the use of a floating net instead of chemicals to combat viruses is an effective management practice only from an environmental, not economic, point of view.

A number of reservations should be kept in mind when interpreting the results of the economic analysis as described above. The shortcomings of the analysis may be overcome for

future field experiments if their design would explicitly take into account the possibility of an ex-post economic analysis of the experimental data. First, partial budgeting analysis should ideally be performed on data from on-farm rather than on-station experiments, to let all nonexperimental variables reflect actual farmers' practices and conditions as closely as possible. This is particularly important where the ultimate goal of the analysis consists of making recommendations that are likely to be adopted by farmers. Since AVRDC leaves the on-farm evaluation of its technologies to its national partners, the results of its on-station experiments are mainly useful in guiding further research rather than making farmer recommendations.

Second, partial budgeting and marginal analysis should ideally be done over the pooled results of a number of locations, usually over more than one year and/or season. Only then can it be confidently predicted that the results are representative of a wide spectrum of conditions that farmers can expect to be confronted with. This will also allow for the possibility of a meaningful minimum returns analysis in which the average (across locations) of the lowest benefits for each nondominated treatment is compared to farmers' current practices. This gives farmers additional information about the variability in returns implicit in a proposed recommendation in comparison with farmers' current practices.

Third, for experiments to be evaluated from an economic viewpoint in a logical way, they should examine relatively few factors at a time. The various practices to be evaluated should ideally follow each other in a sequential and incremental manner across the different treatments. This will allow a meaningful marginal analysis of each individual treatment as well as of packages consisting of a number of different treatments. This is important in view of the fact that stepwise adoption of technological packages among farmers is a common phenomenon.

The Contribution of the Horticultural Sector Towards Taiwan's Agricultural Development: a Spatial and Temporal Analysis

Summary

The vegetable industry in Taiwan has been very successful over the course of the postwar era in ensuring an adequate supply of vegetables to consumers, while at the same time generating substantial foreign exchange earnings from high value-added agricultural exports and attractive incomes to Taiwan's many small farmers. The general objective of this study is to analyze the role of various government policies in promoting agricultural development and more specifically, the role of vegetable production and marketing in promoting economic development. Specific objectives include analyzing the determinants of spatial and temporal differences in horticultural cropping patterns; identifying physical and economic factors contributing to growth in vegetable production in Taiwan over the past 30 years; and distilling lessons for countries which consider similar paths towards agricultural development.

Introduction

The vegetable industry in Taiwan has been very successful during the postwar era in providing high value-added agricultural exports and attractive incomes to Taiwan's small farmers. Canned mushroom, asparagus, processed tomatoes, and frozen vegetable soybean are just a few of the individual success stories. In analyzing the reasons behind the success of Taiwan's vegetable industry, a twofold approach was taken. First, a spatial and temporal analysis of the determinants of the location of horticultural (i.e., vegetables and fruits) crop production in

Taiwan is under way. Second, case studies of various individual industries were prepared. This report addresses the first approach.

Materials and Methods

A township-level database (303 observations) (table 11) was constructed using secondary data for the years 1961, 1970, 1980, and 1990 which includes sown-area figures for nine major crop groups and various measures of market access. Least squares regression analysis will be applied with the percentage of total area sown to vegetables and/or fruits as the main dependent variable. A set of access variables will be used to explain the spatial variation in cropping patterns for each of the four years. The same set of variables will also be regressed against the changes in the same cropping pattern indicators over the following five years (e.g., 1961 access variables against cropping pattern changes 1961-65). In addition to identifying variables that are significantly related to high levels of horticultural crop production, marginal products will also be calculated. Using the distance to the nearest wholesale market as an example, the marginal product would give the percentage change in each of the cropping pattern indicators which could be expected from a one-kilometer change in this distance. GIS will be used to calculate distances to markets and help visualize temporal and spatial differences in cropping patterns.

Table 11. Database for the locational analysis of Taiwan's vegetable industry

Data item	Source
Sown areas by crop groups (1-9)	Taiwan Food Bureau
Distance to cities (1-7)	AVRDC, GIS
Population of cities (1-7)	Taiwan Statistical Yearbook
Distance to nearest fruit and vegetable wholesale market	Agricultural Wholesale Market Yearbook
Railway dummy	Ministry of Transport
Road density of county	Ministry of Transport
Percent irrigated area	Taiwan Agricultural Census
Percent area in each of 3 elevation classes	AVRDC, GIS
Percent area in each of 3 soil-type classes	AVRDC, GIS

Results and Discussion

The results of the analysis will be of use to policymakers in planning programs to support the development of horticultural crops, especially in the rapidly growing countries of East and Southeast Asia. As farmers begin to shift their land away from grain and other field crops and into horticultural crops, their main concerns change from being simply the provision of a scarce commodity to finding the best combination of modern inputs, ensuring proper postharvest handling, and monitoring markets for signals of changes in consumer demand. How best can government agencies support them in this effort?

The proper location of production areas is very important in this respect, including not just the selection of optimal growing conditions but also of areas with excellent infrastructure and easy access to processing facilities. At the national level, too, it is vital that countries choose crops that are appropriate to their endowment, e.g., lower-income countries with abundant and cheap labor should choose labor-intensive crops for which quality and processing requirements are not severely limiting factors.

Provision of proper infrastructure is another important element in a horticultural development program. But, specifically, how important is each type of infrastructure? Should governments invest in roads, railways, wholesale markets, or irrigation systems? How important are such unchangeable factors such as distance to cities, elevation, and soil type? The present study can aid decisionmakers in dealing with these problems by providing policymakers with answers as to how strongly each of these factors were associated with greater allocation of land into vegetable and fruit production over the course of Taiwan's fast-growth era. If a particular type of supporting factor is deemed essential to commercial horticultural crop production, the government can respond either by investing public funds in the provision of what is lacking or by targeting programs to areas already well supplied with what is needed.

A Case Study of the Mushroom and Asparagus Industries in Taiwan

Summary

The vegetable industry in Taiwan has been very successful after the war in providing high value-added agricultural exports and attractive incomes to Taiwan's many small farmers. Canned mushroom and asparagus, representing two of the outstanding success stories, were the subject of individual industry case studies. The major objectives of these studies were to analyze the factors responsible for the success of the mushroom and asparagus industries and to distill lessons for countries which consider similar paths towards agricultural development. Taiwan's experience suggests that, while production, processing, and marketing of high value-added agricultural produce is best left to individual farmers and the private sector, there exists an important facilitative role for the government which should develop appropriate support policies in the areas of input supply, credit, extension, and marketing. Moreover, government regulations and risk-reducing measures can ensure optimal location of production and processing, and stimulate farm-level adoption of new crops during the initial learning period. Finally, nonstandard, independent, and flexible organizational approaches with active farmer involvement are important for successful rural development.

Introduction

The development of the canned mushroom and asparagus industries in Taiwan are famous examples of successful agricultural development policies. Neither had been grown in Taiwan before the 1950s; in fact, both crops had been considered unsuitable to the subtropical conditions of Taiwan. Yet, after cultivation methods were devised, both diffused rapidly across the island with local farmer associations teaching the new skills involved. Since both crops were very labor-intensive while requiring little in the way of either capital or land, average farmers were able to adopt the crops and gain an important supplement to family incomes. Moreover, mushroom had the important additional trait that it was a winter (i.e., off-season) crop.

The spread of mushroom cultivation was able to make use of another available resource as well. Under the Japanese occupation an extensive network of canneries had been built, and prewar exports of canned pineapple had reached a peak of 1.6 million cases. After World War II the industry at first went into a sharp decline, but by the late 1950s it had reached new highs. When not being used to can pineapple, the same plants could be used to process mushroom with only minor adjustment. The export of canned mushroom grew from 147,000 cases in 1961 to over 2 million before the end of the decade (table 12). The same kind of explosive growth occurred with

Table 12. Production and marketing statistics for mushroom

Year	Sown area (1000 m²)	Output (m.t.)	Yield (kg/m²)	Exports (1000 of standard cases)	Price to farmer (NT$/kg)	Export price per case (US$)
1961				147	14.5	12.3
1962				709		
1963				1378		
1965	8565	32430	3.79	1606	13.5	12.8
1968	12530	52400	4.19	2320	15.0	13.1
1971	11788	57422	4.87	2958	15.0	15.6
1976	5463	51992	9.52	2671	17.0	20.8
1981	6437	66947	10.40	1948	25.5	27.9
1984	4274	54562	13.94	2785	25.5	27.7
1989	2109	27359	12.97	1033	26.5	25.9
1991				455		

Source: Cols 1, 2 and 3: Provincial Department of Agriculture and Forestry.
Col 4: Taiwan Canner's Association.
Cols 5 and 6: Hsiung (1990), pp. 88-89.

canned asparagus, followed only a few years after by mushroom (table 13). By the late 1960s, the two crops together accounted for 18% of Taiwan's agricultural exports (table 14).

Materials and Methods

The case studies for mushroom and asparagus drew on secondary information in both Chinese and English, as well as on interviews with knowledgeable individuals, to analyze the determining factors behind the growth of each industry and draw implications for agricultural development policies (Luh 1965).

Results and Discussion

Mushroom

In the early 1950s canned mushrooms from Japan or France were an expensive imported item in Taiwan. Beginning in 1953 the Joint Commission on Rural Reconstruction (JCRR) in collaboration with the Taiwan Agricultural Research Institute (TARI) initiated trials to see if the white or French mushroom (*Agaricus campestris*) could be grown locally. The goal was to find a method of cultivation which did not rely on techniques beyond the reach of the average farmer—such as air-conditioned mushroom houses. Initial experiments in abandoned mines using horse manure, the standard growing media for mushroom, were encouraging. There are very few horses in Taiwan, however; so efforts focused on developing an artificial compost. After many failures, research workers at TARI succeeded in developing a compost made from rice straw and chemical fertilizer (a mixture of N, P, and K). Huts made from bamboo and rice straw were used as growing sites.

After the second rice crop, the farmer could construct his mushroom hut and mix the compost using a few simple locally available ingredients. Mushroom culture quickly became a small but profitable business in the northern and central parts of the island. They were marketed locally as a fresh vegetable; at first at a very high price (NT$ 32 per catty), but later as more farmers entered the market the price fell to 30-60% of its peak level. By 1959, 6000 t were being produced.

Table 13. Taiwan's annual production and marketing statics for asparagus

Year	Sown area (ha)	Output (m.t.)	Exports (standard cases)	Value of exports (US$)	Canneries	Townships	Collection stations	Price to farmer (NT$/kg)	Export price per case (US$)
1964	270	616	33,244	410,952	43			12.80	12.36
1965	9,535	16,776	801,039	11,047,654	73			16.10	13.79
1966	10,877	44,120	916,328	14,218,221	113	75	113	8.20	15.52
1967	8,002	31,010	1,744,509	23,956,381	130	103	154	8.30	13.73
1968	6,385	51,583	2,136,386	28,827,137	163	99	103	12.60	13.49
1969	8,315	67,679	3,353,314	38,866,254	161	71	100	9.20	11.59
1970	12,588	112,331	3,723,417	35,573,382	161	116	150	9.70	9.55
1971	17,456	127,517	4,017,814	35,043,829	159	110	196	7.70	8.72
1972	15,918	106,602	3,376,303	39,630,331	121	32	240	9.00	11.75
1973	16,146	112,477	3,741,974	55,207,178	116	31	240	11.05	14.75
1974	17,355	111,146	3,493,318	84,826,979	104	76	238	16.30	24.28
1975	17,636	80,113	3,659,566	78,893,259	99	68	234	16.30	21.56
1976	12,936	93,986	3,899,449	97,020,879	94	59	205	18.50	24.88
1977	13,741	102,117	2,835,369	79,103,052	78	58	204	21.11	27.89
1978	13,583	97,393	4,344,340	117,870,770	68	57	195	21.11	27.13
1979	11,754	101,520	3,773,612	119,121,938	66	54	191	22.50	31.58
1980	12,428	112,871	3,937,816	135,658,724	65	52	192	24.70	36.13
1981	12,369	81,338	3,057,606	101,171,746	63	46	172	24.70	34.50
1982	11,236	52,808	2,656,715	88,183,571	62	44	175	25.70	32.60
1983	9,500	45,638	1,758,927	60,878,623	58	33	137	27.70	34.61
1984	9,400	54,143	1,665,485	60,716,515	54	32	130	27.70	36.46
1985	9,903	62,068	1,136,122	35,833,287	49	30	124	27.70	31.54
1986	9,326	41,836	2,055,634	62,612,425	47	27	112	26.20	30.46
1987	5,046	13,706	561,153	22,972,762	34	24	113	27.70	40.94

Source: Liu, Tai-Sheng. 1988. Luhsun ch'anhsiao kungtso paokao (report on asparagus production and marketing work). Proceedings of the fourth symposium on asparagus research in Taiwan, Tainan DAIS, Tainan, Taiwan.

Table 14. Percent of Taiwan's total agricultural exports — annual average

	1962-66	1967-71
Mushroom	7.1	9.8
Asparagus	1.8	8.2

Source: Lee, T.H. and Chen, Y.E. 1974. Diversification of agricultural exports, in T.H. Shen, ed. Agriculture's place in the stategy of development: The Taiwan experience, Joint Commission on Rural Reconstruction. Taipei.

In 1960, a tour group which included three members of the JCRR, a representative of the canners' association, and two government officials traveled to Europe and the United States to study production and marketing issues. A pilot-scale operation was set up that same year with designated local farmer associations providing mushroom to contracted canners. This led to the initial export of 130,000 cases which were well received by overseas buyers. Within a few years, mushroom exports had reached 2 million cases, a level that was maintained for over 20 years (table 12). Mushroom cultivation diffused so rapidly across the island that by 1964 over 47,000 households (or 10% of all farm households) were engaged in mushroom growing. Eventually, mushroom was grown in all areas of the island, except for the high mountains and the east coast.

The geographical concentration of mushroom exports has always been very high. In the 1960s, Germany and the United States took about 80%, with Germany having the larger share. By 1974, the United States was the major buyer and Germany's share was falling very rapidly. By 1979, North America purchased 68% of exports, and by 1986, 79%.

Once the industry was in place, government involvement continued on several levels: regulation of production and processing, continuing research into improved techniques, and (beginning in 1962) institution of the planned production and marketing system. The inspection and grading of fresh mushrooms were done at collection centers scattered around the countryside. These were run jointly by representatives from the local farmer association and the contracting canner. The standards used, however, were set by the Provincial Department of Agriculture and Forestry (PDAF). At the canneries, government inspectors examined the product before and after canning. The government also regulated the spawn houses.

Continuing research was carried out by TARI (financed out of the government budget) and by the Food Technology Center of the Taiwan Pineapple Corporation (a private corporation). Topics of research included selection of desirable strains, improvements in the performance of synthetic compost, and pest control techniques. For example, eight strains were introduced with the goal of finding which was best suited to the local conditions in each of the island's mushroom-growing areas.

Developing a better synthetic compost was the single most important research issue. In 1963, mushroom yields in other producing countries ranged from 5 to 15 kg/m^2, while Taiwan at this time was averaging less than 4 kg/m^2 (table 12). The major reason for this difference was the insufficient application of spawn and reliance on synthetic compost in Taiwan. Moreover, since horse manure, where it was readily available, was much cheaper than synthetic compost, Taiwan growers were at a cost disadvantage in this regard. Researchers focused on both improving the compost formula and disseminating preparation techniques to farmers. Yields continued to improve gradually right up to the late 1980s (table 12).

The final government intervention was perhaps the most significant, and certainly the most surprising. In 1962, at a time when rapid expansion of output had led to downward pressure on prices, a system of planned production and marketing was introduced. Each year total demand was projected for the next year, then each cannery was assigned a quota based on its share of the

previous year's output. Each of the canners would then contract with the farmer associations in their locality to provide the needed supply of mushroom. Prices were determined through collective bargaining between the canners and the farmers under government arbitration, with contracts signed before the crop was planted. This system froze out areas where production had not yet started. The system was maintained until 1990, and was even extended during that time to include asparagus, bamboo shoots, and pineapple. Taiwan's mushroom industry dealt with world markets as a cartel, all canners citing a single price.

Yet another part of the planning system was the control of the manufacture and distribution of the empty cans. The Provincial Materials Bureau carried out the importation of tin plate on a unified basis and allocated it to the 10 or so can makers. A single processing price was established, and canners could purchase empty cans as they saw fit. The purpose of the system was to assure the quality of the cans (which had been a real problem in the 1950s) and to provide a guaranteed supply. However, the system may also have contributed to the high costs of Taiwan's canning industry. This system too was only brought to an end in 1990.

The policymakers who instituted the planning system on the mushroom industry were deeply suspicious of unfettered, free markets, which could arbitrarily impose large gains or losses on persons which might bear no relation to the social worth of the activity they were engaged in.

Asparagus

Beginning in 1955, the JCRR assisted the Taipei District Agricultural Improvement Station (DAIS) in introducing several varieties of asparagus for test planting. It was soon discovered that the cultivation techniques used in temperate regions were not suited to Taiwan. After a series of experiments, the mother-stalk method was successfully developed. The first commercial growing began in 1958 when two hectares were planted near Changhua.

In 1962 the Taiwan Asparagus Corporation was formed and began to make arrangements for contract growing with individual farmers. A year later 441 t of white asparagus were harvested and 335 cases test-exported. As with mushroom, the reception was favorable and production sky-rocketed: 800,000 cases were exported in 1965 and over 3 million in 1969 (table 13). Exports remained at 3 to 4 million cases per year until 1982. The market for Taiwan's asparagus was even more concentrated than that for mushroom. Germany took between 60 to 75% in almost every year, with most of the remainder going to other European countries.

Asparagus production was concentrated in the west-central part of the island, especially in the valleys of six small rivers. The sandy soils found in these areas were low in fertility, and were thus unsuited to most other crops. However, asparagus culture in Taiwan relied on much higher rates of fertilization than found in other countries; and in sandy soils fertilizers are easily leached. On average, 4 t/ha of chemical fertilizer were applied each year, and in some areas as much as 10 t/ha were used. In addition, various organic fertilizers were also applied at a rate of 30 t/ha or more. The result of all these nutrients were yields that were about double those found in the United States at around the same time. Another reason for such high yields was that the extended warm weather in Taiwan enabled two harvests per year. Initially, harvesting had been confined to the March to June period only, since the high temperatures of July and August shifted the plants' metabolism towards respiration, decreasing shoot development. Beginning in 1968, however, a second harvesting was carried out in the fall (September-November), greatly increasing the yield (table 13).

The involvement of government agencies in regulating the industry was similar to that of mushroom, except that the organization of the industry appears to have taken a little longer. By 1970 there were 160 factories packing asparagus, and competition among them had driven the

export price of a case down from over $15 in 1966 to about $9 (table 13). Importers of Taiwan asparagus held off buying in hopes of further price cuts, and so the factories had to cut back on their purchases of fresh asparagus from the farmers. As a result, starting in 1972, asparagus farmers and canners were placed under the planned production and marketing system. For similar reasons, the pineapple industry was also placed under the system in that same year, and bamboo shoot in 1980.

In 1979 the various existing government regulations were brought together in a single law: Methods for the Planned Production and Marketing of Mushroom, Asparagus, and Pineapple for Export. The International Trade Division of the Economics Ministry, in consultation with the relevant parties, was responsible for projecting the next year's total production. This was then allocated to the various canners on the basis of their share of the prior year's output. The actual method used was that each canner's quota was adjusted up or down based on 50% of their relative share of the previous year's total output and 50% on the average output per canner. Quotas were transferable via sale, but only to canners who met the Economic Ministry's standards for the product, and only after the PDAF had given its consent (to assure regional balance). Thus, by limiting entry the government created economic rents for those canners who had been fortunate enough to start processing a product before regulations were imposed. That is, they were assured a profit above that which a free market would have provided and, thus, could sell their place in the quota system to an outsider at a substantial premium.

The advantages usually cited for the system are the stability of prices, the stability of incomes for farmers and a guaranteed supply for canneries. Certain drawbacks of the system also seem very clear, among which is a general loss of responsiveness to competitive pressures. In addition, the fact that Taiwan reported a single price each year meant that other countries only had to undersell Taiwan by a little to be sure of a market for their products. Taiwan became the price protection umbrella of the entire world.

Another problem with the system was that since canners and growers were protected from competition, products of inferior quality were sometimes produced. In theory, this could be dealt with through grading standards, but given the inherent degree of subjectivity in the grading process, problems could still be expected to result. Another potential issue was how quotas were distributed within the townships by the local farmer associations.

Despite these problems, Taiwan totally dominated the world's canned asparagus industry for nearly 20 years, and was the single largest exporter of canned mushroom for nearly as long. To claim that a significantly better performance might have been forthcoming if the government had been less intrusive seems doubtful. By the 1980s, Taiwan's comparative advantage was shifting away from labor-intensive goods due to rapidly rising wages and the sharp appreciation of the NT$ in 1987 (from 42 to 28 per US$).

Conclusions

The major conclusion from the mushroom and asparagus case studies is that it is certainly possible to achieve considerable success in the production and export of high value-added horticultural crops using programs aimed at many small, dispersed farmers. In terms of its use of idle labor, the low levels of investment and land needed, its impact on Taiwan's income distribution, and its generation of foreign exchange, mushroom cultivation was virtually an ideal agricultural development policy. Asparagus was perhaps slightly less so. First of all, this was because asparagus was not a winter crop, so its labor demands overlapped with agricultural busy periods; although it also made use of a relatively idle resource (sandy bottom land). Secondly, asparagus concentrated in a particular geographic area (the river basins of the west-central coast)

and, thus, was not available to everybody. As a result, mushroom cultivation, compared to asparagus, diffused much more widely across the island.

In terms of guidelines to policymakers in contemporary less developed countries, Taiwan's experience with the development of the mushroom and asparagus industries offers the following lessons:

- In developing export crops, it is important to choose areas with well-developed infrastructures. In Taiwan, even relatively easy traveling crops such as mushroom and asparagus were not cultivated to any significant extent in regions with poor transport infrastructure or without nearby canners. The promotion of high value-added export crops is not an appropriate development policy for poor and remote areas.
- Access to international markets is essential in providing farmers with an attractive and relatively stable income which, in turn, acts as an important incentive to adopt new crops.
- Export marketing of agricultural produce is best left to the private sector, including multinationals. The processing and marketing of horticultural products requires a sophistication and responsiveness to consumers' needs that state agencies often cannot provide. Taiwan relied to a large extent on foreign firms to do the overseas marketing of its products while cultivation, collection, and processing systems were left to domestic agencies.
- After land reform in Taiwan was completed in the early 1950s, 90% of farms were less than 2 ha in size. Taiwan, thus, relied entirely on many small, dispersed growers to supply the canners with mushroom and asparagus. Experience shows that this may be preferable to focusing on relatively few large growers, if the right kinds of crops are selected for promotion — labor-intensive using relatively little capital or land.
- Support farmers with 'one-stop' programs for inputs, credit, extension, and marketing. Horticultural crops will generally be more input- and skill-intensive than most field crops. The more individual suppliers that farmers have to seek out to put together the needed package of support services, the less likely they are to adopt a new crop.
- Risk-reduction measures should be included in government programs aimed at assisting farmers. The theme of risk reduction is a recurrent one in Taiwan's agricultural development. Risk-reduction measures should be of a temporary nature to help farmers overcome the initial learning period.
- Finally, the importance of nonstandard, independent, and flexible organizational approaches needs emphasizing. The farmer associations were run by the farmers themselves and much more likely to be trusted than a top-down government agency. The JCRR's independence was ensured by the fact that its funding source was American aid rather than the government budget. The experts on its staff had the right to put money into projects without the need for prior approval of any government agency. Together these organizations were carrying out integrated rural development long before the concept was promoted in the development literature.

Adoption of AVRDC-developed Technologies: Bacterial Wilt-Tolerant Tomato Varieties in Taiwan

Summary

A survey among 46 summer tomato growers in Nantou county, Taiwan, was carried out in the summer of 1992 by AVRDC in cooperation with the Puli branch of the Taichung DAIS. The main objective of the survey was to assess the extent of adoption of AVRDC-developed tomato varieties which are moderately resistant to bacterial wilt (BW). The results indicate a nearly complete adoption of ASVEG varieties which, compared to KY varieties, are more tolerant to BW. A few shortcomings of the survey are pointed out.

Introduction

Fresh-market tomato is one of the most important cash crops of the summer season in Taiwan. Because of high temperatures during the summer months, these tomatoes can be grown only in the mountainous areas of central Taiwan. Consequently, supply of fresh-market tomatoes during summer falls significantly short of demand, resulting in very high prices to growers — about 17 times the price of canning tomatoes in 1990.

The bacterial wilt disease, caused by *Pseudomonas solanacearum*, is consistently one of the most important problems of tomato growers in subtropical and tropical regions. It is so difficult to control that it frequently destroys from 50 to 90% of a tomato crop. Research on host plant resistance has been one of the primary means of seeking to control this disease. In 1989 and 1990, two AVRDC-developed hybrids (Taichung ASVEG No. 4 and Hualien ASVEG No. 5, hereafter referred to as ASVEG varieties) were released in Taiwan. These varieties had been rated moderately resistant to bacterial wilt in regional yield trials. In surveys of farmers' fields made during the summer of 1990, the average incidence of wilt was only 22% for the two ASVEG varieties, vs. 55% for all other varieties (KY 301 or 501 from the Known You Seed Company, hereafter referred to as KY varieties).

Materials and Methods

A survey questionnaire was prepared and translated into Chinese. The survey asked farmers for the details of all their costs and revenues from growing fresh-market tomato, as well as to report the size and wilt incidence of each field. Farmers were asked specifically to give their costs for seeds, fertilizer, agricultural chemicals, tractor usage, irrigation, and hired labor; they were also asked to report all other relevant costs as well, including packaging and marketing. The survey was tested in June 1992 by interviewing some farmers in Nantou county, with the main survey carried out in July and August of the same year. Most farmers were interviewed in person, even though some were approached by mail. The identification of respondent farmers was left to the Puli branch of the Taichung DAIS. An attempt was made to reach as many growers as possible without in any way identifying a priori which tomato varieties they were growing. Follow-up calls were made to all growers in January 1993 to assess their final sales and profits from fresh-market tomato. A total of 46 completed surveys were obtained; 29 from farmers exclusively growing ASVEG varieties, four from farmers exclusively growing KY varieties (reflecting the difficulty of finding them), and the remaining 13 from farmers growing both ASVEG and KY varieties. Only farmers who exclusively grew either ASVEG or KY varieties were retained for further analysis, since it turned out to be impossible to split total input expenditures among each variety.

Results and Discussion

The most significant result of the survey is that nearly 2/3 of farmers growing summer fresh-market tomato were using exclusively ASVEG lines, while only 10% was using only KY varieties. Since the ASVEG varieties were released only 2 to 3 years ago, this indicates very fast adoption, reflecting a strong preference among summer tomato growers for ASVEG varieties. A direct result of this strong preference was that the survey team had great difficulties identifying summer tomato growers who did not grow any ASVEG variety at all, resulting in a very low sample size for this group.

The survey results suggest some of the reasons behind the farmers' rapid adoption of ASVEG varieties. The mean profit (defined as revenues minus variable costs but excluding labor and land costs) per 0.1 ha for those planting only ASVEG varieties was a little over NT$ 73,000 vs. only NT$ 3,600 per 0.1 ha for those growing KY varieties (table 15). This difference is exaggerated by the fact that one of the four KY growers had both a 50% incidence of bacterial wilt and labor costs greatly beyond the average. If this particular farmer is excluded, the remaining three KY growers earn an average return of nearly NT$ 95,000/0.1 ha. This compares with an average return for the ASVEG growers of just over NT$ 80,000/0.1 ha if the four growers with the highest incidence of bacterial wilt are excluded from this group. The significance of this difference is difficult to determine given the small sample size of KY growers. However, there are seven growers in the ASVEG group who have profits exceeding that of the highest KY earner.

Table 15. Costs and returns of summer tomato in Taiwan

	ASVEG growers (n = 29) Mean	c.v.	KY growers (n = 4) Mean	c.v.
Total sales (kg/0.1 ha)	5817	0.51	5679	0.58
Average price (NT$/kg)	22.2	0.18	20.5	0.05
Total revenue (NT$/0.1 ha)	131643	0.57	113138	0.57
Total cost (NT$/0.1 ha)[a]	58385	0.45	109543	0.92
Total profit (NT$/0.1 ha)[b]	73258	0.99	3595	44.47

[a]Excluding labor and land costs.
[b]Returns to land, labor, and management.

Why did some farmers continue to grow KY varieties? Farmers were asked their reasons for choosing a tomato variety (table 16). Note that in both groups 80% of the farmers gave wilt resistance as among the reasons for choosing their variety. This would seem to indicate that the four KY farmers were unaware of the existence of the ASVEG lines. As to whether differences in the price of the fruit or in marketable yield were factors in favor of the KY varieties, here too the differences are slight. In fact, overall the pattern of responses between the two groups is so similar that there is a better than 90% chance that they were drawn from the same distribution (chi-square test).

As to why the KY farmers were still unaware of the ASVEG lines, some insights emerge when farmers were asked to name their main sources of farming information (table 17). Here the overall pattern of responses were different enough that there is only one chance in four that they were drawn from the same distribution. The major differences were that ASVEG growers rely relatively more on television and government departments, while the KY group relies significantly more on private companies. Thus, relying on KY seed dealers for information has resulted in this

Table 16. Reasons for choice of tomato variety[a]

Reasons	No. of ASVEG respondents	Proportion of ASVEG respondents	No. of KY respondents	Proportion of KY respondents
1. Availability of seed	11	0.38	1	0.25
2. Price (cost) of seed	9	0.31	1	0.25
3. Disease resistance of plant	26	0.90	4	1.00
4. Pest resistance of plant	11	0.38	2	0.50
5. Bacterial wilt resistance	24	0.83	3	0.75
6. Heat tolerance of plant	14	0.48	3	0.75
7. Plant structure (ease of picking, etc.)	6	0.21	2	0.50
8. Fruit characteristics (color, flavor, size, etc.)	15	0.52	2	0.50
9. Resistance to cracking	11	0.38	2	0.50
10. Firmness, storability	14	0.48	2	0.50
11. Market price of fruit	14	0.48	2	0.50
12. Marketable yield	22	0.76	3	0.75
13. Other	1	0.03	0	0.00

[a]Number of farmers replying "important".

Table 17. Source of farming information[a]

Sources	No. of ASVEG respondents	Proportion of ASVEG respondents	No. of KY respondents	Proportion of KY respondents
1. Television	9	0.31	0	0
2. Newspapers	7	0.24	1	0.25
3. Radio	6	0.21	0	0
4. Private companies	7	0.24	2	0.50
5. Other farmers	22	0.76	2	0.50
6. Government departments	15	0.52	0	0
7. Parents	5	0.17	0	0
8. Farmers' associations	19	0.66	2	0.50
9. Other	0	0.00	0	0

[a]Number of farmers replying "important".

group of farmers initially being unaware of the superior ASVEG lines. However, this temporary information problem is rapidly being overcome as virtually all summer tomato growers in the survey area are switching to ASVEG varieties.

The final set of questions dealt with the main growing constraints for tomato (table 18). Bacterial wilt was mentioned by 72% of all farmers, as well as by 72% of ASVEG growers. Thus, even despite the clear benefits stemming from the widespread adoption of the more tolerant ASVEG lines, bacterial wilt remains a serious problem. Only high variability of tomato prices was cited by more farmers as among their major concerns. As might be expected, the availability of labor was cited by more than half of the farmers as a problem as well.

Conclusions and Recommendations

The major result of the survey is the high appreciation among Taiwan's summer tomato growers for the bacterial wilt tolerance of ASVEG varieties. This is demonstrated by the rapid adoption of these new lines.

Still there were some problems with the data collected by the survey, which should be kept in mind by future researchers. First, since tomato was usually only one crop among two or three to be grown on the same plot over the course of a year, quite a few farmers did not know how much fertilizer they had used specifically on their tomato crop. Their expenses had to be estimated by

Table 18. Main tomato growing problems[a]

Type of constraint	No. of ASVEG respondents	Proportion of ASVEG respondents	No. of KY respondents	Proportion of KY respondents
1. Availability of credit	2	0.07	2	0.50
2. Availability of land	6	0.21	3	0.75
3. Availability of labor	13	0.45	4	1.00
4. Weeds	7	0.24	1	0.25
5. Insect pests	13	0.45	1	0.25
6. Disease	19	0.66	4	1.00
7. Bacterial wilt	20	0.69	3	0.75
8. Soil fertility	12	0.41	2	0.50
9. Soil erosion	9	0.31	1	0.25
10. Availability of vegetable prices	20	0.69	4	1.00
11. Availability of fertilizer & chemicals	17	0.59	2	0.50
12. Availability of seeds	11	0.38	1	0.25
13. Availability of information	10	0.35	1	0.25
14. Other	0	0.00	0	0.00

[a]Number of farmers replying "important".

taking the average fertilizer costs per unit area over those farmers who did report their expenses. Similarly, a number of respondent farmers had used ASVEG on some of their plots and other varieties on the remainder. None of these farmers were able to report separate expenses for the different lines they were using and they had to be dropped from further analysis. In the future when planning surveys of an individual vegetable crop, which is likely to be relay- or multicropped, it is advisable to contact the farmers ahead of time and enlist their assistance. If they could be convinced to keep separate accounts by crop, and by variety if appropriate, much more useful information could be gathered.

Second, the difficulty with which farmers could be found who still grew exclusively non-ASVEG lines resulted in a very small sample size for this group. In the future, it is desirable to ascertain by talking to extension workers and others in frequent contact with farmers whether each of the desired target groups does, in fact, exist. There was just enough usable data from this survey to be able to make the desired comparisons. However, the results are subject to an unknown, but probably relatively large, amount of error.

Household Gardens in Bangladesh and Indonesia

Summary

Two case studies were carried out on household garden characteristics, benefits, and constraints using existing data sets for Bangladesh and Indonesia. The Helen Keller International (HKI) household garden project in Bangladesh has led to full adoption of gardens among its target households resulting in significant measurable educational, nutritional, and health benefits. However, the economic sustainability of the project remains rather uncertain.

In Indonesia, gardens have traditionally played an important role in household food supplies despite significant regional variation in their relative importance. Household gardens have enjoyed renewed attention in the light of the government's Food and Nutrition Diversification

Project. Analysis of two data sets (one cross-sectional and one longitudinal) for a number of provinces is currently under way.

Introduction

Helen Keller International initiated a household garden and nutrition education project in 81 villages in northern Bangladesh in 1990. It requested the assistance of AVRDC for the production and socioeconomic analysis component of the midterm evaluation of the project (HKI/AVRDC 1993[18]).

In Indonesia, household garden development has a much longer history than in Bangladesh. The government of Indonesia has sponsored numerous household garden intensification projects over the last 10 to 15 years. The current attention on household garden development stems mainly from its potential role in the ongoing Food and Nutrition Diversification Project sponsored by the Ministries of Agriculture and Health. AVRDC cooperated with researchers from the Center for Agro-Socioeconomic Research (CASER) in analyzing two sets of survey data.

Materials and Methods

Detailed household level data in Bangladesh were available from: (1) a baseline survey carried out at the beginning of the project, (2) a midterm evaluation survey carried out 2 years after initiating the project, and (3) five monitoring rounds. Target (n = 1000), control (n = 200), and interaction (n = 100) households were interviewed for the baseline and midterm evaluation surveys, but only the target group was included for the monitoring rounds. The research design of the project, therefore, allowed comparisons over time between baseline and midterm (for target, control, and interaction) and among the target, control, and interaction groups at the time of the baseline and midterm surveys. Using detailed structured questionnaires, the midterm evaluation was carried out by multidisciplinary HKI teams consisting of a medical doctor, a sociologist, an agriculturalist, and a specialist at taking anthropometric measurements. The data were thoroughly verified before analysis took place.

The Indonesian case study is based on two sets of data, collected during 1983-89 (monitoring data from the transmigration project in Jambi) and in 1990-91 (cross-section data for four provinces). The latter data set will be used to explore interregional variations in basic household garden characteristics and land and labor productivity. The former data set will be used to assess household garden development over time in the same region.

Results and Discussion

Bangladesh

In the time between the baseline survey and the midterm evaluation, target households all adopted household gardens. At 138 m^2, average garden size nearly doubled during the period of intervention, while the average number of varieties grown throughout the year increased fivefold. This substantially increased vegetable availability throughout the year, particularly that of high vitamin A species including carrots, spinach, amaranth, and papaya. Average total garden production increased by over 60% between monitoring rounds 1 and 4. Similarly, household vegetable consumption increased significantly for the target group over baseline levels, from an average of 5.8 kg per week to an average of 7.4 kg per week. During the same period, vegetable

[18]HKI/AVRDC. 1993. Home gardening in Bangladesh. Evaluation Report. Dhaka, Bangladesh.

consumption for the control group did not change, remaining at 5 kg per week. Preliminary figures on intrahousehold consumption indicate that the project has had a positive impact on vegetable consumption by infants and very young children. As a result, the incidence of night blindness has declined from 2.3 to 1.2% in the target group. Also, children in the intervention group were less underweight as well as less stunted than children in the control villages.

Indonesia

While the data are currently being analyzed, preliminary results suggest that household gardens make an important contribution to household nutrition and income, though conditions vary widely across regions and even within villages. The relative importance of government interventions and variations in household decision-making with respect to resource allocation for variations in garden productivity will be determined. Using the monitoring data from the transmigration project in Jambi, particular emphasis will be given to identification and analysis of the factors underlying the transition from primarily subsistence garden cultivation to production for the market.

Conclusions and Recommendations

The HKI household garden and nutrition education project has been successful in increasing the year-round availability of particularly vitamin A-rich vegetables for a relatively large number of poor households in northern Bangladesh. As a result, vegetable consumption among target households has increased significantly and the incidence of a number of diseases, particularly night blindness, has diminished substantially. However, while the project has been successful from an educational, nutritional, and health point of view, its economic sustainability may be questioned. The total monthly benefits from savings on purchased vegetables and income earned from sale of vegetables are only 150 taka (1 US$ = 38 taka), an unknown portion of which can be considered as profits. On average, one hour per day is spent on gardening, resulting in an average benefit of only 5 taka per hour worked. After allowing for variable nonlabor input costs of vegetable production, returns to labor are nearly certainly lower than its opportunity costs. Even where no alternative employment opportunities are available, returns to labor of less than 5 taka per hour are likely to be significantly below an individual's value assessment of leisure time.

Analytical Laboratory

Processing Quality of Soybeans

Summary

Soybean is very rich in protein and oil which make it an important food commodity, especially in Asia. It is generally consumed after being processed. The most common soybean products are soymilk and tofu. Good quality in soybean is expressed by the protein recovery ratio in milk and gel yields after coagulation with calcium salt. Soybean samples of different varieties, harvest seasons, and storage periods were evaluated for their processing quality. Tannin, present in the seed coat, was found to be the major factor contributing to the poor processing quality of freshly harvested seed in good weather (fall). Prolonged storage, especially under higher temperatures and higher humidity, dramatically reduced the processing quality of soybean seed. It was demonstrated that the processing quality of soybean is negatively associated with the acid value (AV), peroxides (PO), and thiobarbituric acid value (TBA value); and positively correlated with phospholipids of soybean samples (R^2 =0.93 for protein recovery; R^2 =0.96 for gel yield). It was suggested that the poor processing quality of soybean seed is primarily due to oxidation of lipids and damage of biological membranes. This explains why the stored seeds generally have a higher conductivity to the soaking up of water. Analysis of soybean seed samples harvested at spring and summer seasons showed a high AV and PO. This result suggested that oxidation of lipids can be stimulated if the seeds are matured in the wet and hot season.

Near-infrared reflectance spectroscopy (NIRS) was used as an analytical tool to evaluate the quality of soybean seeds. Regression analysis suggested that NIRS was effective for rapid evaluation.

Introduction

Many food commodities derived from soybean are processed. Different processes usually require specific seed properties. High protein recovery and gel yield have been suggested as suitable properties for making soymilk and tofu. Prolonged seed storage may reduce the tofu yield and its quality. Experimental results indicate that some soybean varieties make good-quality tofu if they are used right after harvest; otherwise they deteriorated faster than other varieties and, consequently, the tofu quality is reduced. Soybean seed quality varied vastly among planting seasons. The soybean seed had a poor germination rate and storage property when it was harvested in the spring. It was not clear whether the physical and chemical properties affected seed germination.

Near-infrared reflectance spectroscopy (NIRS) has been successfully used as a routine method for compositional analysis of many crops in the Analytical Laboratory. This method proved to be a reliable, low-cost, tool for rapidly analyzing many samples.

This study aimed to evaluate factors affecting the processing quality of soybean such as tannin content in the soybean seed, variety planting season and storage conditions. NIRS was used to evaluate soybean seed quality.

Materials and Methods

Among 60 varieties of soybean seeds supplied by the soybean breeder, three were stored in the incubator at 30°C and 80% relative humidity (RH); and 20 varieties harvested from three seasons were stored in the laboratory at room temperature for 1 year.

Soybean seeds were immersed in water at 4°C for 16 h. The pH value, soluble solids, conductivity, and color value (b) (b is the degree of the yellow color) of seed soaked in water were measured under 25°C. The swollen beans were homogenized with water at a bean:water ratio of 1:9 in a Waring blender and clarified with suction filtration through cheesecloth to obtain the soybean milk. The protein recovery of soymilk was expressed as the percentage of protein in milk per total protein in the sample.

The tofu-like gels were prepared by heating 30 ml of soybean milk in a centrifuge tube above boiling water for 10 min. The soybean milk was poured into another tube which contained 2 ml of water and 200 mg of coagulant ($CaSO_4.2H_2O$). The gel-like texture was developed by incubating the milk at 85°C for 20 min. The tube was centrifuged at the rate of 4000 rpm for 10 min. The weight retained after discarding the supernatant was expressed as gel yield (g gel/g bean).

Hexane-extracted crude oil was premixed with an ether/ethanol mixture before it was titrated with KOH-ethanol solution for acid value (AV) determination. Peroxides were assayed by the ferric thiocyanate method. The crude oil was diluted and colorimetrically reacted with ammonium thiocyanate (30%) and ferrous chloride solution. The O.D. value of the mixture measured at 500 nm indicated the peroxide content. The crude oil was reacted with the thiobarbituric acid. The mixture was measured at 532 nm.

The Vanillin-HCl method was used to determine the tannin content in soybean seeds. Tannin content was measured as having an absorbance value of 500 nm.

An NIR system model 6500 was used in this study. The reflectance spectra, ranging from 400 to 2500 nm, were used for the statistical analysis.

Results and Discussion

Effect of tannin content on the processing quality of soybean

A vast difference in protein recovery (42.5 - 83.4%) was found among the tested varieties. Varieties with poor protein recovery were found to have high tannin content. Tannin is able to precipitate proteins with cross-linkage properties. The tannin content of the 60 varieties ranged from 5.0 to 98.5 mg/100 g. The correlation coefficient (r) between protein recovery and tannin in 50 samples was high at -0.81 (fig.1). This result showed that tannin is a major factor affecting the processing quality of soybeans.

NIRS was used because it is a good tool to rapidly evaluate the tannin content of soybean seeds. The regression coefficient (R^2) for calibration and prediction of standard error was 0.89 (fig. 2) and 0.64, respectively.

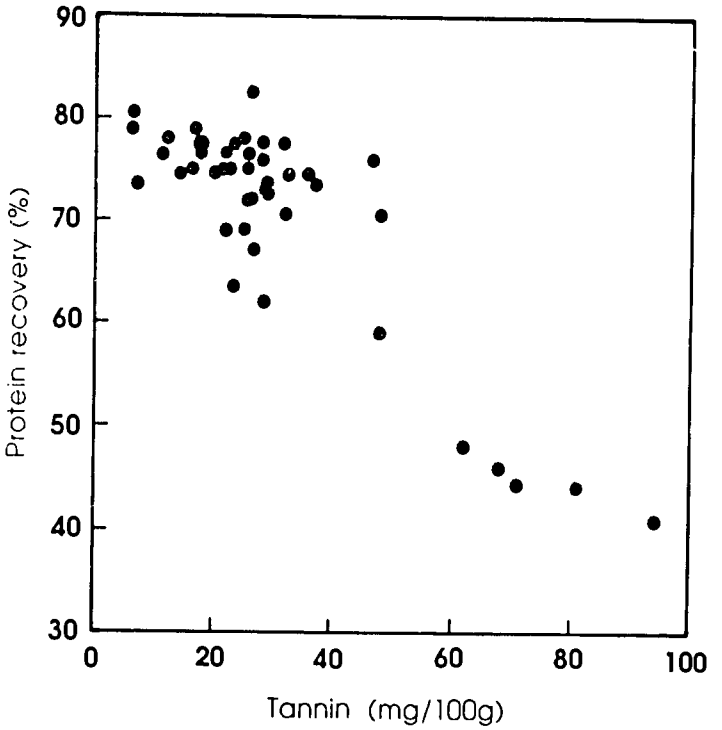

Fig. 1. The relationship between tannin content and protein recovery in soybean

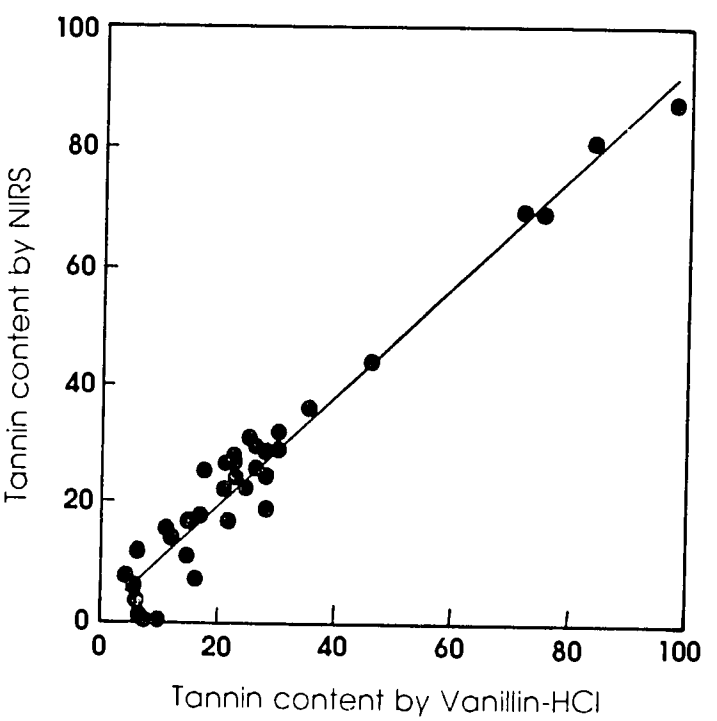

Fig. 2. The calibration curve of tannin content (mg/100 g) in soybean obtained by NIRS

Effect of storage on the processing quality of soybean

Three varieties of soybean, AGS 129, AGS 66, and PMT, were stored at 30°C and 80% RH for one year. Protein recovery and gel yield were dramatically reduced in seed varieties stored for 5 mo or more (fig. 3). Therefore, soybean storage conditions decreased not only the germination rate but also the processing quality. To investigate the lipid oxidation of soybean during storage, three varieties of soybean were used to determine the acid value (AV), peroxide (PO), thiobarbituric acid value (TBA value), and phospholipids (PL). The results revealed that the processing quality of soybean was negatively associated with AV, PO, and TBA values, and positively correlated ($R^2 = 0.93$ for protein recovery; $R^2 = 0.96$ for gel yield) with phospholipids of soybean samples (table 1 and fig. 4). Poor processing of soybean seeds could be primarily due to the oxidation of lipids and the damage of the biological membrane. This explained why the stored seeds generally have a higher conductivity in the soaking water.

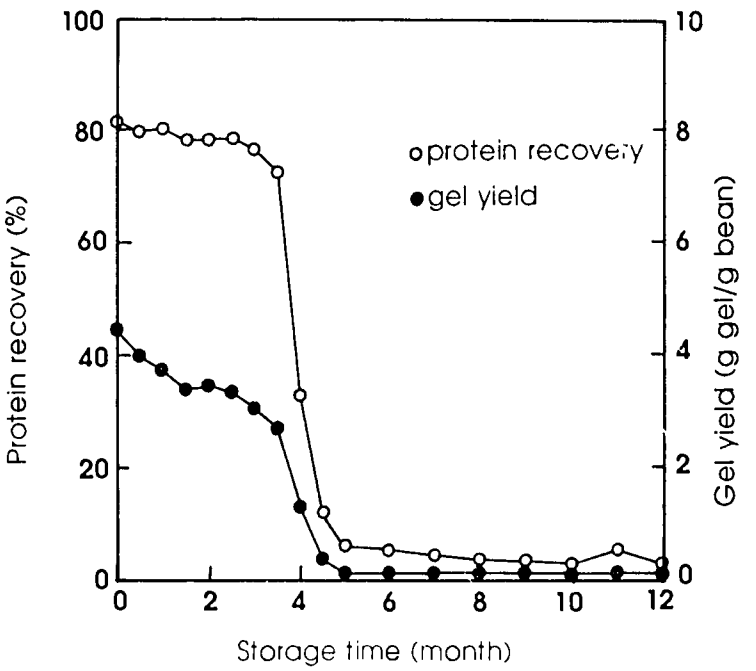

Fig. 3. The relationship between protein recovery and gel yield in soybean during storage

Table 1. The coefficient of determination between lipid oxidation and related factors by step-wise regression

Variable	R^2 of protein recovery	Variable	R^2 of gel yield
PL	0.934	PL	0.964
PL, PO	0.939	PL, AV	0.969
PL, PO, TBA	0.941	PL, AV, TBA	0.970
PL, PO, TAB, AV	0.943	PL, AV, TBA, PO	0.970

PL: Total phospholipids PO: Peroxides TBA: Thiobarbituric acid value AV: Acid value

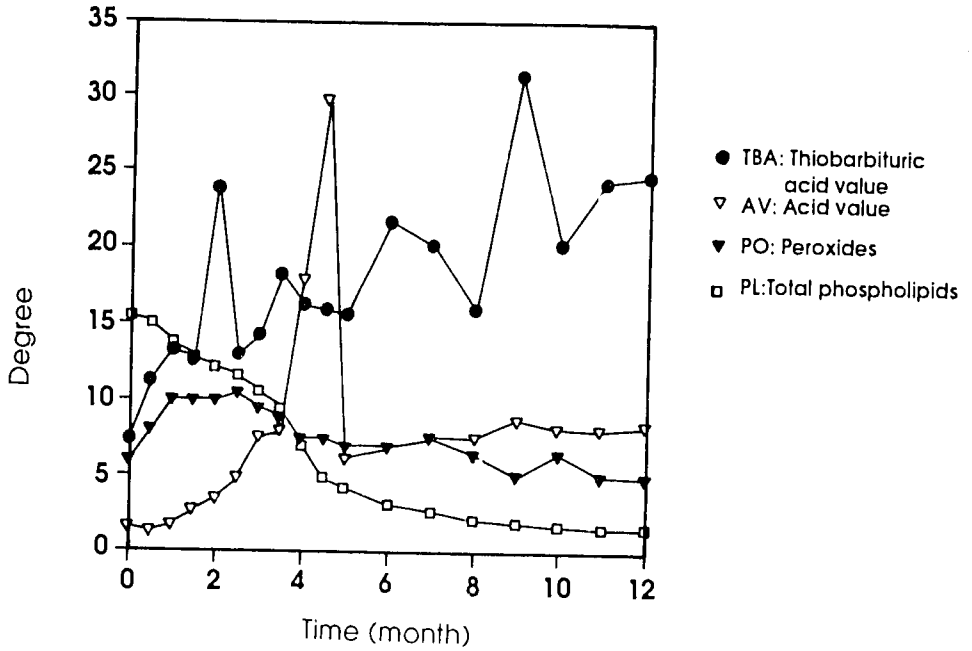

Fig. 4. Lipid oxidation of soybean during storage

Effect of planting season on the processing quality

Soybean seed harvested in the spring were found to have poor storage properties and germination rate. To investigate whether planting season affects processing, 20 varieties of soybean planted in spring, summer, and autumn were evaluated for processing quality. The soybean seed samples harvested in spring and summer showed a low pH, but high soluble solids and conductivity, and the soaking water was dark yellow before processing (table 2). Big differences were observed in protein recovery and gel yield among planting seasons. Analyses of lipid oxidation of soybean seed samples harvested at spring and summer showed the significant highest AV, PO, and TBA values, and the significant lowest PL (table 3). Soybean seed planted in the spring always matured in the period from June to July. June and July are characterized by a lot of rain and high temperature. This suggests that oxidation of lipid can be stimulated if the soybean seeds are matured in the hot and wet season.

Table 2. Processing quality differences at three planting seasons

Planting season	Soaking water				Soymilk			Gel yield (g gel/ g bean)
	pH	Soluble solids (°Brix)	Conducti-vity (M ohm)	Color (b value)	pH	Yield (ml)	Protein recovery (%)	
Spring	5.92b	0.7a	2.22a	- 0.8a	6.27b	13.8b	72.6c	2.37c
Summer	5.95b	0.4b	1.71b	- 1.58ab	6.52a	13.9b	77.1b	2.46b
Autumn	6.24a	0.4b	1.58c	- 1.60b	6.58a	14.3c	80.5a	2.97a

Means obtained from the 20 varieties.
Means followed by the same letter are not significantly different at 1% level (DMRT).

Table 3. Lipid oxidation of soybeans harvested in three seasons

Harvesting season	Acid value (mg KOH/g oil)	Peroxides	TBA value (mg/g bean)	Phospholipids (mg/100 g bean)
Spring	0.727	0.21	3.491	14.012
Summer	0.582	0.19	2.512	15.322
Autumn	0.426	0.12	1.472	17.695
LSD (1%)	0.205	0.03	0.275	2.012

Note: Means separation within columns at 1% level by DMRT.

Evaluation of processing quality of soybean by NIRS

NIRS was used to calibrate protein recovery and gel yield of 60 soybean varieties. The coefficients of determination observed were 0.92 for protein recovery and 0.93 for gel yield (table 4). The standard error of prediction (SEP) were 7.67 and 0.40, respectively, for protein recovery and gel yield. These results suggest that NIRS can be a potential tool to rapidly evaluate the processing quality of soybean samples.

Table 4. Statistical results of processing quality of soybean obtained using NIRS

Quality	Range	Calibration curve			Performance test		
		No. of wavelength	R^2	SEC**	R^2	SEP	Slope
Protein recovery (%)	9.30 - 83.61	4	0.92 (30)*	6.02	0.87 (29)	7.67	1.00
Gel yield (g gel/g bean)	0.23 - 4.85	3	0.93 (30)	0.31	0.89 (30)	0.40	0.98

*Values in parenthesis indicate the number of samples.
**Standard error of calibration.

Screening of Lipoxygenase in Soybean

Summary

Lipoxygenase catalyzes the hydroperoxidation of unsaturated fatty acids. It is a key enzyme in the lipid oxidation chain of soybean seed. This enzyme is responsible for the beany flavor of soybean milk and is possibly associated with soybean quality degradation in processing. To improve the processing quality of soybean, a breeding program was initiated at AVRDC to eliminate this enzyme using germplasm which lacks this enzyme.

It is known that there are three isozymes of lipoxygenase in soybean seed, namely, L-1, L-2, and L-3. They are controlled by different genes. An assay of all the three isozymes for progeny is, therefore, necessary to identify lines free from all of them.

Polyacrylamide gel electrophoresis (PAGE) has been tried by many scientists in separating these isozymes. However, no reliable method has been developed specifically for separating L-3 from L-2. A rapid colorimetric method with ferrous thiocyanate was adopted to determine L-2. Samples found free of L-2 were then further tested for L-1 and L-3 by electrophoresis. This system was found reliable using samples of known lipoxygenase patterns. As lx_2 is a single recessive gene, only 1/4 of the samples tested by colorimetric method required further analysis

by electrophoresis. The cost of analysis was thus dramatically reduced. It was demonstrated that 200 seed samples could be analyzed per day by one laboratory assistant. This method is nondestructive and requires only a small piece of cotyledon. The seed sample could be used for generation advance after analysis.

Introduction

Lipoxygenase is a dioxygenase that catalyzes, as a primary reaction, the hydroperoxidation of linoleic acid and other polyunsaturated lipids that contain a cis-cis-1,4-pentadiene moiety. The oxidation products are middle-chain aldehydes and alcohols associated with the development of undesirable grassy beany flavor and bitter taste in soybean products. The hydroperoxides formed by the enzyme reaction also oxidize the sulfhydryl groups of proteins in soybean homogenates, resulting in a decrease in gel-forming ability. On the other hand, the lipoxygenase may accelerate the rate of lipid oxidation and then reduce the storage life of soybean seeds. Therefore, the lipoxygenase actions are significant problems in the effective use of soybean seeds for human food.

Lipoxygenase normally exist in soybean seeds as three isozymes called lipoxygenase-1 (L-1), lipoxygenase-2 (L-2) and lipoxygenase-3 (L-3) that represent different gene products. They can be eliminated by breeding. Genetic studies have demonstrated that the absence of L-1, L-2, and L-3 from seeds is due to the operation of single recessive alleles, lx_1, lx_2, and lx_3, respectively; the lx_3 locus is independent of the lx_1 and lx_2 loci. And, the lx_1 and lx_2 loci are very tightly linked.

Several analytical techniques, such as SDS-PAGE, isoelectric focusing (IEF), activity determination, immunological method, carotene bleaching method, and ferrous thiocyanate method, had been developed for the identification of the three isozymes. However, no reliable methods were found individually suitable for separating L-3 from L-2. In this report, a more rapid procedure was developed for screening null-triple lipoxygenase seeds. It screens the L-2-lacking lines first by ferrous thiocyanate method with some modification to avoid the problem of separating L-2 from L-3 by advanced SDS-PAGE analysis.

Materials and Methods

Colorimetric method with ferrous thiocyanate

The following method referenced by Hammond et al. (1992)[1] with some modification has been used to prepare soybean seeds for analysis of lipoxygenase-2.

Solution A: 10 g refined soybean oil blended in 100 ml of water containing 1.25 g of gum arabic. Solution B: solution of 4 g ferrous sulfate and 4 g ammonium thiocyanate in 100 ml water. Solution A can be stored at 4°C for 1 wk. Solution B should be prepared daily.

The pieces of seeds cut from the nonembryonic end were prepared and placed into each well of microplate with 96 wells. Two to three drops of solution A were added to the seeds. When all the seeds had been treated, the wetted seeds were clipped with forceps and spotted onto the Whatman no. 1 filter paper formatted previously by 1.5 cm x 1.5 cm for one sample. The paper was allowed to dry until most of the water had evaporated but the spots were still slightly moist. Then it was sprayed lightly with solution B. The spots from seeds with L-2 turned brown quickly, while those lacking the enzyme remained cream colored. The colors were recorded as soon as they became apparent because the whole paper turned dark red in 0.5 to 1 h.

[1] Hammond, E.G. et al. 1992. Rapid Screening Technique for Lipoxygenase in Soybean Seeds. Crop Sci. 32:820-821.

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE)

The stock solutions used to prepare the gel were:

Solution A: 181.5 g of Tris and 2.0 g of SDS in a total volume of 500 ml, pH 9.1.
Solution B: 35 g of Tris and 2.0 g of SDS in a total volume of 500 ml, pH 7.0.
Solution C: 30 g acrylamide and 0.8 g Bis in a total volume of 100 ml.
Solution D: 1.4% ammonium persulfate prepared immediately before use.
Solution E: 4 mg riboflavin in a volume of 100 ml.

A constant concentration acrylamide gel was used as a running gel. The 7.5% gel solution contained 10 ml A, 10 ml C, 4 ml D, 36 ml water, 45 µl Tetramethyl ethylene diamine (TEMED). A stacking gel was formed with a solution consisting of 5 ml B, 3ml C, 0.5 ml D, 4.0 ml E, 7.5 ml water, and 10 µl TEMED. The samples were prepared as follows: a few chips from seeds were suspended in 0.5 ml of 0.05 M Tris (pH 8.0) containing 0.2% SDS and 5 M urea. After 30 min incubation, 10 µl of 2-mercaptoethanol with a little of bromophenol blue was added to the solution, then centrifuged at 12,000 rpm for 5 min. Ten microliters of samples were applied to the gel and electrophoresed at 80 volts for 1.5 h using the BRL mini-electrophoresis apparatus. The reservoir buffer was a tenfold dilution of a stock solution containing 144 g glycin, 30 g Tris, and 12.5 g SDS. The gels were stained with 0.02% Coomassie blue R-250 in H_2O-MeOH-HOAc (48:45:7) for 15 min, and destained with H_2O-MeOH-HOAc (73:20:7) for 1 h.

Results and Discussion

The diagram of the mass-screening method for null-triple lipoxygenase of soybeans is shown in fig. 5. Since the lipoxygenase-lacking trait is a single Mendelian recessive trait, theoretically only 1/4 of the samples were required for further analysis by PAGE. In the test of lipoxygenase-2, the isozyme oxidizes the polyunsaturated fatty acids in the soybean oil to hydroperoxides. The hydroperoxides oxidize ferrous ion to ferric ion, and ferric ion turns brown with thiocyanate. The separation by SDS-PAGE depends on the size of the proteins. L-1, L-2, and L-3 have the molecular weight of 94,038, 97,035, 96,541 dalton, respectively, according to the identified amino acid sequences. It is not easy to separate L-3 from L-2 because of the close molecular weight and sensitiveness to small changes in ionic strength of the buffer.

Fifty seeds from eight lines of soybean, of which isozymes had been identified, were prepared and mixed without any marks for confirming the accuracy of the combined method. The number of seeds selected from the eight lines are listed in table 5.

There should be 34 positive and 16 negative spots shown on the filter paper by the colorimetric method (fig. 6). The 16 L-2 lacking seeds were further analyzed by SDS-PAGE (fig. 7). The result corresponded correctly with the isozyme types listed in table 5 (table 6).

In consideration of cost and efficiency, three analytical methods were compared (table 7). For SDS-PAGE analysis, three apparatuses of mini-electrophoresis with 20 wells a set were used in the laboratory. It would be faster if there were more sets of electrophoresis because the cost would still be the same. For the combined method, time and cost were NT$450 and 7.5 h per 200 samples, which were the lowest in the three methods. It was demonstrated that 200 seed samples can be analyzed per day by a single laboratory assistant. This method only required a small piece of cotyledon and the analyzed seeds can be used for generations. Therefore, the combination of colorimetric method and mini-electrophoresis is suitable for breeding and genetic programs.

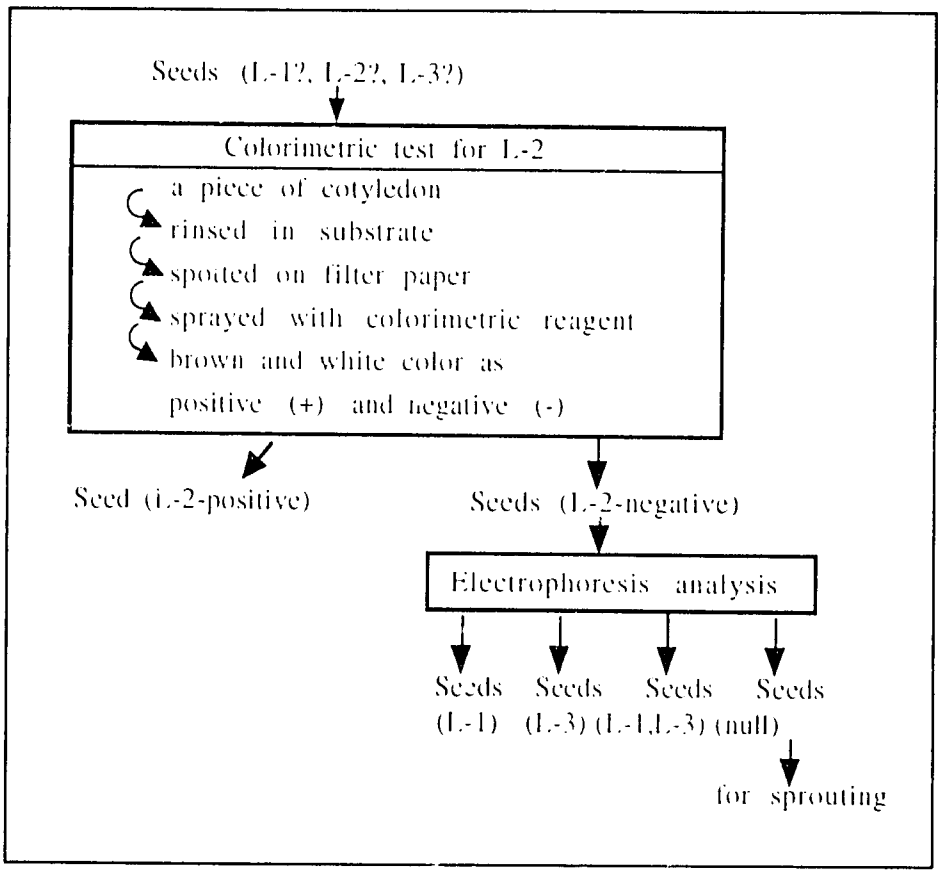

Fig. 5. The mass screening procedure for null-triple lipoxygenase of soybeans

Table 5. Number of seeds selected from eight lines of soybean and their isozyme types

Soybean line	Isozyme types	No. of seeds selected
Century	L-1, L-2, L-3	10
L2L3-2-4	L-1	5
L1L3-4-4	L-2	6
B1F3*	L-3	3
G2891	L-1L-2	8
L2-3	L-1L-3	5
L1-5	L-2L-3	10
B1F3*	Null	3

* Lines given by Kitamura, National Agriculture Research Center, Tsukuba, Japan.

Table 6. The results of the accuracy test of the screening method

	Colorimetric analysis	Electrophoresis analysis			
Isozyme types	L2-negative	Lx1	Lx3	Lx1Lx3	Null
Theoretical value	16	5	3	5	3
Experimental value	16	5	3	5	3
Accuracy (%)	100	100	100	100	100

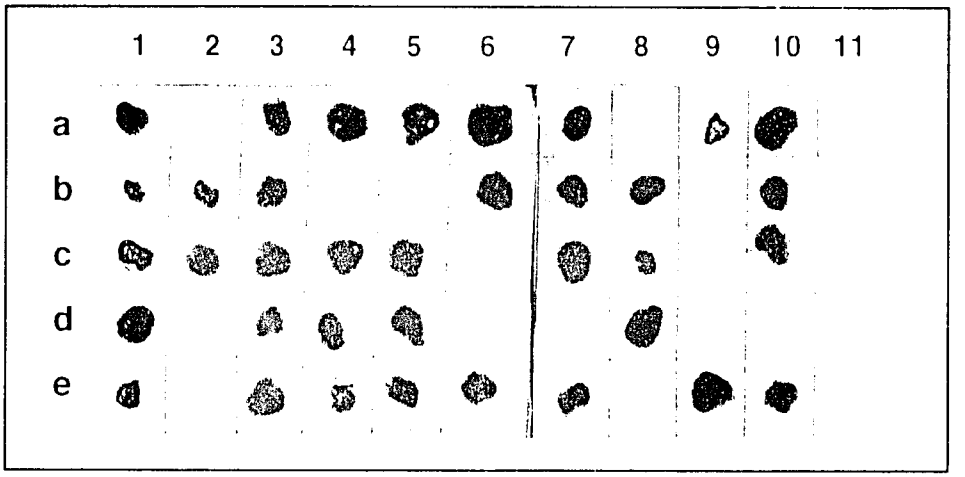

Fig. 6. Colorimetric test for lipoxygenase-2

Among 50 seeds analyzed, 34 were brown colored (lipoxygenase-2 positive) and 16 were cream colored (lipoxygenase-2 negative).

a10 and b10 were positive controls using the line with L-2. c11 was negative control using the line with L-1+L-3.

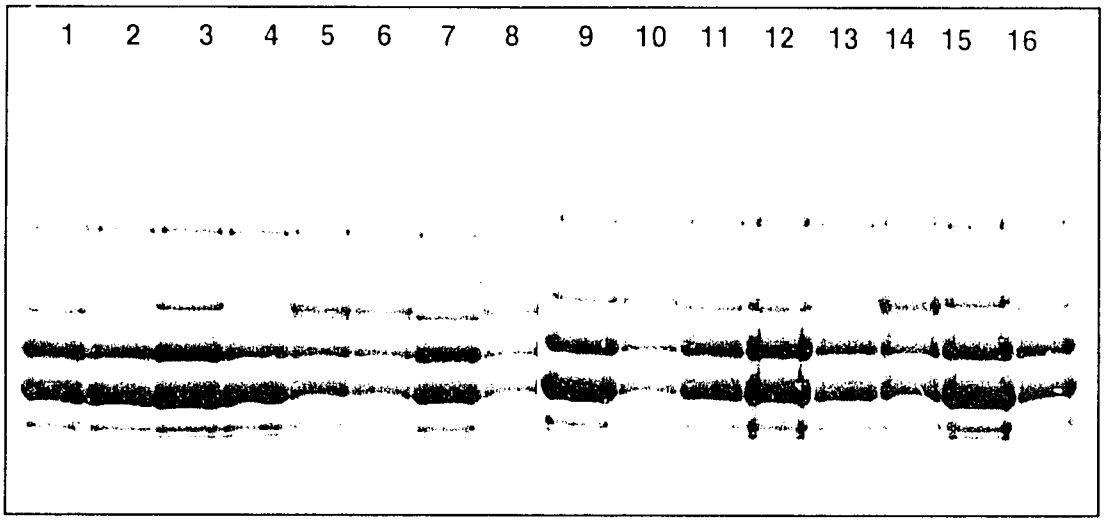

Fig. 7. SDS-PAGE analysis for lipoxygenase-1 and lipoxygenase-3

Lines 2, 6, 13, 14, and 16 were types with L-1 and L-3
Lines 1, 7, and 11 had L-3
Lines 3, 4, 8, 9, and 15 had L-1
Lines 5, 10, and 12 were null types

Table 7. Comparison of three analytical methods for screening lipoxygenase isozymes

	PAGE analysis	Combination of colorimetric and PAGE analysis	Enzyme activity determination
Time spent (h/200 samples, person)	13	7.5	40
Cost (NT$/200samples)	1430	450	920
Analytical procedure	L-1,L-2, and L-3 simultaneously determined	L-2-negative then L-1 and L-3 simultaneously determined	L-1,L-2, and L-3 separately determined

*The cost of reagent, tips, and microcentrifuge was included.

Dehydration of Vegetable Samples by Rotary Dehumidifier

Summary

Near-infrared reflectance spectroscopy (NIRS) has been adopted as a mass-screening technique for composition analysis of various vegetable samples. It has many advantages: it is rapid, less costly than other methods, safe, and can be used to simultaneously determine several compositions. However, it requires drying the samples before they are submitted to instrument tests. In minimizing composition change during dehydration, a relatively low drying temperature (45°C) has been used at AVRDC. Due to the humid climate at AVRDC, a long drying time (>48 h) is required, especially during the summer. The technique is not only time and energy consuming, but also carries the risk of spoilage by microorganisms.

In cooperation with the Energy and Resources Laboratories, Industrial Technology Research Institute, Taiwan, a dryer attached to a rotary dehumidifier was designed. The dryer was able to control the inlet air with relative humidity (RH) of 10% and temperature of 45°C. Vegetable samples could be dried to about 13% within 24 h.

Samples dried in the new dryer were compared with those dried using the traditional system. The quality was encouragingly comparable. The regression equations calibrated for the moisture, oil, and protein contents of samples dried by the old method are still applicable to samples prepared using our method. These calibration equations developed at AVRDC can be used by partners who do not have this type of dryer.

Introduction

Near-infrared reflectance spectroscopy was found reliable in determining the moisture, protein, oil, fiber, starch, sugar, and ash in vegetable soybean; it is also rapid, less costly, and safe. However, samples need to be dehydrated and ground before they are subjected to NIRS analysis. The method traditionally used for drying vegetable samples at AVRDC is hot-air drying (45°C, 24%RH), which retains most of the constituents of the samples, but it is time-consuming.

There are many other methods that can be used to dry vegetables: e.g., spray drying, film drying, freeze-drying, and puffing, etc. Among these methods, freeze-drying is able to obtain the highest quality samples but at higher cost. The advantages of hot-air drying are high drying rate and low cost, but the quality of samples dried is not as good as those dried by freeze-drying. To obtain high drying quality and high drying rate, a rotary dehumidifier which used low temperature and low relative humidity was designed.

Materials and Methods

Dryer

Two types of dryers, the hot-air oven and rotary dehumidifier, were used to dry samples. The hot-air oven can be used when the temperature is 45°C and the relative humidity is 24%.

The rotary dehumidifier shown in fig. 8 was designed in cooperation with the Energy and Resources Laboratories, Industrial Technology Research Institute. The dryer removes the moisture from samples with its rotary dehumidifier which dries with hot air (about 90-100°C). The relative humidity can be reduced to 10% RH at 45°C using this instrument.

Sample preparation of vegetable soybean

Fourteen varieties of vegetable soybean were harvested from trials at AVRDC in summer 1993. The graded pods were blanched in boiling water for 90 seconds. After precooling, the blanched pods were frozen at -40°C and kept below -18°C before further use.

After removing from the pods, vegetable soybean seeds were dehydrated at 45°C for 48 h in a hot-air oven and at 45°C 10%RH for 21 h in a rotary dehumidifier, in duplicate, and then ground into fine powder in a high-speed centrifuge mill passing through a 0.5 mm screen. The samples, in powder form, were analyzed by the NIRS as well as the chemical method.

NIRS system

A technicon InfraAlyzer 400 was used in this study. InfraAlyzer 400 is a filter-type instrument installed with 19 fixed wavelengths. The calibration curves had been established to predict the constitutents of samples dehydrated with both type of dryers.

Chemical analysis

The moisture and protein were determined by the AOAC (Association of Official Agricultural Chemists) method. The moisture was determined in a 105°C oven. The fat was extracted with extraction unit (Soxtec System HT6; 1046 Soxtec Service Unit, Tecator) 1 h by hexane.

Results and Discussion

Dehydration conditions

As shown in fig. 9, there was a significant difference in the dehydration curves of vegetable soybean using these two types of dryers. The moisture content was reduced to 13% after 10 h in the rotary dehumidifier, but 20 h in the hot-air oven. Moreover, the equilibrium moisture of samples dried by the rotary dehumidifier was lower than those by the hot-air oven. The dehydration time required was 21 h at 45°C, 10% kH for the rotary dehumidifier, and 48 h at 45°C for the hot-air oven (table 8 and fig.8).

The energy consumed by the hot-air oven was almost half that of the rotary dehumidifier. To improve this, the rotary dehumidifier will be connected with a solar energy system in replacement of the heater (fig. 8). With this change, the energy consumed is expected to decrease comparably and make the rotary dehumidifier a better dryer.

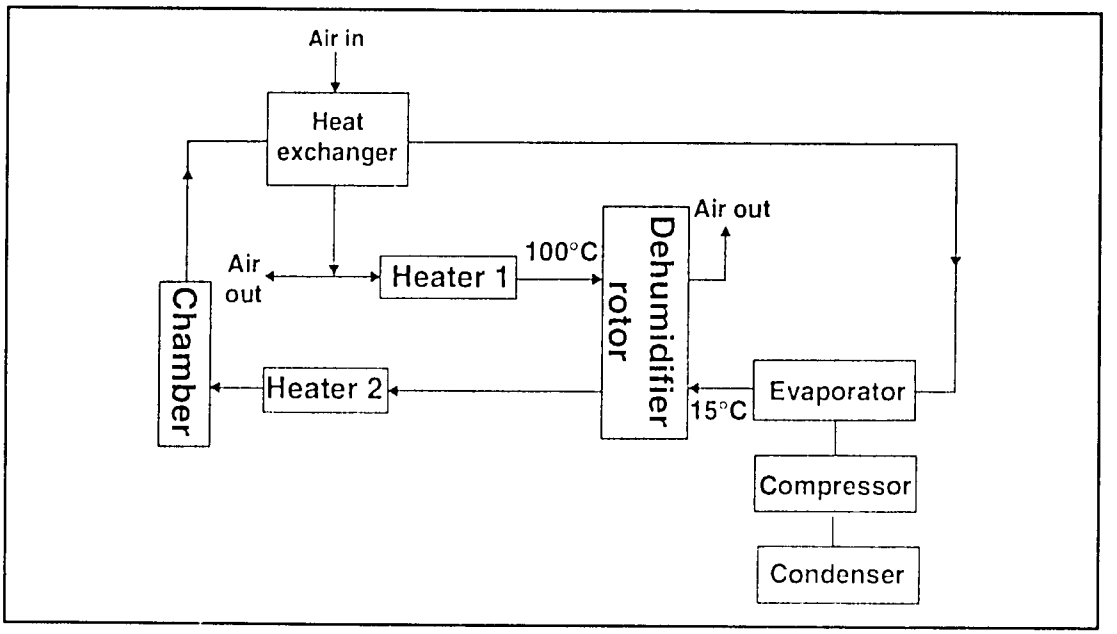

Fig. 8. The rotary dehumidifier system

Table 8. Drying conditions of different dryers for vegetable soybean

Dryer	Condition		Time consumed	Energy consumed
	Temperature (°C)	RH (%)	(h)	(kw/h)
Hot-air oven	45	24	48	40.5
Rotary dehumidifier	45	10	21	69.2

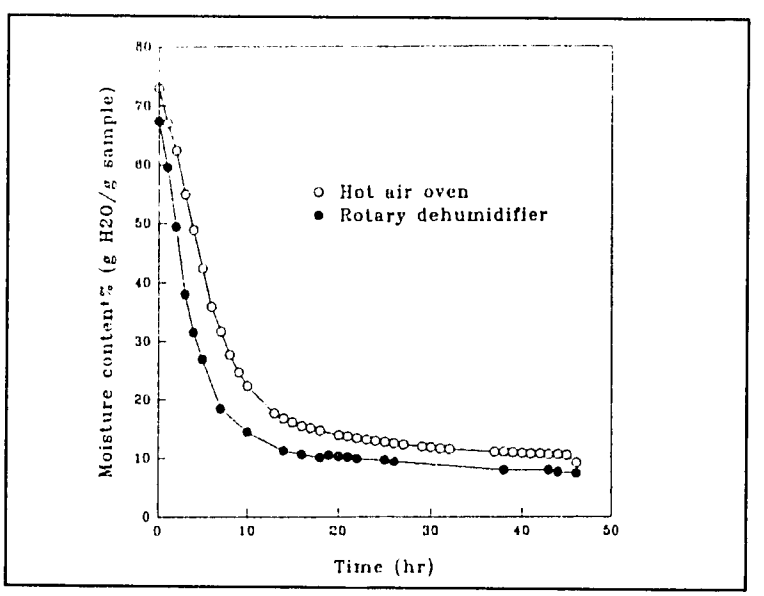

Fig. 9. Dehydration curve of vegetable soybean by hot air oven and rotary dehumidifier

Prediction of three constitutents of vegetable soybean by NIRS

Three constituents, moisture, protein, and oil, of vegetable soybean dried by the rotary dehumidifier were determined by the chemical method as well as the NIRS method. The chemical and prediction values obtained were subjected to regression analysis. The analysis for the rotary dehumidifier was further compared with the result for hot-air oven to make sure the existing calibration equations obtained from the hot-air oven were suitable for predicting constitutents of vegetable soybean dried by the rotary dehumidifier.

The correlation coefficient (R^2) and standard error of prediction (SEP) of moisture obtained using the hot-air oven were 0.97 and 2.13, and 0.99 and 2.22 for the rotary dehumidifier. The SEPs of both dryers were biased and reduced to 0.14. The correlation coefficients of oil and protein were 0.97 and 0.95, and the SEPs were 0.32 and 0.47 after being biased. These results showed that three constituents of the samples dried by the rotary dehumidifier could be determined by regression equations after bias. Although the SEP of protein for the rotary dehumidifier drying was higher than the hot-air oven, it is still less than the coefficient of field variation (3.5%) (table 9).

Vegetable soybean samples can be prepared using the rotary dehumidifier as a substitute for the hot-air oven in determining moisture, oil, and protein content. The regression equations for other constitutents are still being tested.

Table 9. Prediction statistics of calibration equation for three constituents of vegetable soybean

	Hot-air oven (45°C, 30%RH)		Rotary dehumidifier (45°C, 30%RH)	
Constituent	R^2	SEP	R^2	SEP
Moisture	0.97 (24)*	0.14	0.99 (28)	0.14
Oil	0.97 (25)	0.32	0.96 (27)	0.33
Protein	0.95 (22)	0.47	0.90 (21)	0.70

*Values in parentheses are the number of samples.

Crop Management and Cropping Systems

Summer Tomato Production

Summary

Combining the use of raised beds, a fruit-set hormone, and simple plastic rainshelters increased yield threefold in tomato compared to the control. Lower canopy temperature, less leaching of nitrate, and greater light interception by this treatment combination were evident.

Introduction

The rainy tropical summer represents one climatic season when satisfactory production of temperate vegetables remains beyond the means of most farmers. While hydroponic culture represents one feasible approach (AVRDC 1991[1]), simple field-based management practices have been researched at AVRDC (AVRDC 1993[2]). This year a pyramid of successful practices was tested over three transplanting dates to quantify risk and economic returns to each of the practices. Currently, two of the three trials are still in the field, hence, data from the first trial only are presented here.

Materials and Methods

The heat-tolerant F_1 hybrid FMTT 22 was sown on 9 April 1993 and transplanted to the field on 5 May 1993. Treatments imposed were as follows:

(1) Control — standard field management, transplanted in 20-cm-high, 1.5-m-wide double-row beds

(2) As in (1), but transplanted on 40-cm raised bed

(3) As in (2), but each truss sprayed with a fruit-set hormone (0.12% by weight) when 50% flowers were open

(4) As in (3), but with addition of a plastic rainshelter straddling two 1.5-m beds.

Plot size was 4 m x 3 m. Apart from tomato yield data, air:canopy temperature differential (Everest model 112ALCS infrared thermometer), light interception (Licor LI 1000 radiometer), spectral irradiance composition (Licor radiospectrometer), and soil nitrate data were also periodically collected during the conduct of the experiment.

Results and Discussion

Tropical storms occurred during the conduct of this trial causing wilting of plants in low beds but not mortality.

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[1]AVRDC. 1991. AVRDC 1990 Progress Report. AVRDC, Shanhua, Tainan, Taiwan.
[2]AVRDC. 1993. AVRDC 1992 Progress Report. AVRDC, Shanhua, Tainan, Taiwan.

Total yields differed among treatments (table 1). Raised beds alone did not result in greater fruit yields in contrast to previous years' data. Yields differed significantly in treatments with hormone and hormone plus rainshelters and from the control.

Light interception was significantly improved by the use of raised beds and rainshelters and plants wilted much less under these treatments than on low beds. However, the rainshelter reduced incoming solar irradiance (300-1100 nm) by an average 44% during the middle of the day and increased the difference between leaf and air temperature (i.e., resulted in a greater depression of leaf, relative to air temperature — table 1).

Following a heavy rainfall, soil nitrate content was measured. Under the rainshelter 70.1 ppm was present, compared to 0.73 ppm in the open low bed.

The combination of rainshelter, hormone, and raised beds led to a threefold increase in yield above the control treatment and may have led to a more efficient use of fertilizer N (with less leaching and potential soil water pollution). The economic implications of these treatments and for the two repetitions of this experiment are pending and are particularly important since the harvest period spanned 2 July - 20 August, a period when fresh tomatoes command high market prices.

Table 1. Influence of raised beds, fruit set hormone, and plastic rainshelters on various growth, environmental, and yield parameters in a summer tomato crop

	Light interception (%)			Canopy temperature depression (canopy: air °C)	Marketable fruit	
Treatment	49 DAT	62 DAT	79 DAT	(39 DAT)	no./m²	t/ha
Low bed	41.8	41.4	47.9	-0.24	14.2	10.2
Raised bed	47.0	42.0	55.3	-1.45	12.6	8.9
Raised bed + hormone	50.0	44.5	40.4	-1.70	25.7	21.9
Raised bed + hormone + rainshelter	58.3	60.0	53.9	-2.85	29.0	28.4
SED (9 df) between two means	1.43	2.47	n.s.	0.41	2.34	2.01

Overcoming Flood-induced Damage to Tomatoes Using a New Grafting Technique

Summary

The potential for grafting heat-tolerant scions onto flood-tolerant rootstocks was further studied in 1993 in an artificially and naturally flooded field.

Grafting FMTT 22 (Taichung ASVEG No. 4) onto tomato lines tolerant to flooding resulted in yields more than twice as great as the ungrafted FMTT 22 control, but self-grafting of FMTT 22 also increased yield compared to the control. Grafts with two lines, L 150 and L 973, resulted in yield significantly greater than that of self-grafted FMTT 22.

Grafting FMTT 22 scions onto wild eggplant relatives also resulted in greater yield than that of the ungrafted FMTT 22 control. All grafted plants survived flooding, whereas all the FMTT 22 control died. Eggplant roots apparently have more aerenchyma which may favor survival under flooded conditions, and grafted tomato lines with FMTT 22 scion had more fine root following flooding than ungrafted controls.

Root activity, measured as O_2 consumption, did differ between natural or tomato grafted plants, and was not related to flooding tolerance among tomato lines or eggplant rootstocks. Data from further experiments are currently being analyzed.

Introduction

Of the seasonal stresses, flooding remains one in which little inroads have been achieved by way of plant breeding. Observations 2 years ago of eggplant, adjacent to tomato and surviving waterlogging during the wettest period of the year, prompted this study. In 1992, simple experiments were run to develop quick and inexpensive grafting procedures and to ascertain the graft compatibility between tomato, pepper, and eggplant scions onto eggplant rootstocks. For the genotypes tested, grafts between pepper and eggplant were incompatible, while tomato:eggplant and eggplant:eggplant were successful. Tomato:tomato grafts were also undertaken to graft the best heat-tolerant table tomato onto rootstocks with known tolerance to waterlogging (AVRDC 1981[3]). Preliminary studies were also undertaken under flooded conditions that year and extended in 1993 to include field evaluations, spreading to include a range of potential rootstocks chosen from within the *Solanaceae*. Studies on root anatomy and root respiration were also conducted in 1993.

Materials and Methods

Four major field experiments were conducted, the data for two of which are presented (the others are still in the field). One experiment (1), transplanted 5 March 1993, compared tomato:tomato grafts (FMTT 22 onto tolerant rootstocks) to a tomato control; the other (2), transplanted 18 March 1993, compared tomato:eggplant grafts to the same tomato control.

Based upon the 1992 experiments, grafting of tomato onto tomato was done when tomato seedlings were 18-21 days old. The best available fresh market tomato line, FMTT 22, was grafted onto tomato scions of various lines, and self-grafts of the same lines were also made. Both were compared to the ungrafted lines and to a control, FMTT 22. For tomato:eggplant, the eggplant was sown approximately 15 days earlier than tomato, since initial growth was slower than that of tomato. Once the tomato reached 15-18 days, they were grafted onto eggplant rootstocks. Tomato scions were sliced with a razor blade between the cotyledonary and first leaf, at an angle of 30° to the perpendicular (fig. 1). This scion was inserted into a sliced piece of rubber tubing (as used in bicycle valves). The stock seedlings were also sliced at a similar angle and the rubber tubing plus scion slipped onto the cut surface. Lining the angle of cut of the scion with the angle of slice of the rubber tubing prevents errors in positioning of the scion onto the stock (fig. 1). Grafted seedlings (of which 150-200 may be prepared in 1 hour by one person) were then placed in the shade at an RH of > 80% and temperature of 20-30°C for 3-4 days for tomato:tomato and 5-7 days for tomato:eggplant before treating as in the control (ungrafted) seedlings. Success of grafting ranged from 90 to 95%. All other nursery and field practices followed were standard.

Three significant tropical storms occurred during the conduct of these experiments (24/24 April, 25-27 May, and 10/11 June with 70 mm, 242 mm, and 198 mm rainfall, respectively). These were supplemented by artificial flooding on four occasions (14-21 April; 6-14 May; 28 May-4 June; 11-17 June) to enhance differentiation between rootstock genotypes in their response to waterlogging. Data on wilting, crop biomass (55 and 90 days after transplanting [DAT] in experiments 1 and 2, respectively) and fruit yield were collected from twice-replicated

[3]AVRDC. 1981. AVRDC 1980 Progress Report. AVRDC, Shanhua, Tainan, Taiwan.

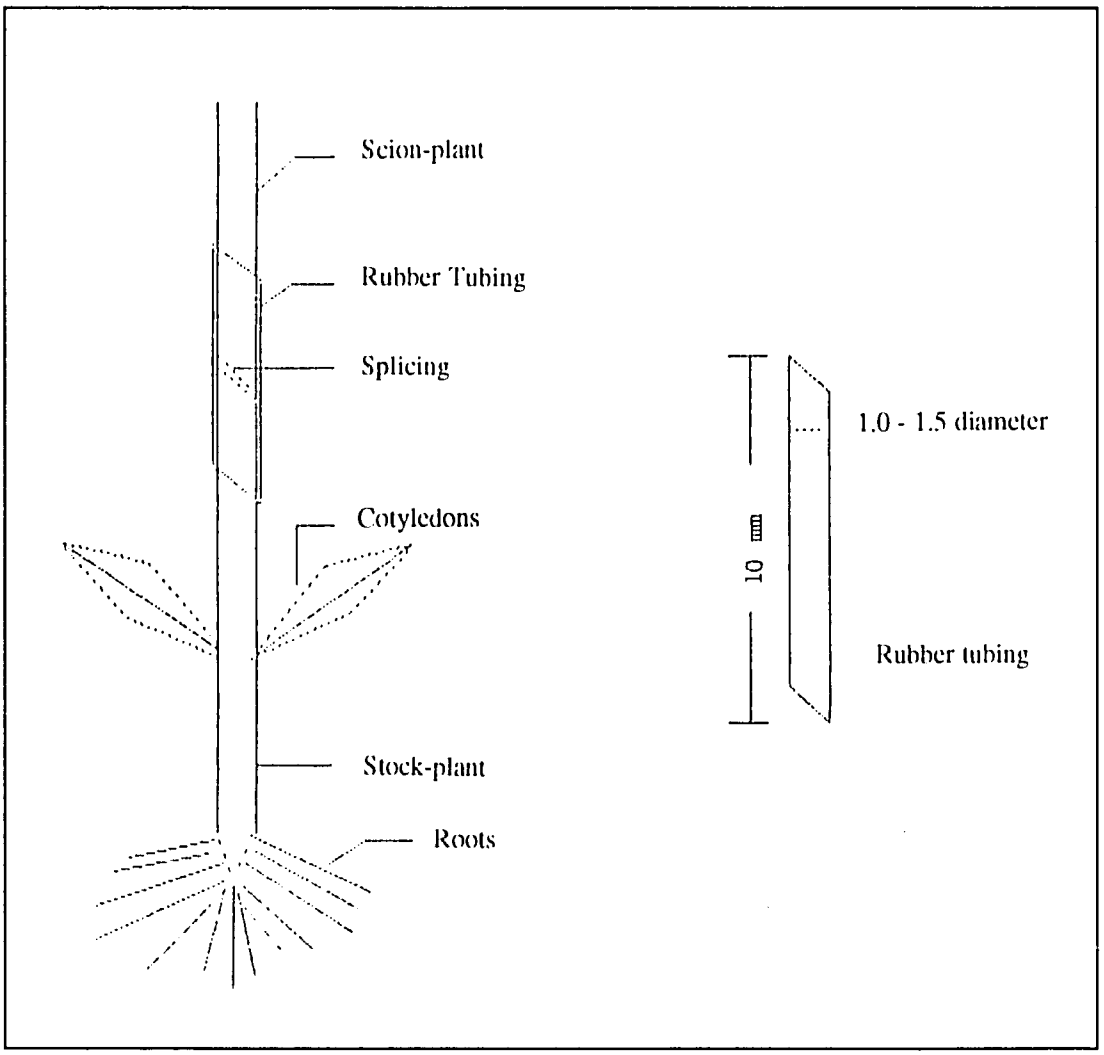

Fig. 1. AVRDC (Taiwan) graft

plots measuring 1.5 m x 3.2 m. Root activity (oxygen consumption) was also measured when the growth analysis sample was taken. Three-gram samples of fine root were submerged in 300 ml of air-saturated tap water and readings of O_2 content were taken immediately and after 2 h to estimate O_2 uptake by the roots. Samples of roots (6 - 8 cm from the root tip) were collected twice (at 2 and 4 weeks after emergence [WAE]) from FMTT 22 and the eggplant line TS 28 for determination of anatomical structure.

Results

Experiment 1 — tomato:tomato grafts

Significant yield differences were observed in the mean performance of the rootstock lines and between grafted (with FMTT 22), self-grafted or natural plant yields. No interaction was

evident between the rootstock lines and grafting or no grafting — this resulted in the close correlation ($r^2 = 0.788$, $p \leq 0.0001$) between self-grafted and natural plant yields across lines. Fruit yields (table 2) of lines grafted with FMTT 22 bore no relationship to the self-grafted or natural plant yields. Grafted plants gave the highest yields (to be expected since the scion was the heat-tolerant line); the self-grafted lines gave a higher, but nonsignificantly different yield than the natural ungrafted plants. Average yields of plants grafted with FMTT 22 were 1.03 kg/plant, compared to 0.45 kg and 0.36 kg/plant, respectively for self-grafted and natural plants (SED 28 df = 0.06). Of major importance was the comparison in yields of grafted plants with the greatest yields of the un- or self-grafted lines (including FMTT 22), i.e., which performed best under the prevailing conditions.

Table 2. Total tomato yield for plants grafted with FMTT 22

Line	Yield/plant (kg)	Name	Species	Country
L 123	1.17 a-c[a]	TK-3	ESCU	Japan
L 125	1.07 a-d	DIVISORIA-2	ESCU	Japan
L 143	1.00 a-d	LA 1280 SAL 369-2	ESCU	Peru
L 146	1.27 ab	LA 1291 SAL 374-3	ESCU	Peru
L 150	1.34 a	LA 1311 SAL 395-1	ESCU	Peru
L 163	1.33 a-d	LA 1388 SAL 472	ESCU	Peru
L 191	1.00 a-d	LA 393	ESCU	Peru
L 973	1.33 a	PI 129084	ESCU	USA
L 3072	0.86 c-e	PI 298943	ESCU	Poland
L 3091	0.76 de	PI 303716	ESCU	USA
L 4313	0.81 c-e	PI 3855935	ESCU	Malawi
L 4360	0.86 c-e	PI 390510	ESCU	Ecuador
L 4422	0.89 b-e	PI 390716	ESCU	Peru
FMTT 22 (Self-graft)	0.92 bcde			
FMTT 22 (Natural plant)	0.53 e	(AVRDC F_1 fresh market tomato)		

[a]Means in the same column followed by the same letter are not significantly different at 5% level (DMRT).

Yields of grafted plants of L 150, L 973, L 146, L 123, L 163, L 125, L 191, and L 143 differed significantly from the yield of the ungrafted FMTT 22; however, only grafted L 150 and L 973 differed significantly in yield from the self-grafted FMTT 22 (fig. 2). Major differences in yield between these lines and the control (FMTT 22) occurred in the second and third harvests, when control plants suffered wilting symptoms (the first harvest was on 10 May; the field had undergone one prolonged flood and was undergoing another). Differences between the ungrafted control and the lines grafted with FMTT 22 (fig. 2) in the first harvest were also very marked due to the earlier flooding. No yield of ungrafted tomato lines surpassed 0.75 kg/plant, and only self-grafts of one line (L 3091) surpassed that with a yield of 1.10 kg/plant.

A simple growth analysis sample, taken 1 wk after the end of the first flood period, revealed significant differences between the mean values for tomato lines (mean obtained across grafted, self-grafted or ungrafted) in all characters measured except root and leaf weight. Differences between grafted, self-grafted, or ungrafted lines (mean obtained across all tomato lines) were significant for all characteristics except plant height (table 3). In general, grafted plants were heavier, but had fewer fruit. Interactions were significant for height, fruit number, and leaf weight. Self-grafting increased plant height in six out of 14 lines, while grafting with FMTT 22 increased it in five (particularly the short-stature lines). For fruit number a similar response was evident, with self-grafting increasing the number in four lines but only in two lines when grafted

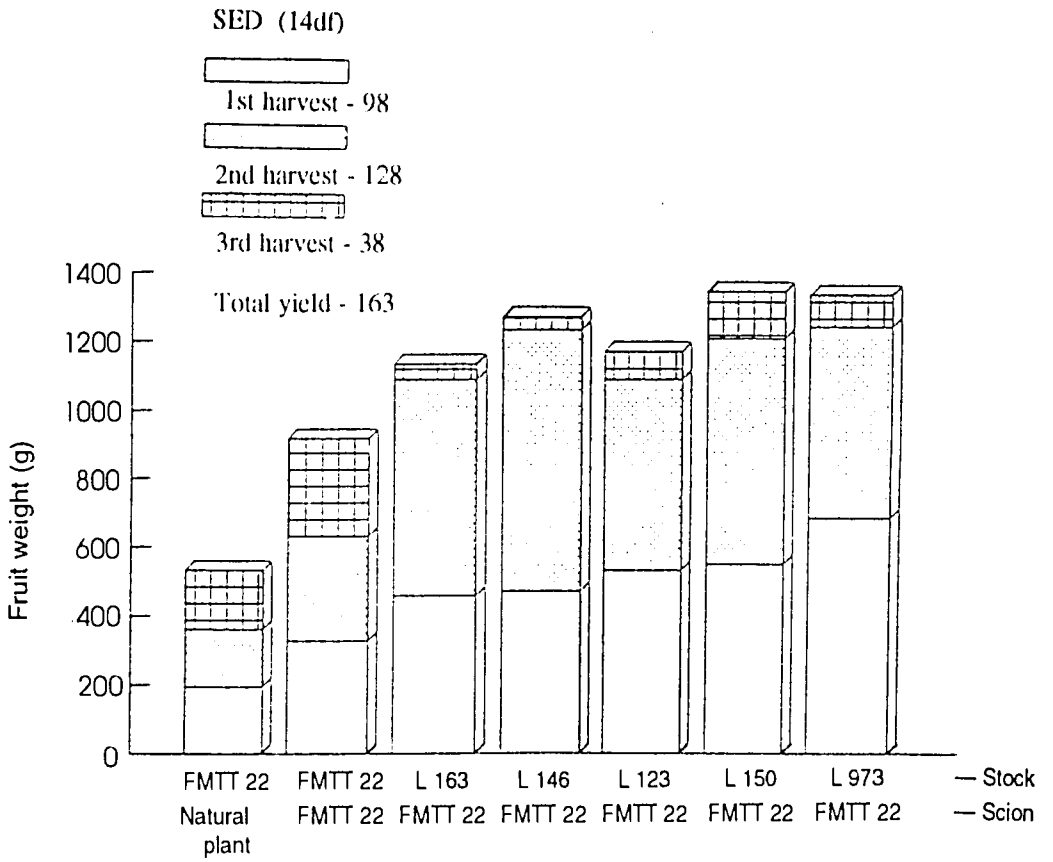

Fig. 2. Tomato fruit yields at three harvests for stock lines grafted with scion FMTT 22 and compared to natural plant of FMTT 22 under flooded conditions in Taiwan, summer 1993

Table 3. Influence of self-grafting, grafting with FMTT 22, or no grafting on growth characteristics of tomato plant measured 55 days after transplanting

	Plant height (cm)	Fruit no. (/plant)	Fresh weight (g/plant)				
			Root	Leaf	Stem	Fruit	Total biomass
Natural plant	98 a	23 a	29 b	124 b	417 b	262 b	833 b
Self-grafted plant	103 a	23 a	29 b	125 b	470 b	325 b	949 b
Grafted with FMTT 22	98 a	14 b	36 a	276 a	880 a	648 a	1841 a

with FMTT 22 (the only two with natural fruit < 10/plant). Leaf weight was increased in five lines with self-grafting and for 12 lines when grafted with FMTT 22.

Differences in mean values between lines for the fresh weight of fine roots and their unit activity and total activity per plant (oxygen consumption) were not significant; however, grafting significantly influenced the fine root fresh weights and the unit activity. Grafting increased root weight and self-grafting the unit root activity in both by almost 20% compared to the means of the other respective treatments.

Experiment 2 — tomato:eggplant

In Experiment 1 there was some indication that self-grafting improved tomato yields; the same was not evident for eggplant. Self-grafted eggplant lines had similar fruit weight (self-grafted — 0.56 kg; ungrafted — 0.59 kg, mean of 32 lines, $p \leq 0.19$) but fewer fruits (self-grafted — 7.55; ungrafted 8.20, $p \leq 0.04$) per plant than the ungrafted eggplants. Eggplant lines differed considerably in fruit yield (from 0.29 to 1.20 kg/plant), but, as seen later, the ranking of ungrafted eggplant yields did not correspond to the ranking of tomato yields when grafted onto the eggplant rootstocks.

Flooding, which occurred after the first harvest of tomato, caused death of ungrafted plants of FMTT 22, whereas all tomato:eggplant grafts survived to produce more fruit. Early flooding (at 32 days and 40 days after transplanting) apparently did not diminish growth and yield of control FMTT 22 more than that of the grafted plants (fig. 3). Indeed, the control at that stage had more fruit harvested than any other grafted lines. This agrees with our observation in other

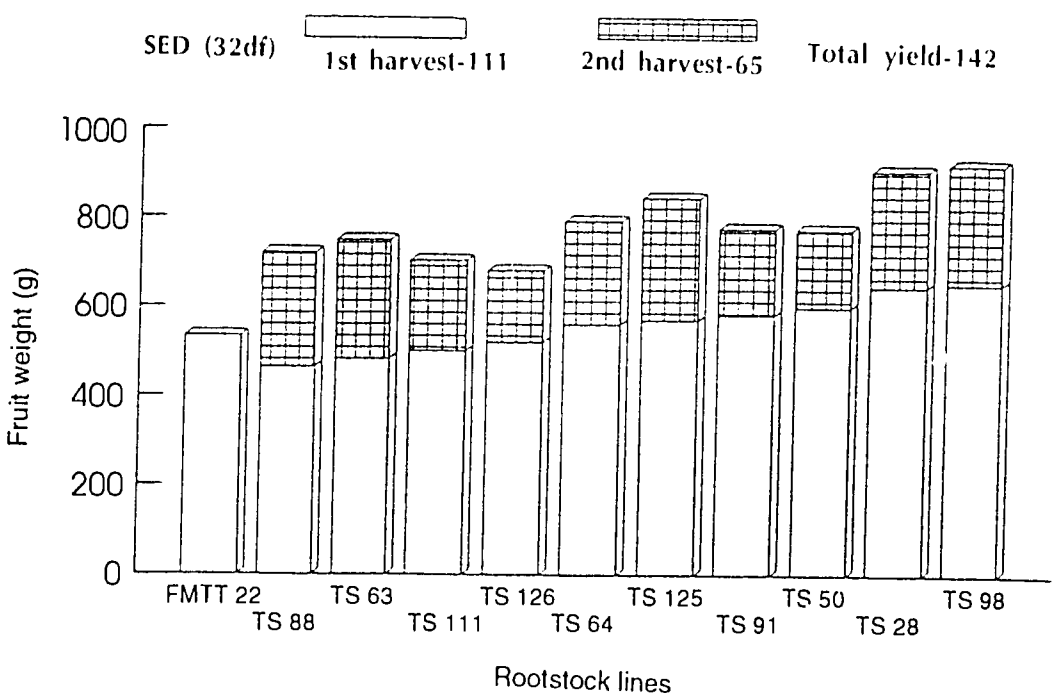

Fig. 3. Tomato fruit yields at two harvests for various eggplant stock lines grafted with FMTT 22 and compared to natural plant yields of FMTT 22 grown under flooded conditions in Taiwan, summer 1993

species that early exposure to flooding does not necessarily result in plant mortality. Young root systems probably recover following flooding due to their superficial distribution near the soil surface which dries out first when flooding ceases.

A biomass sample was only collected on tomato:eggplant grafts; the control FMTT 22 had already wilted by the time of sampling (3 mo after transplanting). No significant difference was evident between lines in any measured character, although for total fresh weight per plant differences were significant at $p = 0.07$ (data not presented).

Root activity differed significantly between grafted and ungrafted plants (table 4) and across lines, but there was no interaction. Grafting of FMTT 22 onto eggplant rootstocks diminished the amount of fine root and the oxygen uptake per unit root weight and per plant (table 4), as was seen for tomato grafts between different genotypes.

Activity per unit root weight of FMTT 22, 0.073 µl O_2/g/h, was as great as that of the most active ungrafted eggplant and superior to most tomato:eggplant grafts but, due to the very low amount of fine roots in FMTT 22 (3.85 g/plant), the activity per plant was one of the lowest of all treatment combinations measured.

Table 4. Comparison of root activity (measured as oxygen uptake and amount of fine roots) for grafted and ungrafted lines of eggplant, measured 3 months after transplanting

For graft types averaged over 32 eggplant lines

	Fine root (g/plant)	Oxygen uptake (µl/g/h)	Oxygen uptake (µl/plant/h)
Natural plant	20.6 a	0.052 ab	1.070 a
Self-grafted plant	20.4 a	0.057 a	1.192 a
Grafted with FMT22	10.3 b	0.047 b	0.491 b

For eggplant lines averaged over various grafts or nongrafts

Line	Fine root (g/plant)	Oxygen uptake (µl/g/h)	Oxygen uptake (µl/plant/h)	Line	Fine root (g/plant)	Oxygen uptake (µl/g/h)	Oxygen uptake (µl/plant/h)
TS 1	22.0 cd	0.052 a-e	1.177 b-d	TS 84	15.3 f-i	0.060 ab	0.917 b-i
2	20.7 c-f	0.063 a	1.286 a-c	87	8.5 m	0.055 a-d	0.464 g-i
17	14.9 g-i	0.054 a-d	0.796 c-i	88	15.8 e-j	0.057 a-d	0.930 b-i
28	16.8 d-i	0.047 a-e	0.808 c-i	89	13.8 h-l	0.035 e	0.540 f-i
33	18.0 d-i	0.053 a-d	0.894 c-i	91	9.3 k-m	0.043 b-e	0.424 i
49	18.5 d-i	0.056 a-d	1.063 b-f	96	25.1 bc	0.055 a-d	1.315 a-c
50	27.5 b	0.058 a-d	1.711 a	98	20.1 c-g	0.042 c-e	0.954 b-i
55	9.4 k-m	0.049 a-e	0.481 g-i	101	32.2 a	0.056 a-d	1.754 a
56	14.6 g-k	0.051 a-e	0.734 d-i	103	13.2 i-m	0.047 a-e	0.637 e-i
61	20.0 c-g	0.056 a-d	1.114 b-e	111	17.1 d-i	0.049 a-e	0.855 c-i
62	13.9 h-e	0.047 a-e	0.680 d-i	112	19.9 c-g	0.057 a-d	1.187 b-d
63	19.1 d-h	0.052 a-e	0.998 b-g	114	21.2 c-e	0.050 a-e	0.933 b-i
64	19.3 d-h	0.041 de	0.807 c-i	121	18.0 d-i	0.052 a-e	0.962 b-h
66	11.2 j-m	0.061 a	0.699 d-i	123	15.6 f-i	0.051 a-e	0.807 c-i
69	8.6 pm	0.049 a-e	0.430 hi	125	17.8 d-i	0.059 a-c	1.092 b-e
83	9.5 k-m	0.049 a-e	0.473 g-i	126	20.8 c-f	0.062 a	1.434 ab

Root anatomy

Cross-sectional areas of eggplant root were greater than those of tomato root at 2 WAE, but by 4 WAE there was no difference between species (fig. 4). The cross-sectional area in the metaxylem to endodermis did not vary between species in either sample, but aerenchyma was clearly developed in the eggplant roots by 4 WAE; in tomato it was not.

Discussion

Quite evidently, grafting of FMTT 22 onto tomato rootstocks tolerant to flooding or onto eggplant rootstocks improved tomato yields under conditions of flooding. Fruit yields of self-grafted tomato lines were closely related to those of natural plants of the same lines ($r^2 = 0.788$; $p < 0.001$), but on average the latter had 24% less yield. Fruit yields of tomato lines grafted with FMTT 22 bore no relation to yields of self-grafted or natural plants. Grafting of FMTT 22 onto flood-tolerant tomato rootstocks improved total yield of tomato beyond that of self-grafted

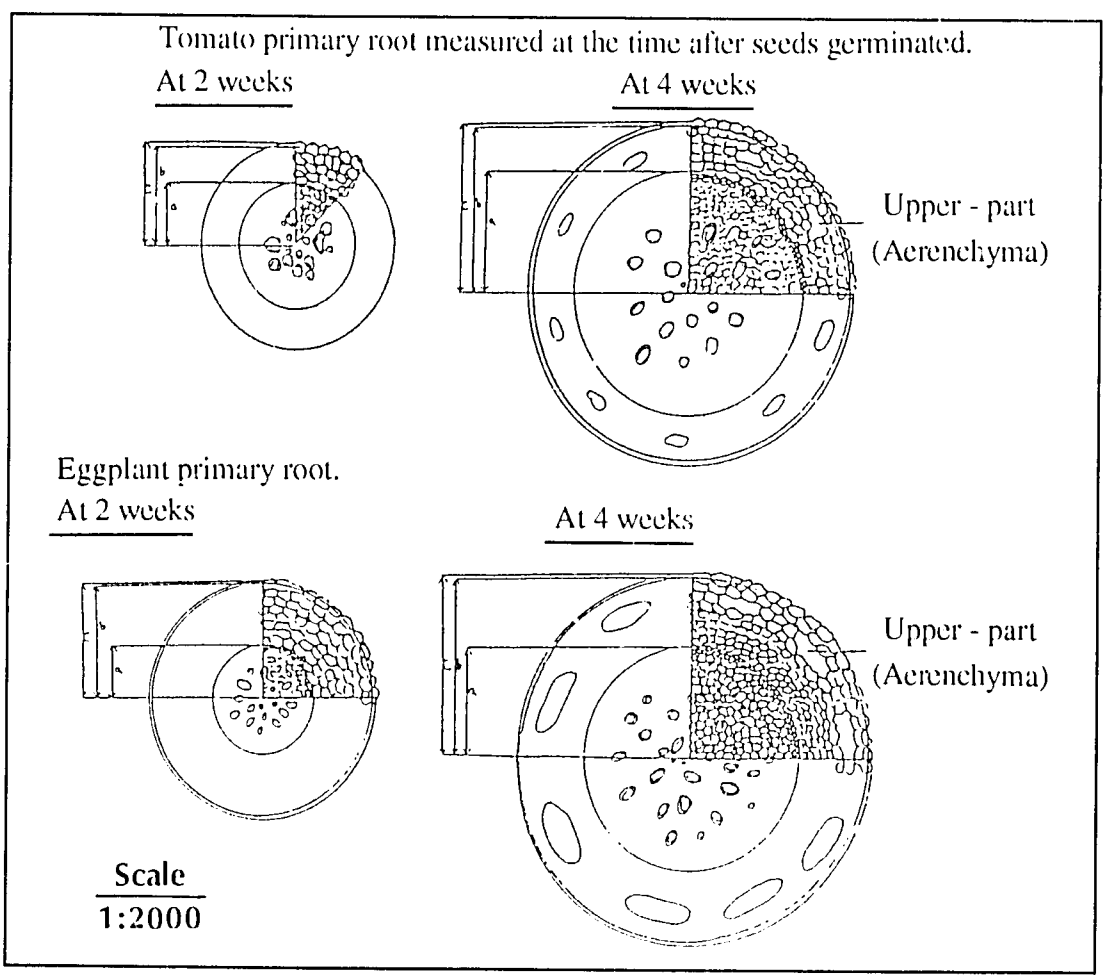

Fig. 4. Transectional diagram of primary root of tomato and eggplant at two different seedling stages

FMTT 22 in only two lines. Grafting with FMTT 22 scions apparently stimulated growth of fine roots (27.5, 22.5, and 21.8 g/plant for FMTT 22 grafts, self-grafts, and natural plant, respectively, SED 26 df = 1.64), but not root activity. A greater recovery in root function of grafted plants, manifested through a greater amount of fine roots, might have been responsible for the higher yields in those plants. The proportional increase (compared to the natural plants) in fruit yield across self-grafted lines was not related to proportional increases in any character measured in the growth analysis sample, but, for the plants grafted with FMTT 22, proportional increases in stem weight ($r^2 = 0.49$ $p = 0.006$), total weight ($r^2 = 0.39$, $p = 0.018$) and fruit weight ($r^2 = 0.68$, $p = 0.001$) over the natural rootstock yield were closely related to increases in grafted yield over the natural plant. Neither increases in root nor leaf weight were related to increased yields of plants grafted with FMTT 22 over the ungrafted plant yields. Simple correlations between the second and total fruit harvest weights, numbers, and biomass sample data of plants grafted with FMTT 22 indicate a close positive relationship between plant height and all harvest data, and between leaf weight and fruit weight for the second and total harvest data. Total biomass at the sample date was not related to fruit yield (neither weight nor number of fruit), nor was root weight (total or fine roots — although the latter at $p = 0.07$ was related to total fruit weight) nor the oxygen consumption data.

Among tomato:eggplant grafts, total yields varied markedly from 0.42 to 0.92 kg/plant, yet eggplant yields bore no relation to yields of tomato grafted onto eggplants (r^2=0.052). Differences between yields of tomato:eggplant grafts were apparently related to plant height, stem, and leaf weight at biomass sampling, but not to total root weight, nor fine root weight nor measures of root activity. Further studies will investigate the role of root activity immediately after a flooding period relative to genotypic tolerance to flooding.

Additionally, to reduce the cost of providing grafted transplants, pruning which results in two or more main stems in place of the current one per plant, while reducing planting density, is being studied.

Intercropping Chili With Maize

Summary

Although intercropping chili (*Capsicum* spp.) with maize reduced virus in chili in previous years, this was not evident this year. Intercropping chili with maize populations > 1.0 plant/m^2 raised intercrop productivity (measured with the land equivalent ratio), but pepper yields were significantly reduced by > 2.0 plants/m^2 of maize. Fruit number, rather than individual fruit weight, was reduced when competition from maize was evident. A greater fruit yield response to increased chili planting density was evident in the autumn, rather than the spring experiment.

Introduction

In two previous years, diminished virus incidence and increased total productivity through intercropping maize with chili have been investigated (AVRDC 1991[4] and 1992 Progress Reports). Two further trials, one with a systematic design to measure the influence of increasing maize population on chili yields, and the other to screen chili genotypes for compatibility as intercrops with maize, were conducted.

[4]AVRDC. 1992. AVRDC 1991 Progress Report. AVRDC, Shanhua, Tainan, Taiwan.

Materials and Methods

Details of experiment 1 comparing six maize and two chili populations were presented in the previous year (AVRDC 1992 Progress Report); the design was identical to another experiment run during the spring of 1992. In summary, maize variety TN 11 was planted at 0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 plants/m^2 on the center of 1-m-spaced beds containing one or two rows of chili (3.3 or 6.7 plants/m^2), with beds orientated in N/S or E/W directions. Chili cv. Chain Fair was transplanted at the time of sowing maize (30 September 1992). Maize was harvested 121 days after sowing (DAS), and chili was harvested over the period 85 to 122 days after transplanting (DAT).

In experiment 2, 15 chili genotypes were transplanted on 30 September 1992, when maize variety TN 11 was also sown. Transplanting or sowing into two-row beds, 1.5 m apart, resulted in populations of 3.3 and 1.0 plants/m^2 of chili and maize, respectively. Treatments with or without the maize intercrop comprised the main plots. Maize was harvested 121 DAS, and chili harvests extended over the period 83 to 121 DAT. One bed of each genotype, 6 m long, comprised the split plots. Data collection was as outlined in the AVRDC 1992 Progress Report and, where feasible, a combined analysis of data from experiment 1 with those of the same spring-sown experiment was conducted. Analysis of chili yields in experiment 2 used data for only 13 genotypes; two [PBC 475 (= Yaberawit) and PBC 641 (= Bird's Eye)] did not yield fruit.

Results

F periment 1

Maize plant and grain yields per unit land area increased with greater maize population and were matched with a decline in total chili yield over the same treatments (fig. 5). The higher of the two chili populations reduced total and grain yields of maize (0.47 vs. 0.60 kg/plant total weight, SED [15 df] = 0.035; 3.2 vs. 3.6 t/ha grain yield, SED [15 df] = 0.081).

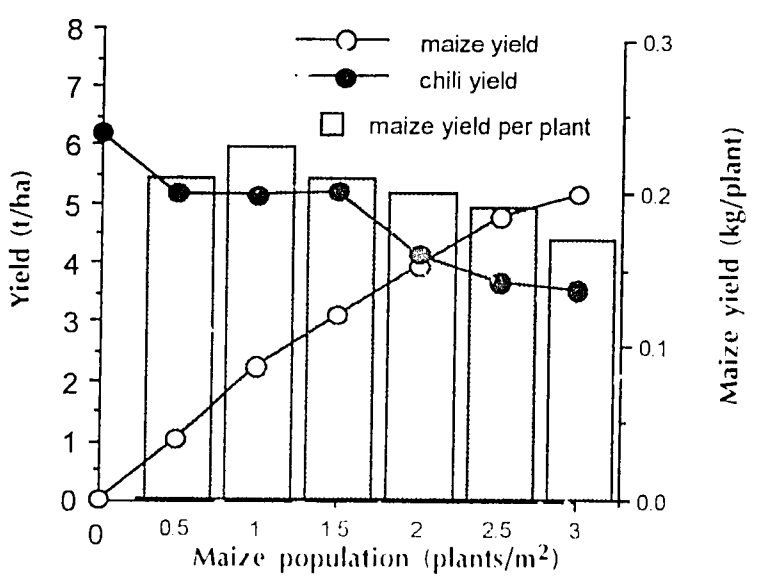

Fig. 5. Total fruit and grain yields of chili and maize at various maize intercrop populations in the autumn (means of two chili population densities, two row directions, and two gradient directions for maize populations)

Total and red fruit yield of chili in the low chili population density was about one half that of the high density planting (e.g., 3.4 vs. 6.1 t/ha, SED [18 df] = 0.33 for total fruit weight), almost entirely due to fewer fruits per unit area in the former (e.g., 16.1 vs. 30.6 red fruit/m^2) since weight per red fruit only differed slightly (11.85 vs. 11.05 g/fruit for low and high chili population densities, respectively). Increasing maize population as an intercrop reduced chili yields, but the reduction was only marked (and significant) at maize population ≥ 2.0 plants/m^2. Although maize canopy senesced before final harvest of chili, no apparent compensation in intercropped chili yields close to final chili harvest (fig. 6) was evident.

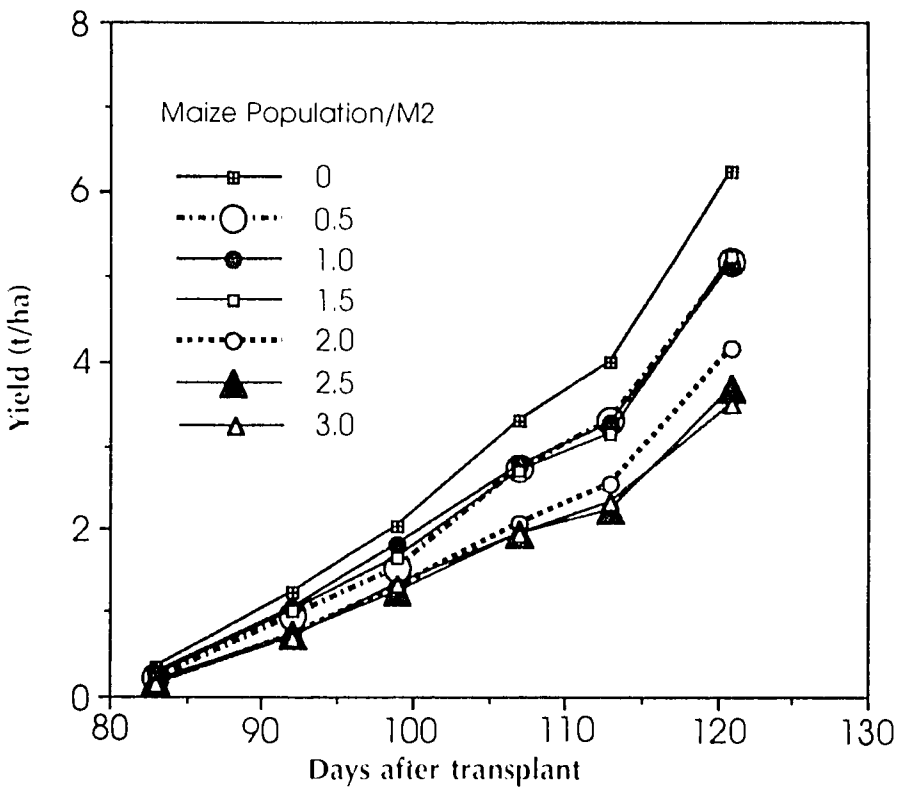

Fig. 6. Cumulative total chili yields, intercropped with six maize populations during autumn (means of two chili populations and low row direction/population gradient treatments)

Infection with CMV was not reduced significantly in the intercropped chili (98% of chili plants were infected with CMV by 72 DAT), although there was a tendency for more infection in the plots without maize. The c.v. of field sampling for virus was surprisingly high at 177% and 40% for the first and second samples.

Combining chili yield data from experiment 1 (autumn crop) with an identical experiment run during the spring/summer (AVRDC 1992 Progress Report) confirmed the main effects of treatments across seasons, but highlighted various interactions between treatments and seasons.

For example, although red fruit (i.e., marketable) yield did not differ across seasons, total yields did (6.0 vs. 4.7 t/ha for spring vs. autumn) as did weight per fruit (4.3 vs. 11.5 g/fruit) and, therefore, fruit number per unit area. The chili response to a double chili population density was greater in the autumn crop (table 5) where growth was restricted by a progressively low temperature (see Meteorological Data for 1993, p.). Chili yield was also significantly greater in the N/S (increasing maize to the W) direction in spring, and in the E/W (increasing maize to the N) in autumn.

Combining maize yield data across seasons showed, as expected, strong effects of maize population on grain yield per plant and per unit area. Grain yield was differentially affected by row direction across seasons, with a marked increase in the N/S compared to the E/W sowing direction in spring, but not in autumn (table 6). The effect of the chili population on maize grain yield also varied across seasons. During autumn, when maize grew somewhat slower, the higher chili population resulted in lower maize yield (table 6) compared to the summer season when significant differences between chili populations and maize yield were not evident.

Table 5. Effects of season and chili population density, and season and row direction, on red fruit yields (t/ha fresh weight measured across maize populations)

Season	Chili population		Row direction			
	Low	High	N/S		E/W	
			Maize increasing		Maize increasing	
			to E	to W	to S	to N
Spring	2.5	3.0	2.7	3.1	2.5	2.6
Autumn	1.9	3.3	2.3	2.4	2.6	3.1
SED within a season	0.35 (6 df)		0.42 (18 df)			

Table 6. Effects of season and chili populations, and season and row directions, on maize dry grain yield (g/plant measured across maize populations)

Season	Chili population		Row direction			
	Low	High	N/S		E/W	
			Maize increasing		Maize increasing	
			to E	to W	to S	to N
Spring	0.09	0.09	0.10	0.09	0.09	0.08
Autumn	0.14	0.12	0.13	0.12	0.12	0.14
SED within a season	0.008 (5 df)		0.010 (15 df)			

Experiment 2

Intercropping maize with chili reduced total fruit number and weight per unit area (table 7, fig. 7a), but most other characters, e.g., plant height, fruit size, plant weight at final harvest, were unaffected. The c.v. for yield data were unacceptably high, ranging from 19 to 51%. Significant differences were evident among all lines for all measured characters, but only for total fruit number per unit area was there a significant interaction between intercrop system and genotype. The line with the highest fruit number (PBC 370) suffered greatest reduction (50%) when intercropped. The main effect of intercropping on chili yield was to reduce the number of fruit set; individual fruit weight was not influenced so markedly by the intercrop treatment (fig. 7b).

Maize yield, although ranging from 0.9 to 1.6 t/ha across intercropped plots with chili, was not significantly affected by chili genotypes (SED [14 df] = 0.335). On average, intercropped maize yield at 1.3 t/ha was 24% of sole maize yield. Heavier ear weight in intercropped maize was responsible for this since intercropped maize had only 8% more ears per plant.

Table 7. Yield and growth data for chili, intercropped or not with maize (mean of 13 genotypes)

Treatment	Plant height (cm; 55 DAT)	Plant dry weight at harvest (g)	Marketable		Total	
			Fruit size (t/ha)	Fruit yield (/m²)	Fruit no. (t/ha)	Fruit yield
Control	38.6	42.4	8.8	1.6	1178	3.1
Intercrop	37.1	41.7	9.1	1.0	719	2.0
SED (1 df)	n.s.	n.s.	n.s.	n.s.	98	0.22

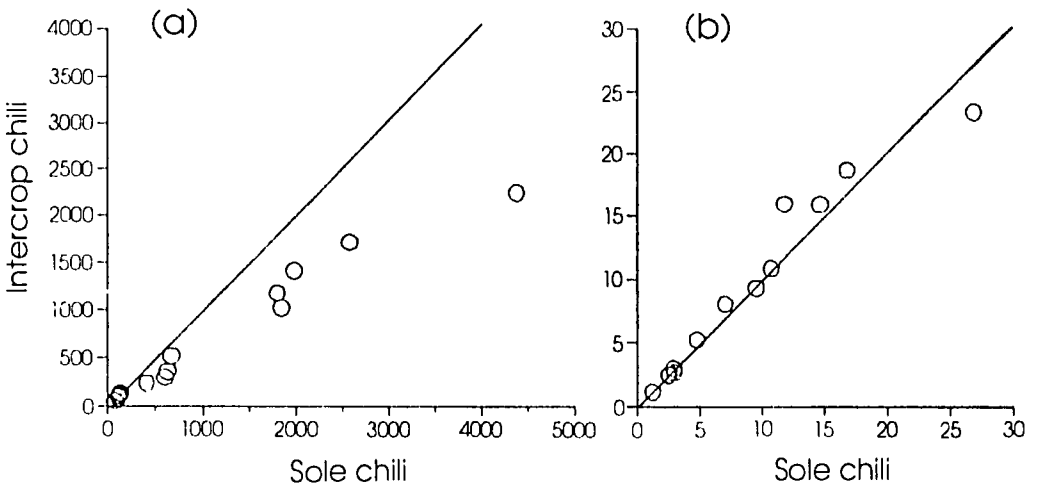

Fig. 7. Plots of a) chili total fruit yield and b) chili marketable fruit size in intercropped vs. sole treatments for 13 genotypes in the autumn

Light interception (LI) beneath the chili canopy differed significantly across chili genotypes at the three sample dates (33, 54, and 77 DAT), but the differences between main (intercrop or not) plots were only significant at the two later dates, with the intercrop on average exceeding the control by 11% (table 8). A significant interaction at the final date was the result of a proportionately greater increase in leaf index with intercropping in genotypes with low LI in the sole treatment. When intercrop LI was regressed on sole crop LI, this effect was highlighted by the value of the slope which was <1.0 ($y=0.30+0.44(\pm0.08)x$, $P=0.0002$) The experimental mean maximum light interception at 40% was extremely low compared to our other intercrop experiments. This in part may have been due to the planting in 1.5-m-wide beds. For two chili genotypes, light interception was also measured above the chili canopy (table 9) to determine the actual interception of irrradiance by the maize crop. The maize crop intercepted up to a maximum of 37% of incoming irradiance, more so where the chili genotype exhibited poorer LI.

Discussion

Reduction of virus incidence through intercropping with maize was not so marked as in previous years. However, overall productivity of intercrops in experiment 1 was greater than that of sole crops, as measured with the LER. As in the previous year, greater LERs were evident at the higher maize populations (table 10), but the optimum combination of intercrop densities will depend upon the unit prices for each commodity. Apparently, at low maize populations the loss in chili yield is not offset by gain in maize yield (as a proportion of their side crop yields), until the intercrops contain > 1.0 plants/m² of maize. Economic analyses of these data are under way.

In the comparison between chili genotypes, only two genotypes (Orias Kossarvu and a sweet pepper genotype) resulted in LER > 1.0 (table 10). The reduction in intercropped chili yield was due to reduction in fruit numbers, not individual fruit weight. Since total plant weight was not reduced by intercropping (table 7), it is probable that bud or flower abscission in intercropped plants was responsible for the reduced yield, and not a reduction in the number of branches. Further studies will elucidate this hypothesis.

Table 8. Total light interception in sole or intercropped chili on three occasions (mean for 15 genotypes)

	Light interception (%)		
Treatment	33 DAT	54 DAT	77 DAT
Control	11.1	29.4	33.1
Intercrop	15.8	38.8	44.9
SED (1 df)	n.s.	1.30	1.42

Table 9. Light interception (% of incoming) by two chili genotypes with and without intercropping with maize

	PBC 485			Sweet pepper genotype		
	33 DAT	54 DAT	77 DAT	33 DAT	54 DAT	77 DAT
Intercrop						
Above chili (= a)	2.6	18.5	37.4	6.0	18.8	29.7
Below chili (= b)	14.2	38.4	44.2	24.9	44.3	57.1
By chili (= b-a)	11.6	19.9	6.8	18.9	25.5	27.4
Sole chili crop	9.2	25.4	27.9	12.7	34.9	50.6

Table 10. Land equivalent ratios (LER) for experiments 1 and 2

Experiment 1			
Maize population (plants/m²)		LER	
0		1.0	
0.5		0.967	
1.0		1.181	
1.5		1.376	
2.0		1.407	
2.5		1.460	
3.0		1.586	
Experiment 2			
Chili genotype	Name	Origin	LER
COO 835	Orias Kossarvu	Hungary	1.25
Sweet pepper genotype			1.10
PBC 412	Tam Mild Chile-2	USA	0.98
PBC 451	Cayenne Cajun IA	USA	0.88
PBC 374	Jatilaba	Indonesia	0.88
PBC 462	MI-2	Sri Lanka	0.85
PBC 373	Keriting	Indonesia	0.84
PBC 485	MI-1	Sri Lanka	0.80
PBC 401	KA-11	Sri Lanka	0.77
PBC 140	Jawahar 218	India	0.77
PBC 075	Szechwan 92068	Taiwan	0.73
PBC 600	LC-Serdang	Malaysia	0.70
PBC 370	PBC 370	Thailand	0.63

Intercropping Sugarcane with Legumes

Introduction

To reduce levels of purchased inputs and to improve upon their efficiency of use and that of solar irradiance, various intercrop combinations of sugarcane and legumes have been studied (AVRDC 1991 and 1992 Progress Reports). The earlier studies highlighted the suppression of weed growth by using legumes intercropped with sugarcane. These studies, however, indicated the possible detrimental effect on cane yield, especially the intercrop with mungbean, perhaps as a result of allelopathic effects. Complete data for the two latter experiments in this series are presented.

Materials and Methods

A detailed description of the three field experiments was presented in AVRDC 1991 and 1992 Progress Reports.

In essence, experiment 1 compared intercrops of two vegetable soybean lines, at two rectangularities (two or three rows per bed between sugarcane) with residues incorporated, removed, or removed and followed by mungbean. Experiment 2 was the same as experiment 1, with the exception that all plots following vegetable soybean were sown to snap bean. In experiment 3, two sugarcane planting rectangularities (single rows at 1.3 m or paired rows at 0.7 m with 1.9 m between pairs) were sown with vegetable soybean as an intercrop, with residues removed or incorporated. Superimposed on these treatments was a second intercrop of vegetable soybean, mungbean, or no intercrop. In each experiment, sole crops of sugarcane and the intercrops were included within the experimental designs.

Results and Discussion

Experiment 2

Intercropped and sole vegetable soybean yields (graded pod and total fresh weight) were identical and not influenced significantly by the variety of vegetable soybean nor by the rectangularity of sowing (table 11). Snap bean following vegetable soybean as an intercrop yielded 20% of sole snap bean, yet total aboveground fresh weight per plant was similar. While snap bean yields were reduced in plots with incorporated residues of vegetable soybean (664 vs. 311 g/m^2, p=0.12), there was a tendency for intercropped snap bean yield to be greater in the treatment previously sown to the three, than the two rows of vegetable soybean per plot, i.e., those plots in which cane light interception was marginally, yet not significantly, less than the others. Biomass surveys taken 31 and 66 DAS for snap bean also highlighted the reduction in growth of snap bean where vegetable soybean had been incorporated, and where vegetable soybean was sown as two-row plots.

Light interception in intercropped plots already reached 78% by 30 DAS, and a maximum of 92% by 42 DAS, declining to 87% at 63 DAS (fig. 8). No differences between vegetable soybean lines nor sowing rectangularities were evident. Following harvest of vegetable soybean, and immediately before sowing snap bean, interception by the remaining sugarcane was 18-19%, compared to 44% in the sole cane plots. Three weeks later, light interception in the intercropped cane plots (3 wk into the snap bean crop) was similar whether above or below the snap bean, indicative of the poor crop coverage by the snap bean. Five weeks after sowing the snap bean, light

interception in the intercropped plots reached 46% at ground level and 29% above the snap bean (i.e., snap bean intercepted 17% of available irradiance). In a further 3 wk (139 days after start of the experiment), interception by the intercropped cane (above the snap bean canopy) was greater in plots previously with AGS 292 than with G 9053, (58.7 vs. 51.4%, SED(16df)=1.8) as was snap bean fresh biomass (47.1 vs 33.8 g/pl).

Table 11. Harvest data for vegetable soybean and snap bean following vegetable soybean, Experiment 2

Treatment		Vegetable soybean			Snap bean	
		No. plants (/m²)	Total fresh weight (t/ha)	Graded pod yield (t/ha)	Marketable yield (t/ha)	Fresh weight aboveground 66 DAS (g/pl)
Variety	AGS 292	30.7	18.8	7.0	0.5	47.1
	G 9053	30.2	18.7	5.4	0.6	33.8
Spacing	Two rows	29.6	18.0	6.0	0.5	37.0
	Three rows	31.3	19.5	6.4	0.6	44.0
SED (3 df)	Within pair	0.4	n.s.	n.s.	n.s.	n.s.
Sole crop	AGS 292	34.4	18.4	6.9	2.7	48.9
	G 9053	36.5	18.6	5.4	3.0	65.9

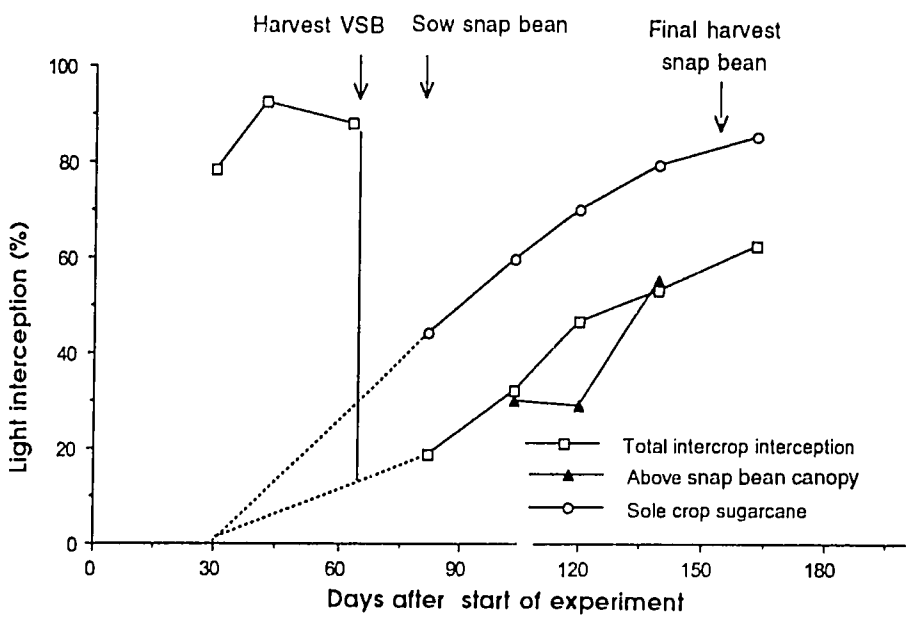

Fig. 8. Light interception by sugarcane and its intercrops, (means of treatment combinations) Experiment 2

Sugarcane yields were not affected in sole plots by additional fertilizer (equivalent to that applied to the intercrops) nor by rototilling (80 DAS), although the number of stems per unit area was higher if rototilled and receiving no extra fertilizer (table 12).

Intercropping with vegetable soybean, as in experiment 1, significantly reduced the yield of cane (table 12) and the Brix. Reduction in the number of stems per unit area was largely responsible for the depression of cane yield, which was similar with either vegetable soybean variety. Incorporation of vegetable soybean residues resulted in a significant 10 t/ha increase in cane yield (table 12) due to more stems per hill, but no effect on Brix.

Indices of productivity of the intercrop combinations were calculated (table 13). Land equivalent ratios (LER) indicated a great response to intercropping, as would be expected if cane yields were not greatly reduced by intercrops, and if intercrops gave yields close to their sole crop counterparts. The area x time equivalency ratios (ATER) which take into account land opportunity use over time, were not markedly greater than unity. LERs and ATERs were consistently (but not significantly) greater with vegetable soybean variety G 9053, with three-row sowings of vegetable soybean, and if no vegetable soybean tops were incorporated (table 13).

Experiment 3

Vegetable soybean line AGS 292 was sown between single cane rows (as one two-row bed with 0.4 m between rows on the bed) or paired cane rows (as two two-row beds with 0.3 m between rows on the bed), with both crops in each treatment at the same population density. Early growth of vegetable soybean did not differ between the two treatments, but by the R_4 stage aboveground dry weight per plant was greater within the single-row cane planting, that with more space between vegetable soybean rows. This effect was manifest in the final pod number per plant and in total pod and graded pod weights (table 14). Following vegetable soybean harvest, a succeeding vegetable soybean crop showed a tendency to yield more in the double-row cane planting system, but the reverse was evident for the mungbean crop sown at the same time. Leaving the vegetable soybean residues of the first crop in the field depressed plant population of both vegetable soybean and mungbean with associated reduction in pod and plant yield (table 15).

Light interception differed between cane-planting systems, with the single-row system giving consistently 14 to 7% advantage for the period 54 to 69 DAS; there being no difference at 28 DAS (fig. 9). Following vegetable soybean harvest (74 DAS), interception by intercropped cane ranged from 7.9% (single row) to 12.3% (double row, SED (12 df) = 2.0), compared to 14.7% for the sole cane in the single-row planting system. Following sowing of the succeeding vegetable soybean or mungbean crop (82 DAS), light interception of intercropped plots 10 days later was 24% (vs. 37.7% for sole cane plots). Prior to final harvest of the second intercrop (151 DAS), the single row system intercepted more light compared to the double-row system (87.7 vs. 83.1%, SED [18 df]=1.3%); but no difference occurred immediately after harvest (average 71%). Later, the single-row system continued to intercept light better (86.3 vs. 82.0% at 160 DAS, and 93.9 vs. 89.0% at 215 DAS) (fig. 9).

Cane yields were reduced in the intercropped paired-row cane planting system compared to the single-row system (by 9%) and in the intercropped cane compared to the sole cane (table 16). In particular, a reduced cane population in the paired-row system (perhaps due to more intraspecific competition), resulting in fewer stems per unit area, was responsible for the low yield in that system. Heavier individual canes in the sole crop led to yields greater than those of intercropped cane. The second vegetable soybean intercrop increased cane yields slightly, and the mungbean decreased them, compared to the treatment with no second intercrop. Returning vegetable soybean residues to the field made no difference in the final yield of sugarcane.

Table 12. Sugarcane yields (t/ha) and components of yield following fertilizer and intercrop treatments, Experiment 2

Treatment Fertilizer	Rototilled	Yield	Stem no. (/m²)	Treatment	Yield	Stem no. (/m²)	° Brix	Treatment	Yield	Stem no. per hill
Normal	No	176.3	7.6	No intercrop	184.7	8.0	21.0	VSB residue incorporated	154.9	3.8
Extra	No	168.0	7.7	Intercrop AGS 292+snap	147.6	6.8	19.9	VSB residue removed	144.9	3.6
Normal	Yes	204.1	9.1							
Extra	Yes	190.4	7.6	Intercrop G 9053+snap	148.9	7.0	19.9			
SED (3 df)		n.s.	0.21	SED (2 df)	7.8	n.s.	0.12	SED (1 df)	0.2	0.001

Table 13. Land equivalent ratios (LER) and area x time equivalency ratios (ATER) for various cane/intercrop combinations, Experiment 2

Treatment	LER	ATER
Intercrop AGS 292	2.62	1.09
Intercrop G 9053	2.80	1.13
SED (15 df)	n.s.	n.s.
Two-row intercrop	2.25	1.11
Three-row intercrop	2.87	1.12
SED (15 df)	n.s.	n.s.
Leave 1st crop residue	2.47	1.10
Remove 1st crop residue	2.95	1.13
SED (15 df)	n.s.	n.s.

Table 14. Harvest data for the first vegetable soybean crops in Experiment 3

Intercrop system	R_4 stage			Final harvest			
	Top dry weight (g/plant)	Nodes/ plant	Leaf area (cm^2/plant)	Pods/ plant	Total fresh weight/plant/(t/ha)	Pod yield (t/ha)	Graded pod yield (t/ha)
Single row	8.53	7.89	9.03	14.3	15.4	8.0	5.7
Paired rows	6.53	7.53	7.73	13.1	14.0	7.2	5.0
SED (3 df)	0.52	0.11	n.s.	0.2	0.2	0.1	0.1

Table 15. Harvest data for intercropped vegetable soybean (G 9053) and mungbean (VC 1160) following a vegetable soybean intercrop, Experiment 3

Crop	Previous treatment	Plant no. (/m^2)	Plant yield (t/ha)	Plant weight (g/plant)	Pod yield (t/ha)
Vegetable soybean (VSB)	Single row	13.4	3.2	23.8	7.0
	Double row	14.7	4.6	34.1	9.4
	SED (3 df)	n.s.	0.6	n.s.	0.9
	Leave VSB residue	13.6	4.0	30.5	8.1
	Remove VSB residue	14.5	3.8	27.4	8.3
	SED (6 df)	0.3	n.s.	n.s.	n.s.
Mungbean	Single row	71.2	4.5	7.2	
	Double row	68.2	3.8	6.1	
	SED (3 df)	n.s.	n.s.	n.s.	
	Leave VSB residue	60.2	4.0	6.9	
	Remove VSB residue	79.2	4.3	6.3	
	SED (6 df)	5.7	n.s.	n.s.	

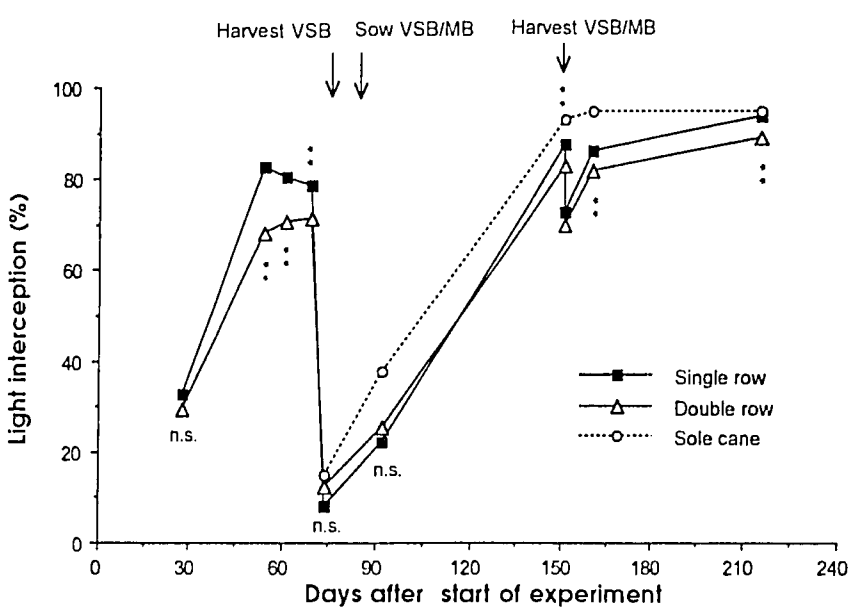

Fig. 9. Light interception by sugarcane and its intercrops, Experiment 3 (significance of difference between intercrop treatments indicated)

Table 16. Cane yield and yield components in various intercrop systems

Treatment	Hill no. (/m²)	Stem no. (/m²)	Cane yield (t/ha)	°Brix
Single-row system	2.6	8.6	127.8	21.6
Paired-row system	2.4	7.3	116.3	21.7
SED (2 df)	0.1	0.3	5.6	n.s.
VSB residue incorporated	2.5	7.9	122.2	21.7
VSB residue removed	2.6	7.9	121.9	21.6
SED (15 df)	n.s.	n.s.	n.s.	n.s.
No second intercrop	2.5	8.2	123.1	21.5
VSB second intercrop	2.6	8.0	127.8	21.6
MB second intercrop	2.5	7.6	115.3	21.8
SED (18 df)	n.s.	n.s.	n.s.	n.s.

Total productivity, measured as LER or ATER, was greater in intercrops than for sole cane. Single-row planting was better than paired-row (table 17), and inclusion of a second intercrop after vegetable soybean also raised overall productivity, whereas, as for experiment 2, incorporation of vegetable soybean residues somewhat reduced overall productivity (table 17).

Table 17. Productivity indices for intercrops with sugarcane, land equivalent ratio (LER), and area x time equivalency ratio (ATER), Experiment 3

Treatment	LER	ATER
Single-row	2.33	1.18
Paired-row	2.16	1.08
SED (6 df)	n.s.	n.s.
Leave 1st residue	2.23	1.13
Remove 1st crop residue	2.26	1.13
SED (6 df)	n.s.	n.s.
2nd crop VSB	2.32	1.18
2nd crop mungbean	2.65	1.18
No second crop	1.77	1.03
SED (6 df)	0.13	0.08

Discussion

The reduction in cane yield as a result of using various intercrop systems, and as a result of incorporation of legume residues, merits further attention. Economic analyses to determine whether the loss in cane yield was offset by gain in legume revenues are under way and should provide the basis for recommendation of this practice, irrespective of whether total productivity was increased or not (tables 13 and 17). The data indicate that planting cane in a paired-row system led to less first vegetable soybean intercrop yields, less mungbean second intercrop yields, and less cane yield than in the single row system, which was matched by less light interception in the paired-row system (fig. 9).

In spite of greatest recorded LER and ATER values for the intercrop combinations involving mungbean (due to less total biomass yield reduction in intercropped mungbean than for reduction of pods in intercropped vegetable soybean), data from experiment 3 and from a previous experiment 1 suggest a possible allelopathic effect of mungbean on cane yields beyond that expected due to direct competition for aerial or edaphic resources. Further research will focus on this topic.

Analyzing Competition Between Soybean and Pai-tsai in a Competition Box Trial

Summary

Two competition box trials were carried out in July and August 1993 in the greenhouse to analyze competition in soybean and pai-tsai grown as intercrops. Pai-tsai yield was lowered most under full competition and least under no competition treatments. Shoot competition by soybean affected pai-tsai yield more than root competition.

Introduction

During 1992-93, field experiments intercropping legume green manure (*Medicago sativa, Desmodium purpureum, Indigofera tinctoria,* and *Glycine max*) with a short-duration (30 days) leafy vegetable were conducted at the AVRDC experimental farm. The goal was to help reduce the time a vegetable farmer would have no cash-crop income in the field while growing legume green manure as soil amendment and fertilizer for the next crop. As a result of these experiments, pai-tsai yield was not affected negatively compared to sole pai-tsai treatments by *Desmodium*, alfalfa, and *Indigofera*, but it was lowered when intercropped with soybean. A competition box experiment in the greenhouse was set up to examine the relative effects of shoot and root competition between pai-tsai and soybean. The trial followed the specific additive (Snaydon 1991[5]) intercropping arrangement where soybean was grown on 2/3 of the soil surface and pai-tsai on 1/3 in a binary mixture.

Materials and Methods

Two experiments, one in July and one in August 1993 were conducted in the greenhouse at AVRDC, Taiwan. The method used differed slightly from that of Martin and Snaydon (1982)[6] because of the different plant species and the planting arrangement. The plants were grown in an additive (Snaydon 1991) design with four arrangements of partitions shown in fig.10: (a) full (shoot + root) competition between species, (b) no competition between species, (c) shoot competition between species, (d) root competition between species. Pai-tsai (*Brassica campestris chinensis*) was sown in a row in the middle of the box, with one plant every 10 cm; soybean was sown in two rows (2 seeds/10 cm) closer to the edge of the box. The boxes in which the plants were grown were 0.6 m long x 0.5 m wide x 0.3 m deep. They were divided into belowground compartments of 0.15 m x 0.5 m for soybean and 0.3 m x 0.5 m for pai-tsai grown in pattern (b) and (c), and 0.1 m x 0.6 m compartments for competition patterns (a) and (d) (fig. 10). Plywood was used for soil partitions as well as for aerial partitions which were covered with reflective aluminum foil. A randomized block design with two replicates per treatment was used.

The boxes were filled with a sandy loam soil (pH 8.2, 0.64% organic C, and 0.08% total N). Soil was fertilized with the surface equivalent of 80 kg P/ha (superphosphate) and 110 kg K/ha (KCl). Fertilizers were mixed with the top 10-cm soil layer before sowing pai-tsai and soybean. Ammonium sulfate (50 kg N/ha) was added to pai-tsai rows only in two sidedressings (10 and

[5]Snaydon, R. W. 1991. Replacement or additive designs for competition studies. Journal of Applied Ecology 28: 930-946.

[6]Martin, M.P.L.D. and Snaydon, R.W. 1982. Root and shoot interactions between barley and field beans when intercropped. Journal of Applied Ecology 19: 263-272.

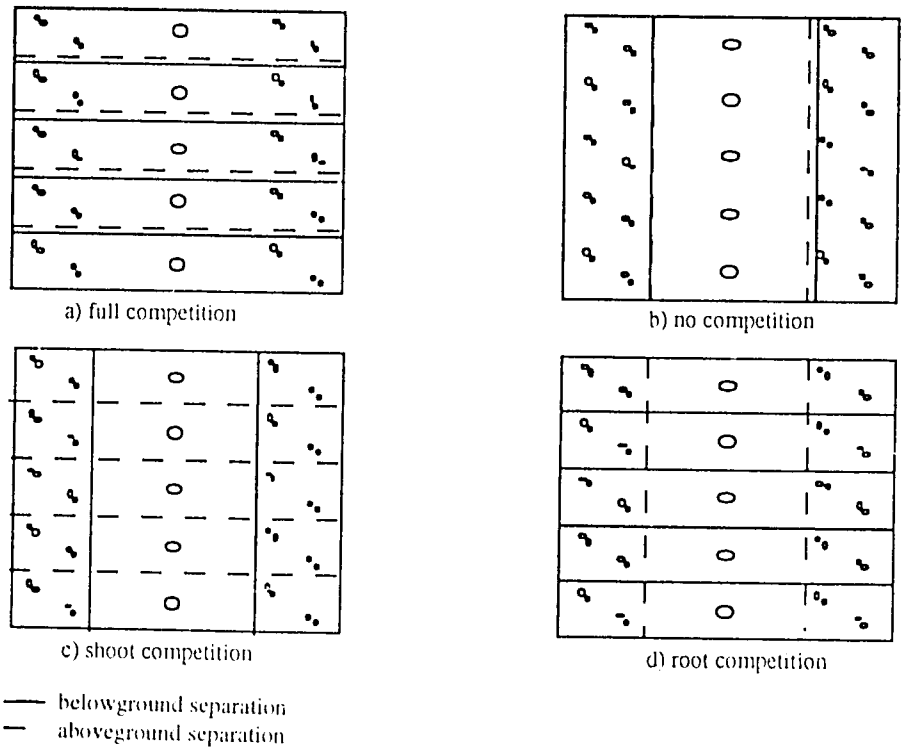

Fig. 10. Planting arrangement of soybean (o) and pai-tsai (∘) to give: (a) full competition between species, (b) no competition, (c) shoot competition, (d) root competition between species

20 DAS), with 25 kg N/ha each. The boxes were watered regularly to keep the soil close to field capacity. Soybean and pai-tsai were harvested 30 days after sowing, separating root and shoot, for fresh and dry weight.

Mixture performances were expressed in Relative Yield Total (RYT)

$$RYT = \frac{Yij}{Yii} + \frac{Yji}{Yjj}$$

where Yij = yield per plant species i grown in mixture with species j, Yii = pure stand yield per plant of species i, Yji = yield per plant species j grown in mixture with species i, Yjj= pure stand yield per plant of species j. RYT measures the ability of one component to obtain limiting resources when grown in mixture with another component compared with its ability to utilize those resources when grown in pure stands (De Wyt and van Den Bergh 1965[7]). Competitive ability was measured by comparing the biomass yield of the component in mixture under full competition and that under no competition. The relative competitive ability of the species is expressed as the aggressiveness of soybean relative to pai-tsai (McGilchrist and Trenbath 1971[8]).

[7]De Wyt, C.J. and van Den Bergh, J.P. 1965. Competition between herbage plants. Netherlands Journal of Agricultural Science 13: 212-221.

[8]McGilchrist, C.A. and Trenbath, B.R. 1971. A revised analysis of plant competition experiments. Biometrics 27: 659-671.

$$\text{Aggressiveness} = \frac{1}{2}\left(\frac{Yij}{Yii} - \frac{Yji}{Yjj}\right)$$

Results and Discussion

Shoot weight

In the July experiment, highest pai-tsai shoot yields were recorded in the no-competition treatment (fig. 10). Shoot and root competition reduced pai-tsai yield significantly (P>0.05). Shoot competition had a stronger effect on pai-tsai shoot yield and differed significantly (P>0.05) from root competition. Full competition reduced pai-tsai shoot yield more and differed significantly (P>0.05) from shoot and root competition. Reduction of pai-tsai shoot yield by competition pattern was from greatest to least, full > shoot > root > no competition. In the August experiment, highest pai-tsai yields were again obtained with no-competition treatment. Shoot and root competition reduced pai-tsai significantly. Full competition had the greatest yield reduction but did not differ significantly (P>0.05) from the reduction with either shoot or root competition. The pai-tsai yield reduction ranking order was full > shoot > root > no competition.

Soybean shoot yields of the full and root competition treatments differed significantly from no- and shoot-competition treatments (P>0.05) in both July and August experiments. In July soybean shoot under full competition differed significantly from root competition and no-competition treatment from shoot competition. These differences were not significant in the August experiment.

Aggressiveness and relative yield total

Table 18 shows the dry matter yields of pai-tsai and soybean in the July and August 1993 experiments, and indices of aggressiveness.

Table 18. Dry matter (shoot + roots = g/plant) yields of pai-tsai and soybean, July (30 DAS), and August 1993 (32 DAS), and indices of aggressiveness

July 1993	Dry matter yields			
competition:	no.	root	shoot	full
Pai-tsai (g/plant)	0.44	0.33	0.19	0.11
Soybean (g/plant)	0.98	1.35	0.93	1.43
Aggressiveness (index)		0.31	0.26	0.61
August 1993				
competition:	no.	root	shoot	full
Pai-tsai (g/plant)	0.23	0.16	0.08	0.09
Soybean (g/plant)	1.21	1.40	1.35	1.40
Aggressiveness (index)		0.21	0.37	0.38

Competitive ability, expressed as the aggressiveness of soybean relative to pai-tsai, was greater in full competition treatment of both experiments. It was much stronger in July than in August. This is probably because under full competition soybean was given more space above and below ground so that it grew better and strongly competed with pai-tsai. Moreover, aggressiveness under full competition in July equaled the sum of the aggressiveness of root and shoot competition. In August the differences between treatments were much smaller so that aggressiveness under shoot competition is comparable to those under full competition (fig. 11).

The RYT was 1.7 in July and 1.5 in August. These values indicate that the components do not fully share common limiting resources, i.e., they compete partially and show partial resource complementarity.

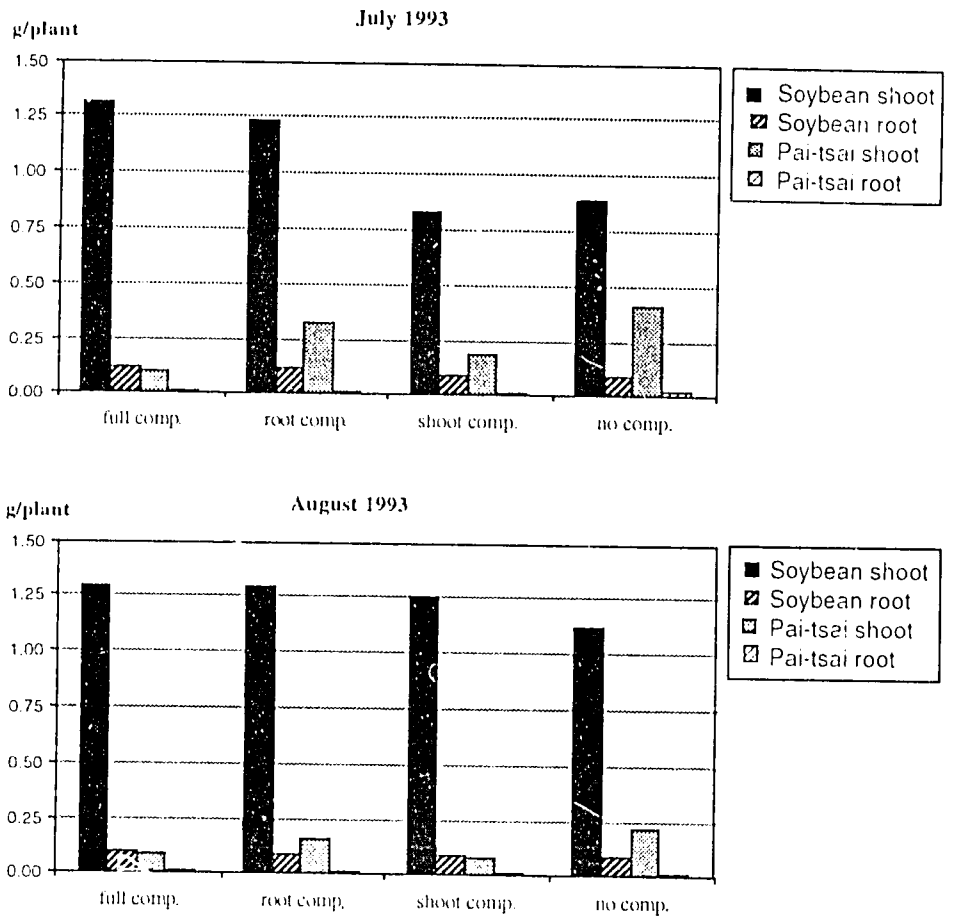

Fig. 11. Dry matter yields (g/plant) of soybean and pai-tsai intercropped and grown under different competition treatments in July and August 1993

Conclusions

Soybean reduced pai-tsai yield due to shoot and root competition. Since soybean was planted densely and grew tall very quickly, it shaded pai-tsai plants so that competition for light (shoot competition) was more severe than root competition. The larger rooting volume, including access to more N, may have contributed to higher soybean yields. It is a general finding that the stronger component in a mixture (aggressor: soybean) increases its yield relative to its pure culture, while the yield of the other component decreases. These compensating changes are usually due to the uneven sharing of environment growth factors, which the components must share. Furthermore, when root barriers were omitted soybean root encroachment into the pai-tsai root volume probably contributed to soybean's dominance. Thus, shoot and root (i.e., full) competition together made soybean in this specific arrangement a strong competitor for pai-tsai.

When sown simultaneously with soybean in the field, pai-tsai contributed little to the income of the farmer while growing legume green manures. Nevertheless, pai-tsai could be transplanted or sown 10 days before soybean to increase its competitiveness and, therefore, contribute to farm income.

Response of Mungbean with Contrasting Morphologies to Various Population Densities and Rectangularities

Summary

The response of some very early and short new breeding lines to increased population densities was compared to that of the control line VC 1973A. While it was felt that the shorter lines would respond differently to the higher population, this was not evident, and may in part be due to our sowing at higher populations on three-, instead of two-row beds. Nevertheless, the early lines were earlier by 4 -7 days in maturity, and shorter by 10 to 20 cm in height than the control. Grain yield in the spring and autumn was greater at the recommended population (40 plants/m^2) in three- rather than two-row beds, but not in the summer when growth was vigorous. The smallest seed-size lines resulted in greatest average yields (at an average population 17% greater than recommended); and for summer and autumn, optimal population was 50 plants/m^2 for maximum grain yield. In the spring, no clear response to plant density was evident. It is suggested that, if farmers broadcast sow the mungbean crop, variety selection on-station be better undertaken on three- rather than two-row beds because the former provides more accessible space per plant than the latter.

Introduction

Breeding of mungbean at AVRDC for early and uniform harvest has lead to a reduction in plant height and canopy width.

Although early studies (AVRDC 1974[9]) with available lines at AVRDC lead to a recommended population of not > 12 plants/m^2 (120,000/ha) and yield barely in excess of 1 t/ha, later work with the smaller seed-size lines showed that maximum yields (> 2.5 t/ha) could be achieved at higher population densities of 40 plants/m^2 (AVRDC 1975[10]). Current AVRDC recommendations for variety evaluations are to sow two rows per 1-m-spaced bed at 50 cm x 10 cm with two seeds per hill. A number of high-yielding, early-maturing lines have been selected under these sowing conditions. These lines have been widely diffused among Asian countries, and, due to their high yield potential, their early maturity and feasibility to fit within cropping systems, they have been adopted on a large scale, accounting, for example, for 90% of the total mungbean hectarage in Thailand (Jansen et al. 1993[11]).

Observations on recent trials with the newest generations of early-maturing AVRDC mungbean lines suggest that full advantage is not being taken of available irradiance once crop cover is maximal; soil remains exposed between adjacent rows within the two-row beds. Mungbean is often grown with minimal purchased inputs and limited field cultivation; this causes loss in potential yield. Besides loss of yield potential through reduced interception of irradiance,

[9]AVRDC. 1974. Annual Report for 1972-1973. AVRDC, Shanhua, Tainan, Taiwan.

[10]AVRDC. 1975. Annual Report for 1974. AVRDC, Shanhua, Tainan, Taiwan.

[11]Jansen, H.G.P., Charnnarongkul, S., and Kim, D. 1993. Economic analysis of mungbean production in Thailand. AVRDC working paper no. 6, 96 p.

weed growth may further reduce yield if not checked by competitive mungbean plants. The current experiments were designed to determine whether the most recent AVRDC lines could be planted at higher densities, and at more favorable rectangularities to raise yields. In the long term, studies on the response of these dwarf lines to irrigation and fertilization are being undertaken as part of a series of management practices aimed at intensifying the production of mungbean.

Materials and Methods

Four experiments were run in the spring (1), summer (2), and autumn (3) of 1992 and the spring (4) of 1993. Details specific to each experiment are presented in table 19. Factorial designs were used within randomized complete blocks with three replications. Five planting densities were sown on three-row beds and were chosen as 20% multiples of the control population (40 plants/m^2); i.e., 20% less, the same, and 20, 40, and 60% greater than the control. With the exception of the summer experiment, the control was sown at 0.5 m x 0.1 m with three seeds per hill thinned shortly after emergence to two per hill (i.e., 40 plants/m^2). For the summer experiment, the control was sown at 0.5 m x 0.133 m to give a lower population of 30 plants/m^2, since vegetative growth during the summer is more profuse than during the other seasons. Fertilizer application for each experiment was at the rate of 30:60:100 kg/ha N: P_2O_5: K_2O, with the N split into two applications.

Both crop cover (using a grid system - Anonymous 1986[12]) and light interception (using a LICOR LI 1000 radiometer) data were collected two or three times within each experiment, as were two sets of growth analysis data at the fifth to sixth week and the eighth to ninth week after sowing. After measurement of height, plants were separated into stem, leaf, root, and pods (if present), and leaf subsamples were taken for leaf area determination. All parts were dried at 70°C for 3 days before weighing. At final harvest, total seed yields and 1000-seed weight were estimated from bordered areas within each plot, and data on yield components (i.e., number of pods per plant and seeds per pod) were collected from five plants per plot. Phenological data, i.e., the date of 50% flowering and 50% pod maturity (= black pods), were also collected biweekly.

All data collected were subjected to statistical analyses. However, in Experiment 1, data from a number of plots in one corner of the field were discarded due to poor growth attributed to allelopathic effects of a previous mungbean crop. Analyses combining data from two or more experiments (McIntosh 1983[13]) were also undertaken and are presented here.

Results

Experiment 1

Early differences between crop cover were evident both among the four lines and the planting density treatments; values for VC 3890A were consistently less than for the other lines, and crop cover was greater at the higher densities (table 20). For the same density, but sown in two or three rows per bed, early cover values did not differ, but by 41 DAS the three-row planting had a better crop cover. Only at the six-week sample for crop cover was there an interaction ($p = 0.048$) between lines and densities, but no trend in the data was apparent. No differences in weight or leaf area between densities were indicated, but with crop cover values at that date barely exceeding 65%, it is unlikely that competition at the higher densities reduced individual plant size. Values for leaf area and weight per unit area were quite obviously greater at the greater densities (data not presented).

[12]Anonymous. 1986. A simple method for interpreting potato crop growth and yield. CIP Circular 14:7-9.
[13]McIntosh, M.S. 1983. Analysis of combined experiments. Agronomy Journal 75: 153-154.

Table 19. Details of field experiments comparing mungbean lines at various population densities and rectangularities in three seasons

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Sowing date	20 March 1992	21 July 1992	29 September 1992	22 March 1993
Plot size	5 m x 4 m	5 m x 2 m	5 m x 2 m	5 m x 2 m
Plant spacing (and density/m²)	0.189 m x 0.33 m (32) 0.15 m x 0.33 m (40) 0.125 m x 0.33 m (48) 0.107 m x 0.33 m (56) 0.94 m x 0.33 m (64) 0.10 m x 0.50 m (40)	0.25 m x 0.33 m (24) 0.20 m x 0.33 m (30) 0.167 m x 0.33 m (36) 0.143 m x 0.33 m (42) 0.125 m x 0.33 m (48) 0.133 m x 0.50 m (30)	As Experiment 1	As Experiment 1
Mungbean lines	V 3726 VC 1178A VC 1973A VC 3890A	As Experiment 1	V 3726 VC 1178A VC 1973A CN 4 NM 92	VC 1178A VC 1973A NM 92 CN 4
First growth analysis	46 DAS	36 DAS	35 DAS	44 DAS
Second growth analysis	66 DAS	58 DAS	56 DAS	64 DAS

Table 20. Crop cover, growth, and yield data for four mungbean lines and six planting densities in Experiment 1

Line	Crop cover (%)			Growth sample (66 DAS)					Final harvest			Grain yield
	27 DAS	35 DAS	41 DAS	Leaf area (cm/plant)	Pod (per plant) no.	Pod (per plant) wt (g)	Dry weight (g/plant) Top	Dry weight (g/plant) Root	Plant height (cm)	1000-seed weight (g)	No. pods/ plant	(t/ha)
V 3726	11.1 a	25.7 a	62.7 a	430 c	8.3 b	4.4 a	8.4 b	0.6 c	36.7 c	62.6 a	7.9	1.8 b
VC 1178A	11.6 a	24.4 a	54.5 bc	357 c	7.6 b	3.9 a	7.5 b	0.5 c	33.3 c	62.1 a	7.7	1.7 b
VC 1973A	11.0 a	21.0 b	56.8 b	628 b	7.8 b	3.0 b	8.5 b	0.7 b	51.7 a	59.7 b	8.3	1.7 b
VC 3890A	9.0 b	19.0 b	48.9 c	739 a	9.7 a	3.5 ab	10.4a	0.8 a	44.9 b	55.8 c	8.9	2.0 a
Planting density												
0.189 m x 0.33 m	7.0	15.6	45.3	693	10.2	4.4	11.1	0.8	42.2	62.0	9.7	2.0
0.15 m x 0.33 m	9.1	19.9	53.2	588	9.6	4.1	9.7	0.7	41.2	60.4	9.4	1.9
0.125 m x 0.33 m	11.5	25.1	61.2	482	7.7	3.2	7.6	0.6	39.4	60.3	8.6	1.8
0.107 m x 0.33 m	11.9	24.4	59.8	464	7.2	3.0	7.4	0.6	40.5	59.0	6.7	1.7
0.094 m x 0.33 m	14.5	29.6	66.9	452	7.0	3.3	7.4	0.5	41.9	59.2	7.0	1.9
0.10 m x 0.50 m	9.8	21.4	47.4	497	8.3	4.5	9.0	0.6	40.6	60.4	8.0	1.6
SED plant density (26 df)	0.57	1.40	2.95	47.6	0.58	1.14	1.90	0.12	n.s.	0.52	0.51	0.09

At the second growth sample, differences were evident between lines and densities for all measured characters. Leaf area and all dry weights per plant were greater in VC 3890A, the line with the least crop cover, as they were at the lowest densities. The same was true for the aboveground dry weight per plant at final harvest. Nevertheless, greatest values per unit area were recorded in the higher densities.

Compared to the control line VC 1973A, all other lines were shorter at final harvest by 7-18 cm. Final height was not, however, influenced by planting density, although the number of pods per plant and the 1000-seed weight were; both significantly greater at the lower populations. At the same population (40 plants/m^2), sowing in three rows resulted in more pods per plant than sowing in two rows, but 1000-seed weight was unaffected by rectangularity of sowing.

For total seed yield, differences between lines and densities barely reached significance ($p = 0.0584$ and 0.0587, respectively) with the latest maturing line VC 3890A, and the highest densities leading to greatest yields. The least yield was recorded in the two-row sown beds.

Incidence of powdery mildew and lodging were also least in that line, but did not differ among densities (data not presented).

Experiment 2

As observed in experiment 1, early crop cover was greatest at the highest planting densities and, at the same population, was greater in the three- than the two-row sowing (table 21). Leaf area index, however, did not differ across the two- and three-row sowings at the same plant density. By 50 DAS differences between densities in light interception had leveled out. The line VC 1178A had consistently less crop cover or light interception than the other lines at 36 DAS; this was related to less leaf area index, but not at 58 DAS. Plants of the control line, VC 1973A, were taller than those of other lines, as were plants at the higher density compared to those at the lower populations. The dwarf line V 3726, as in experiment 1, had the least plant dry weight at the later sample, the least top dry weight at harvest (data not presented), and the least leaf area per plant. Although early crop cover was the greatest recorded in this line, by 50 DAS it was intermediate among lines in light interception, and by 65 DAS it was least, at 30%, largely due to its early maturity (3 days earlier than the latest line). Plant height at 36 DAS was greater in the three- than two-row sowing at 30 plants/m^2 as was plant weight, leaf area index (LAI), and the leaf area to total weight ratio (data not presented), but by 58 DAS many of these differences were no longer evident.

Clear trends, with increasing values at the higher densities, were evident for plant height and LAI (both samples), and lower values for total and component plant weights and leaf areas per plant at the higher densities. Various interactions between densities and lines were evident: early crop cover (24 DAS), plant height (36 and 58 DAS), root dry weight (36 DAS), pod dry weight (58 DAS), and aboveground and total dry weight (58 DAS). Crop cover at 24 DAS peaked at control + 20% in line V 3726, whereas in the other lines it peaked at the maximum plant density (control + 60%). In the shortest line — VC 1178A, crop cover in the two-row sowing was much less than that of the three-row sowing at the same density (by 25%), but the same was also true for the tallest line, VC 1973A. Only in VC 3890A did the cover of the two-row sowing reach the lowest value of the three-row rowing. Plant height of the two-row sowing was less than that of any three-row planting density in VC 1178A and VC 1973A, but for the other two lines it was intermediate among population densities. Root weight was much less in the two- than three-row sowing for two lines, V 3726 and VC 1178A, compared to the other lines for which root weight did not vary markedly across population densities. Total dry weight (58 DAS) was similar to aboveground dry weight to that for the short line, V 3726; the two-row sowing was similar to the

control + 40% population density, whereas for the tallest line (VC 1973A) it was similar to the lowest population density (control - 20%), the other two lines being intermediate.

Flowering and maturity dates differed between lines (with V 3726 and VC 1178A earlier than the other lines), but density had no measurable effect on phenology. Conversely, plant height (measured by the breeders) at the two phenological stages did not differ between lines, but was markedly greater at the higher densities (data not presented). Maximum seed yield (1.2 t/ha) was achieved by VC 3890A, the line with least Cercospora infection and greatest number of pods per plant and seeds per pod (n.s.). However, uniformity of maturity in this line was poor compared to the others; only 71% of the total grain harvest was collected at the first picking, compared to 91% for V 3726. An increasing trend ($p = 0.057$) in yield at greater densities was evident, but other components of yield with the exception of 1000-seed weight ($p = 0.053$) were not significantly affected by population.

At the same plant density (30 plants/m^2) there was no significant difference in yield between sowing in two- or three-row beds (0.9 and 0.8 t/ha, respectively).

Experiment 3

The control line, VC 1973A, was taller than other lines with greater leaf area, root dry weight (35 DAS), and pod number and weight (56 DAS) (table 22). Leaf area to total weight ratio and LAI were also greater in this line than in others on both sample dates, as was light interception 42 and 55 DAS. The shortest line (VC 1178A) was > 20 cm shorter than the control at 56 DAS with V 3726 and NM 92 only 4 cm taller than VC 1178A at 56 DAS. Of those two lines, V 3726 had better dry weight accumulation, light interception (with the exception at 78 DAS) and LAI, but line VC 1178A, particularly at the later (56 DAS) sample, had less dry weight, LAI, and other measurable attributes than other lines.

With the exception of plant height and leaf area to total dry weight ratio, all other attributes differed significantly across planting densities in the same trends as observed in Experiments 1 and 2. Weight and leaf area attributes, however, tended to be greater (and on occasions significantly so) in two- than three-row sowing at the same plant density (40 plants/m^2), yet light interception (LI) was greater in three-row sowing.

Interactions were evident for light interception at 42 DAS ($p = 0.098$), 55 DAS ($p = 0.05$), and 78 DAS ($p = 0.13$). Essentially, at 42 DAS the major influence of population on LI occurred between the two lowest densities, with an increase in LI at the higher of the two. This was, however, not evident for line NM 92, for which LI increased only at the highest but one (i.e., control + 40%) density. At both 42 and 55 DAS, the LI in the two- vs. the three-row bed was much reduced in CN 4 and NM 92 compared to the differences in other lines. At 78 DAS, LI of the two-row sowing was markedly less than that in the three-row sowing for all lines except CN 4.

The tallest line, VC 1973A, was also the latest to reach 50% flowering and maturity (5 and 7.5 days later than the earliest lines, respectively) (table 23). Differences between all lines were significant for seed yield, with the short line NM 92 yielding less than one half that of the highest yielding line CN4. Lodging was serious in the two tallest lines, but they both resulted in maximum yields. The yield advantage of CN 4 was attributed to the greater number of pods per plant than other lines, and of seeds per pod, but 1000-seed weight was least of all lines. Uniformity of maturity was greatest in this line, lending itself to a once-over or mechanical harvest.

Plant density did not influence flowering nor maturity dates, but lodging was greater at all densities compared to the lowest plant density. Nevertheless, grain yield reached a maximum at the penultimate density, but did not differ significantly among the four highest densities. In particular, the pod number per plant was significantly reduced at higher densities, as was the 1000-seed weight, but the latter not significantly so.

Table 21. Crop cover, growth, and yield data for four mungbean lines and six planting densities in Experiment 2

Line	Crop cover (%)	Light interception (%)		Plant height (cm)		Leaf area index		Total plant dry weight (g)		Days to			Harvest	
	24 DAS	50 DAS	65 DAS	36 DAS	58 DAS	36 DAS	58 DAS	36 DAS	58 DAS	Flowering	Maturity	CLS	1000-seed wt (g)	Grain yield (t/ha)
V 3726	72.8 a	69.9 bc	29.8 d	33.3 a	38.8 b	3.1 a	1.3 b	8.8	14.0 b	35.4 b	54.6 c	4.5 a	55.9 c	0.7 c
VC 1178A	67.4 b	65.7 c	43.5 c	29.3 b	38.4 b	2.7 b	1.7 b	8.0	15.0 ab	34.4 b	55.8 b	3.7 b	56.9 b	0.6 c
VC 1973A	71.4 ab	73.8 ab	61.2 b	33.4 a	43.7 a	3.4 a	2.7 a	8.8	15.8 ab	37.1 a	56.1 b	2.9 c	60.8 a	1.0 b
VC 3890A	70.7 ab	77.4 a	68.2 a	29.1 b	38.1 b	3.1 ab	2.9 a	8.3	16.8 a	38.1 a	57.6 a	3.0 c	55.5 c	1.2 a
Planting density														
0.25 m x 0.33 m	64.4	66.7	51.4	29.1	35.4	2.6	1.7	10.1	18.1	35.8	55.7	3.5	58.0	0.8
0.20 m x 0.33 m	73.1	71.6	51.0	32.0	39.3	2.9	2.1	9.4	17.4	36.5	56.7	3.5	57.5	0.8
0.167 m x 0.33 m	75.4	72.3	49.4	31.2	40.3	3.0	2.0	8.2	14.0	35.8	55.8	3.5	56.6	0.9
0.143 m x 0.33 m	76.7	73.6	48.8	33.6	41.8	3.4	2.5	7.5	14.1	36.4	55.9	3.8	56.7	0.9
0.125 m x 0.33 m	79.1	74.4	52.6	34.1	44.5	3.9	2.6	7.6	13.3	36.1	56.2	3.6	57.2	1.0
0.133 m x 0.50 m	54.7	71.7	51.0	27.6	37.3	2.7	2.0	7.9	15.5	37.0	56.0	3.4	57.8	0.9
SED (46 df) between planting density means	2.35	n.s.	n.s.	1.37	1.47	0.224	0.242	0.61	1.21	n.s.	n.s.	n.s.	n.s.	0.05

Table 22. Light interception and growth characteristics of five mungbean lines grown at six planting densities in autumn, Experiment 3

Line	Light interception (%)			Plant height (cm)		Sample 35 DAS			LAI
	42 DAS	55 DAS	78 DAS	35 DAS	56 DAS	Root (g/plant)	Leaf area: total weight (cm/g)	Total (g/plant)	56 DAS
V 3726	84.7 c	86.8 c	62.3 c	19.1 b	31.2 c	0.22 b	125 c	3.23 a	2.57 b
VC 1178A	80.8 d	84.1 d	65.6 bc	16.8 c	27.4 d	0.21 b	103 e	3.35 a	1.89 c
VC 1973A	92.4 a	93.7 a	65.4 bc	23.7 a	49.3 a	0.28 a	155 a	3.35 a	3.87 a
CN 4	87.4 b	91.6 b	68.7 b	19.2 b	37.8 b	0.22 b	139 b	2.91 b	2.84 b
NM 92	79.1 d	83.4 d	73.7 a	20.1 b	31.3 c	0.17 c	113 d	2.90 b	2.05 c
Planting density									
0.189 m x 0.33 m	81.7	85.6	67.6	18.7	35.5	0.25	134	3.61	1.52
0.15 m x 0.33 m	85.6	86.7	67.4	20.1	35.2	0.22	132	3.11	1.65
0.125 m x 0.33 m	87.2	90.2	68.2	20.4	35.2	0.22	123	3.08	1.81
0.107 m x 0.33 m	87.5	89.9	70.1	20.6	36.4	0.20	123	2.91	1.99
0.094 m x 0.33 m	86.5	90.5	68.5	19.4	35.8	0.18	128	2.64	2.19
0.10 m x 0.50 m	80.9	84.6	61.1	19.3	34.5	0.25	123	3.54	1.71
SED (58 df) between planting densities	1.22	1.09	2.38	n.s.	n.s.	0.014	3.8	0.166	0.200

Table 23. Phenological and harvest data for five mungbean lines sown at six densities in autumn, Experiment 3

Line	Days to Flowering	Days to Maturity	Lodging	Pod no./ plant	1000-seed weight (g)	First harvest proportion	Grain yield (t/ha)
V 3726	37.7 c	67.5 c	3.0 c	10.4 bc	71.4 a	0.92 ab	1.8 c
VC 1178A	36.7 d	66.2 d	1.3 e	10.4 bc	68.9 b	0.91 ab	1.6 d
VC 1973A	42.0 a	73.9 a	4.8 a	11.0 b	69.7 b	0.90 bc	2.3 b
CN 4	40.1 b	69.3 b	4.0 b	14.3 a	47.5 d	0.94 a	2.5 a
NM 92	35.2 e	66.3 d	1.6 d	9.1 c	51.2 c	0.88 c	1.1 e
Planting density							
0.189 m x 0.33 m	38.0	68.5	2.6	12.7	62.3	0.91	1.8
0.15 m x 0.33 m	38.5	69.2	3.0	11.5	62.1	0.90	1.9
0.125 m x 0.33 m	38.1	68.2	3.0	10.6	62.1	0.91	2.0
0.107 m x 0.33 m	37.9	68.2	3.0	9.7	61.3	0.92	2.0
0.094 m x 0.33 m	38.9	68.8	3.1	10.2	60.4	0.91	1.9
0.10 m x 0.50 m	38.6	68.9	3.1	11.6	62.1	0.90	1.7
SED (46 df) between densities	n.s.	n.s.	0.16	0.68	n.s.	n.s.	0.07

Experiment 4

The greater height of the control, VC 1973A, and the shortest stature of VC 1178A and NM 92 (especially at the later sample date, 64 DAS), were directly related to their dry weights, above and belowground, leaf areas, and crop cover and LI data (table 24). With the exception of the earliest (28 DAS) cover data, no difference was evident in cover nor LI between the control line and line CN 4 until 63 DAS when a greater LI was maintained by CN 4.

With the exceptions of plant height at both samples and LI at 63 DAS (when values started to decline) differences between other measured attributes across densities were significant. As anticipated from previous data, crop cover and LI increased with increasing planting density, and dry weights and leaf areas per plant were reduced at the higher densities.

Crop cover was greater in three- than two-row sowings at the same plant density (40 plants/ m^2) but by 51 DAS LI data illustrated no difference. Only for the later root weight sample were there significant differences between rectangularities, in the same direction as above.

Interaction between lines and densities was significant for crop cover at 37 DAS and for LI at 63 DAS ($p = 0.07$). For line VC 1973A, crop cover increased over the range of densities to the highest density, whereas in VC 1178A it peaked at control + 20%, for CN 4 at control + 40%, and for NM 92 (after a dip at control + 40%) at control + 60%.

Root dry weight also showed an interaction with the two-row sowing illustrating greater competition (i.e., similar root weight to that of higher densities) in VC 1178A and NM 92 (the two shortest lines) than in the other two lines.

The range between the earliest and latest dates of flowering and maturity among lines were 4 and 3.5 days, respectively, but differences were significant (table 25). The control, VC 1973A, was latest and line NM 92 the earliest. As in experiment 3, yield of the intermediate maturity line CN 4 was greater than that of other lines, with the two shortest lines resulting in lowest yields. Line CN 4 was also least infected with powdery mildew. A superior number of pods per plant and seeds per pod contributed to the high yield of CN 4, while 1000-seed weight was lowest among all lines. In contrast to the previous season's result, CN 4 was not the most uniformly maturing line; at 78% yield recovery at first picking, it was considerably poorer than the other lines.

Table 24. Crop cover, light interception, and growth attributes of four mungbean lines sown at six densities in spring, Experiment 4

Line	Crop cover (%)		Light interception (%)		Plant height	Sample 44 DAS			Top dry weight
	28 DAS	37 DAS	51 DAS	63 DAS	64 DAS (cm)	Top dry weight (g/plant)	Root dry weight (g/plant)	Leaf area (cm/plant)	56 DAS (g/plant)
VC 1178A	43.9 b	79.1 b	80.9 b	69.4 c	33.0 c	4.2 ab	0.4 b	459 b	8.8 a
VC 1973A	50.1 a	87.2 a	83.0 ab	74.2 b	43.8 a	4.5 a	0.6 a	652 a	9.2 a
CN 4	45.5 b	86.1 a	85.4 a	78.1 a	38.6 b	4.3 a	0.5 b	623 a	9.0 a
NM 92	39.6 c	72.6 c	68.3 c	56.2 d	29.9 c	3.7 b	0.4 c	359 c	6.8 b
Planting density									
0.187 m x 0.33 m	36.5	80.0	79.6	69.7	35.5	4.9	0.6	617	10.8
0.15 m x 0.33 m	41.0	82.7	78.8	69.0	36.0	4.4	0.5	546	9.0
0.125 m x 0.33 m	48.9	84.6	78.8	71.0	35.6	4.3	0.5	535	7.9
0.107 m x 0.33 m	52.3	85.9	79.1	69.8	36.0	3.6	0.4	446	7.0
0.094 m x 0.33 m	56.9	87.7	83.5	70.5	36.8	3.6	0.4	456	6.5
0.10 m x 0.50 m	33.2	66.5	76.6	66.9	38.1	4.3	0.5	541	9.6
SED (46 df) between densities	2.00	1.70	2.01	n.s.	n.s.	0.29	0.03	35.7	0.70

Table 25. Phenological and final yield data for four mungbean lines sown at six densities in spring, Experiment 4

Line	Days to		Pod no.	Seed no./	1000-seed	First harvest	Grain yield	Powdery
	Flower	Maturity	plant	pod	weight (g)	proportion	(t/ha)	mildew
VC 1178A	41.8 a	57.2 b	9.5 b	9.6 bc	69.8 b	0.87 a	1.3 c	2.75 b
VC 1973A	41.8 a	58.1 a	7.9 c	9.8 ab	72.0 a	0.83 b	1.5 b	2.50 b
CN 4	40.5 b	56.8 b	11.9 a	10.0 a	45.6 d	0.78 c	1.8 a	2.18 c
NM 92	37.7 c	54.7 c	9.5 b	9.4 c	53.3 c	0.87 a	1.1 d	3.25 a
Plant density								
0.189 m x 0.33 m	40.4	56.5	12.6	9.9	60.4	0.82	1.4	2.71
0.15 m x 0.33 m	40.6	56.7	10.7	9.6	61.1	0.83	1.5	2.54
0.125 m x 0.33 m	40.5	56.8	9.6	9.7	60.2	0.83	1.5	2.54
0.107 m x 0.33 m	40.4	56.6	8.5	9.8	58.9	0.84	1.4	2.58
0.094 m x 0.33 m	40.0	56.8	8.2	9.6	59.8	0.84	1.5	2.75
0.10 m x 0.50 m	40.8	56.8	9.1	9.7	58.9	0.87	1.3	2.88
SED (46 df) between densities	n.s.	n.s.	0.76	n.s.	n.s.	n.s.	0.06	n.s.

Grain yield did not vary significantly between densities, but sowing in two-row beds was inferior to the three-row system. The number of pods per plant was reduced at higher densities, but this was compensated for by the greater number of plants at those densities.

Combined analyses

Combined analyses for four lines in two seasons (experiments 3 and 4) and for two lines (VC 1973A and VC 1178A) in two spring (experiments 1 and 4) seasons were run.

For the four line data, the main effects of season, line, and planting density on grain yield were very highly significant, as was the interaction between season and line (table 26). The same trend was evident for most harvest data, with the exception of seed number per pod and phenological data which did not differ across densities (data not presented).

Grain yield was greater in the autumn season (1.9 vs. 1.4 t/ha). Autumn yield was greater due to a longer maturation period (+ 12 days), although flowering was 2 days earlier.

Over seasons, yield of NM 92 was consistently low (1.1 t/ha), whereas yields of the other lines were greater in the autumn (table 26). The two highest yielding lines (VC 1973A and CN 4) matured later by 3 days than the other two lines in the autumn (which matured late), with many more pods per plant in the former.

Table 26. Interaction means for four lines across two seasons (Experiments 3 and 4).

Line	Grain yield (t/ha)		Maturity (DAS)		No. pods/plant	
	Autumn '92	Spring '93	Autumn '92	Spring '93	Autumn '92	Spring '93
VC 1178A	1.6	1.3	66.2	57.2	10.4	9.5
VC 1973A	2.3	1.5	73.9	58.1	11.0	7.8
CN 4	2.5	1.8	69.3	56.8	14.3	12.3
NM 92	1.1	1.1	66.3	54.7	9.1	9.5
SED (92 df) line within season	0.10		0.62		1.10	

Analysis of variance for two lines (V 1178A and VC 1973A) over the two spring experiments showed similar main effects and interactions as the abovementioned combined analysis. Exceptions were for the number of pods per plant, which did not differ across years nor lines, 1000-seed weight which was similar across lines, and seed weight and plant height at maturity which did not differ across population densities. There was also no significant interaction between years and lines in grain yield. Yields were greater in experiment 1 (1.7 vs. 1.4 t/ha, no valid statistical test) when flowering and maturity were somewhat later (0.75 and 4 days, respectively). Major differences between years occurred in 1000-seed weight (61.1 vs. 71.0 g). Line VC 1973A matured > 6 days later in experiment 1 than in experiment 4, while for VC 1178 it was 2 days later (tables 20 and 25). These differences were, however, not reflected in 1000-seed weight nor in the number of pods per plant, only in the number of seeds per pod and the aboveground dry weights at harvest. This latter character was also subject to an interaction between years and population density; bigger differences between years (larger values in experiment 1) were evident at the lowest densities (tables 20 and 25).

Discussion

Given the shorter stature of the dwarf lines and their more compact habit, it was expected that they would respond to higher plant densities more than the taller lines. This was not so for grain

yield; no interaction between lines and densities was significant for yield or yield components. In part this may have been due to the sowing of most treatments on three rows, which could favor both shorter and taller lines in terms of available space per plant.

With the exception of the summer trial, yield of the three-row sowing was better than that of two-row sowing at the same plant density. The early vigorous growth in the summer (average 8.5 g plant dry weight and 890 cm^2/plant leaf area at 36 DAS compared to the closest maxima of 4.7 g/plant and 523 cm^2/plant for experiment 1 at 44 DAS) would, to some extent, offset the benefit of the more square plant positioning in the three-row sowing. Rigorous comparisons between seasons for growth data are, however, not feasible due to the differences in durations between sowing and sampling.

In spite of the profuse growth during summer, grain yields were least during that season (with an average of 0.9 t/ha), largely due to the reduced number of pods per plant. The greatest grain yield was achieved in autumn (1.9 t/ha) followed by the two spring seasons (1.8 and 1.4 t/ha for experiments 1 and 4, respectively).

Data from previous studies at AVRDC indicate that the smaller-seeded lines respond more to higher densities than larger-seeded lines. Certainly the smallest-seeded lines (VC 3890A in experiments 1 and 2 and CN 4 in experiments 3 and 4) resulted in the highest average yields (mean planting density of each experiment was 17% greater than recommended), but these lines did not differentially respond to a greater degree than did other lines to greater density.

Regression analyses for grain yield data (fig. 12) suggest that by sowing on three-row beds, optimum density could be raised to 50 plants/m^2 or more in the summer and autumn. No interaction within each season was evident between planting density and line for grain yield. The contrasting behavior in the two spring seasons will be subject to further analysis, as will all data for analyses of competition indices, and correlations between yield and growth characteristics. When mungbean is broadcast sown, as it often is in farmers' fields (Jansen 1993), a more square sowing pattern is likely to ensue for between-plant spacing, hence choice of the best yielding lines when sown and not broadcast, with the exception of the summer, might be better undertaken on three-row beds.

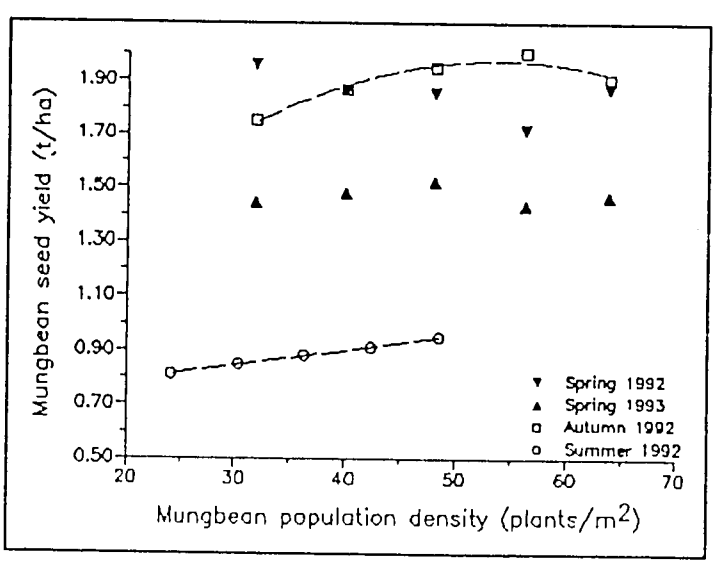

Fig. 12. Mungbean grain yield as a function of population density in four experiments (means over four or five mungbean lines)

Effect of Different Rates of Nitrogen Fertilizer on Pai-tsai Yield and Nitrogen Uptake

Summary

High NPK fertilizer norms in vegetable-growing handbooks for a short-season (30-day) leafy vegetable such as pai-tsai have led to questions of justification for these high rates if the system is to be sustainable. A small field trial varying the nitrogen rates (0, 25, 50 kg N/ha) and recording their effect on pai-tsai yield and N uptake was conducted on the AVRDC experimental farm. Significantly higher yields were achieved with N fertilizer applications compared to none (0 kg N/ha). There was no significant yield difference between 25 and 50 kg N/ha; 25 kg N/ha is sufficient to achieve highest pai-tsai yields, although the best N fertilizer efficiency was only 50.4%.

Introduction

Pai-tsai (*Brassica campestris chinensis*, cv. Green Petiole [563]) is a short-duration (30-day), leafy vegetable frequently grown in Taiwan and other countries of Southeast Asia. The fertilizer norms, e.g., 168 kg N, 90 kg P_2O_5, and 108 kg K_2O /ha (Harvest Farm 1989[14]), or 110-150 kg N, 40-80 kg P_2O_5 and 80-110 kg K_2O /ha (Harvest Farm 1980[15]), or 140-200 kg N, 90-120 kg P_2O_5, 120-150 kg K_2O /ha (JCRR[16]), applied to pai-tsai seem high when its short growing duration and limited root system are taken into consideration. The sustainability of this vegetable production system is, thus, questionable since the residual amount of fertilizer, e.g., nitrogen, is probably leached into the groundwater. The objectives of this trial were to quantify the pai-tsai yield under different rates of nitrogen fertilizer application, to assess nitrogen uptake efficiency of pai-tsai, and to estimate the amount of residual nitrogen fertilizer after pai-tsai harvest.

Materials and Methods

Two field experiments were conducted on AVRDC experimental farm plot no. 79. The first experiment was sown on 12 March and harvested 15 April 1993; the second was sown next to the first field on 7 May and harvested 4 June. Pai-tsai seed was broadcast over the bed and thinned 10 DAS to a plant density of 20 plants/m^2, which is 1/3 of the commonly used plant density. At 30 DAS, pai-tsai plants were pulled out with roots, weighed fresh, and dried. Plant material was analyzed for total N by the Kjehldahl distillation method.

Where:

(a) Nitrogen uptake in pai-tsai plants with 0 kg N /ha

(b) Nitrogen uptake in pai-tsai plants with 25 or 50 kg N /ha

the following terms were defined as:

Residual soil N: (25 or 50 kg N/ha = [b-a])

Fertilizer use efficiency: ([b-a]/25 or 50 kg N /ha) (Uptake from fertilizer N/ applied N)

The plot size was 1 m x 2 m and the field size 3 m x 9.5 m. Phosphorus and potassium were applied to all plots at the rate of 80 kg P/ha (superphosphate) and 65 kg K/ha (potassium chloride).

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[14]Harvest Farm. 1989. Vegetable Growing, Harvest Farm Magazine. Taipei, Taiwan.

[15]Harvest Farm. 1980. Vegetable Growing, Harvest Farm Magazine. Taipei, Taiwan.

[16]JCRR n.d., Chinese-American Joint Commission on Rural Reconstruction. Vegetable Growing, Taipei, Taiwan.

The treatments were 0 kg N/ha, 25 kg N/ha as one sidedressing broadcast over the plot (10 DAS), 50 kg N/ha (25 kg N/ha as sidedressing) (10 DAS) plus 25 kg N/ha as sidedressing (20 DAS) applied as ammonium sulfate. The maximum N contribution, 50 kg N/ha, is approximately 1/3 of the norm fertilizer for 60 plants/m^2. The soil in this site is a sandy loam with a medium texture, pH 8.2; 0.1 dS/cm EC; 0.64% carbon; and 0.08% organic nitrogen.

The trial was a randomized complete block design, with three teatments and four replications. Analyses of variance were performed and linear contrasts were employed to detect differences between treatments.

Results and Discussion

Fresh and dry matter yields

Yield trends over treatments were similar in the two trials. In March/April, fresh yields tended to be higher with higher N fertilizer application. Pai-tsai yields with 25 or 50 kg N/ha differed from 0 kg N/ha significantly only at $P<0.1$. Yield differences between 25 and 50 kg N/ha were not significant. In June, pai-tsai plants were severely affected by striped flea beetle (*Phyllotreta striolata*) which caused a severe yield reduction. Plants remained small and had very slow growth compared to the plants in March/April (table 27). In June also, the fresh pai-tsai yields with 25 and 50 kg N/ha differed significantly ($P<0.05$) from those with 0 kg N/ha, but there was no significant difference in pai-tsai fresh yields between 25 kg N/ha and 50 kg N/ha. Based on the results of both field trials, pai-tsai cannot capitalize and raise its yield with the 25 N kg/ha added in the second sidedressing in the 50 kg N/ha treatment.

Table 27. Fresh and dry matter yields of pai-tsai (kg/ha) grown with different rates of N fertilizer in two field experiments, March/April and June 1993

	N applied (kg/ha)		
March/April 1993	0	25	50
Fresh yield (kg/ha)	3143.75	3818.75	4656.25
Dry yield (kg/ha)	728.92	848.6	903.14
June 1993			
Fresh yield (kg/ha)	1159.25	1410.60	1599.25
Dry yield (kg/ha)	139.82	163.81	182.79

Nitrogen uptake

Pai-tsai plants with N fertilizer applications in April/March ($P<0.05$) and in June ($P<0.1$) had significantly higher nitrogen content compared to those with none (0 kg N/ha) (table 28). Nitrogen content of plants with 25 kg N/ha did not differ from those with 50 kg N/ha in either trial. In April/March and June, significantly more nitrogen was taken up from plants with 25 and 50 kg N/ha compared to those with none (0 kg N/ha). There was no difference in N uptake between plants with 25 and 50 kg N/ha (table 28).

The more nitrogen applied, the lower the fertilizer use efficiency and the higher the residual N in the soil which could be leached into the groundwater (table 28). This looks especially dramatic in June as the yields were so small. A farmer would probably have plowed his crop into the soil and started with another vegetable crop. Nevertheless, with growing environmental concern, a reduction in N fertilizer application in vegetable production, especially with short-duration crops, has to be achieved. As pai-tsai has a very small root system, foliar N application could be a valuable alternative.

Table 28. Nitrogen uptake by pai-tsai (% and kg N/ha), residual N in the soil after pai-tsai harvest, and fertilizer use efficiency (%) in March/ April and June 1993 field experiment

Parameter	Experiment	Kg fertilizer N applied/ha		
		0	25	50
N in pai-tsai plant (%)	March/April	3.1	4.1	4.5
	June	2.8	3.1	3.1
Kg N in plant /ha	March/April	22.5	35.0	40.6
	June	3.9	5.1	5.7
Residual N in soil (kg/ha)	March/April		12.4	31.8
	June		23.8	48.2
Fertilizer efficiency (%)	March/April		50.4	36.3
	June		4.9	3.6

Reducing Bacterial Wilt Incidence in Tomato by Intercropping

Summary

Intercropping tomato with cowpea reduces the area under disease progress curve (AUDPC) of the tomatoes significantly. Intercropping with soybean and Welsh onion has no significant effect on the AUDPC. Compared with a sole tomato crop, intercropping with tomato did not reduce the population of *Pseudomonas solanacearum* in the soil.

Introduction

Intercropping potato with cowpea is known to reduce the bacterial wilt incidence in potato. For the development of an integrated pest management (IPM) program intercropping tomato with different crops was tested on the AVRDC experimental farm during the summer (July to September).

Materials and Methods

Field soil was inoculated with *Pseudomonas solanacearum*, the causal agent of bacterial wilt of tomato, by establishing a bacterial wilt nursery. The soil was infested with *P. solanacearum* strain 4 (PSS 4, standard screening strain of AVRDC) at a depth of approximately 20 cm. Beds with a width of 1.5 m were used for this field experiment. Between the treatments, separation beds were used to avoid cross contamination by irrigation or drainage water.

The following three crops were used for intercropping with tomato: Welsh onion (*Allium fistulosum*), cowpea (*Vigna unguiculata*), and soybean (*Glycine max*). Tomato (*Lycopersicon esculentum*) as a sole crop was the control treatment for wilt incidence and bare fallow was the control treatment for the *P. solanacearum* population in the soil.

The following two tomato cultivars were used: the susceptible Farmers 301 (Known You Seed Company) and bacterial wilt-resistant ASVEG No. 4 (FMTT 22). Both cultivars are indeterminate, fresh-market tomato types.

A completely randomized block design with four replicates was used. The intercrops were sown/transplanted 2 wk before the transplanting of 4-wk-old tomato seedlings. Per treatment one row of tomato and two single (cowpea and soybean) or double rows (Welsh onion) were sown/transplanted per bed. Each treatment comprised of 20 tomato seedlings per cultivar; the two cultivars were transplanted in one separate bed each. The legumes, i.e., cowpea and soybean, were seed-inoculated with *Rhizobium* spp. before sowing. PK fertilizer was based on the needs

of the tomato crop, but distributed over the whole bed in a basal and — for K — two sidedressing applications. Depending on the intercrops, different rates of N fertilizer were applied. The tomato crop received N fertilizer only locally in two sidedressings in all the treatments. Sole tomato crop was mulched with rice straw. The symptoms of wilting tomato plants were recorded regularly, and on several occasions soil samples were taken at a depth of 5 to 20 cm to determine the size of the *P. solanacearum* population in the soil during the field experiment.

Results and Discussion

Fig. 13 shows the disease progress curve for both tomato cultivars. Welsh onion did not reduce the wilt incidence for either the susceptible or the resistant cultivar. For both cultivars, cowpea reduced the wilt incidence more than soybean.

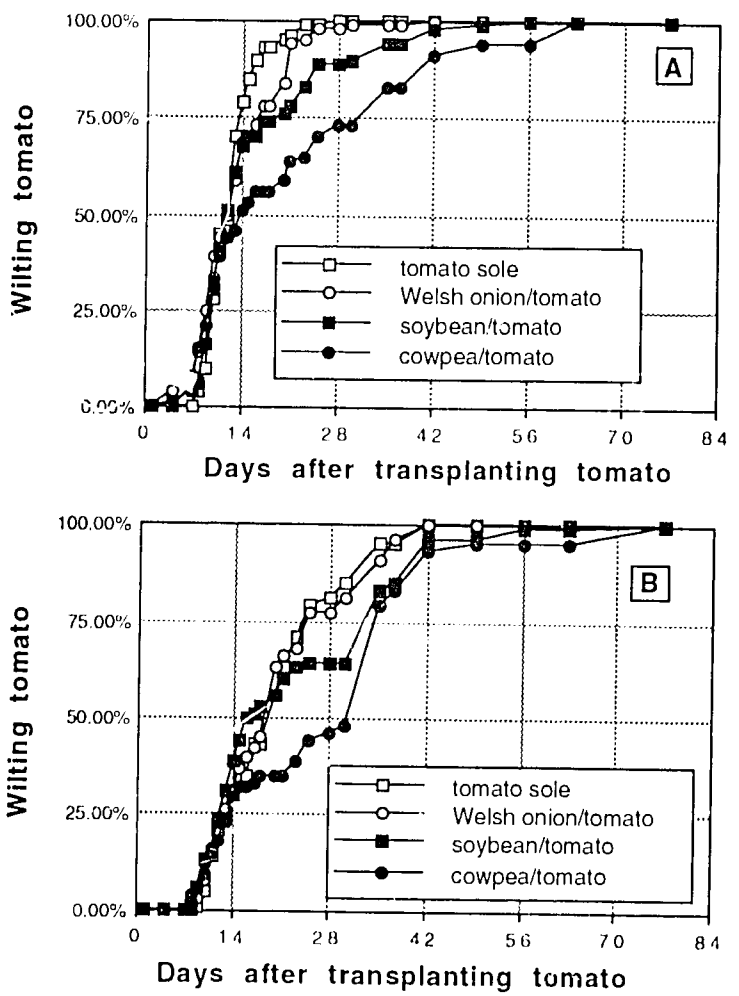

Fig. 13. Progress of bacterial wilt in two tomato cultivars intercropped with Welsh onion, cowpea, soybean, or as sole crop; expressed in % wilting tomato (i.e., from the moment one leaf is partially wilted). A: Susceptible tomato cultivar Farmers 301, B: resistant tomato cultivar ASVEG No. 4

The AUDPCs were calculated from transplanting to 77 days later (table 29). For both cultivars, the AUDPC of the treatments intercropped with cowpea was significantly less ($P \leq 0.01$) than the AUDPC of the control treatment. No significant differences ($P \leq 0.05$) existed between the tomato intercropped with Welsh onion or soybean and the control treatment; neither for the susceptible nor the resistant cultivar.

Intercropping with cowpea can be considered effective in reducing the bacterial wilt incidence of tomato to a limited extent. But even with the (moderately) resistant tomato cultivar ASVEG No.4 the whole crop succumbed to bacterial wilt 77 days after transplanting.

Fig. 14 shows the correlation between the AUDPCs of the different treatments of the susceptible cultivar (Farmers 301) and the resistant cultivar (ASVEG no. 4). The effects of the treatments were independent of the tomato cultivar; cowpea has in both cultivars a significant depression, soybean a slight depression, and Welsh onion no depression on the AUDPC when compared to control values.

Table 29. AUDPC (in days) of two tomato cultivars from 0 to 77 DAT. (Treatments were compared with the control using linear contrast [ns: $P \geq 5\%$, *: $5\% \geq P \geq 1\%$, **: $1\% \geq P$])

Treatment	Farmers 301 (AUDPC)	ASVEG No. 4 (AUDPC)
Welsh onion/tomato	49.92 ns	42.90 ns
Cowpea/tomato	42.20**	36.15**
Soybean/tomato	47.47 ns	40.69 ns
Sole tomato (control)	50.19	43.05

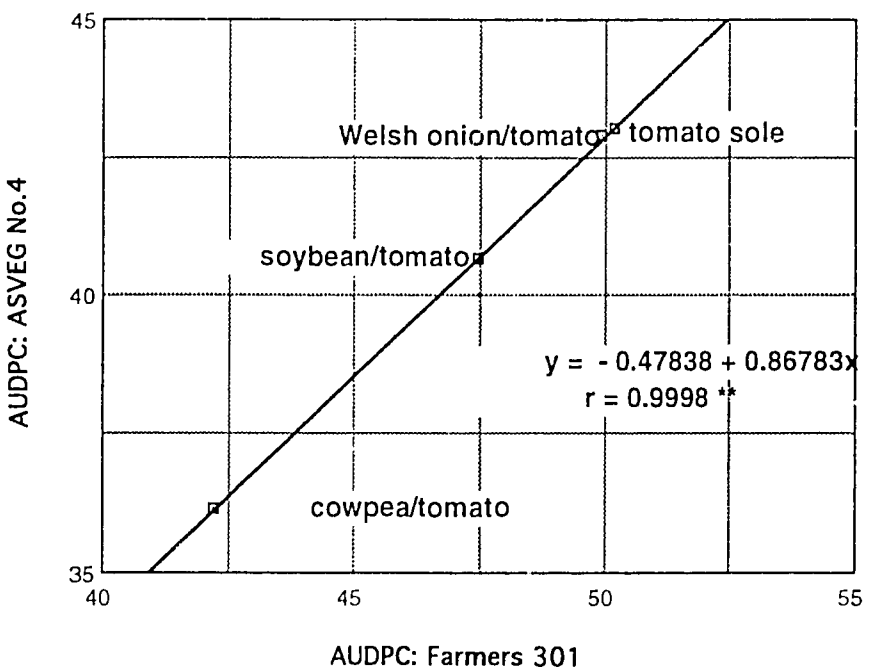

Fig. 14. Correlation between the AUDPCs (in days) of the different treatments of the susceptible tomato cultivar Farmers 301 and the resistant tomato cultivar ASVEG No. 4

Fig. 15 shows the evolution of the *P. solanacearum* population in the soil from 17 days until 60 days after transplanting the tomatoes. The initial population after the bacterial wilt nursery decreased by a factor of 10 in all treatments during the 17 days before the tomatoes were transplanted. During the next two months the population decreased slightly in the soil with the susceptible cultivar. In the soil with the resistant cultivar the population in the legumes and the control treatment also decreased slightly, whereas in the treatment with Welsh onion and sole tomato crop the population of *P. solanacearum* was increasing at the end of the observation period.

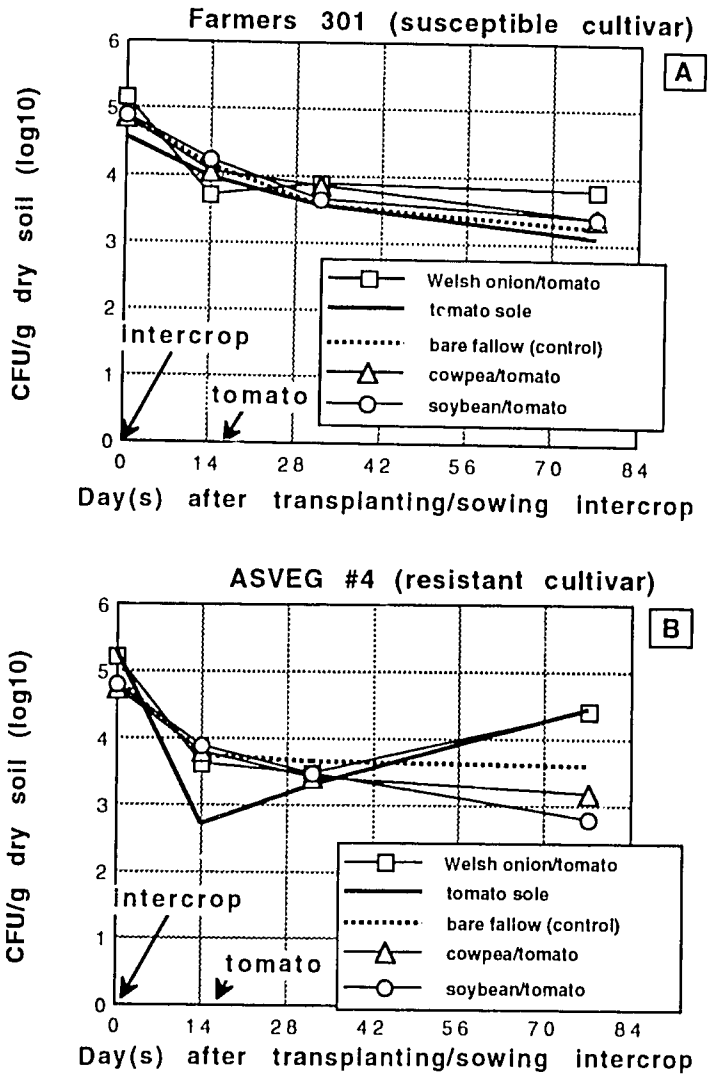

Fig. 15. ***P. solanacearum*** **population in soil (5 - 20 cm depth) after artificial inoculation of the field soil using a bacterial wilt nursery.** ***P. solanacearum*** **population size is expressed in cfu/g dry soil. The intercrops were sown/transplanted directly after the incorporation of the bacterial wilt nursery and the tomatoes 17 days later. A: Susceptible tomato cultivar Farmers 301, B: resistant tomato cultivar ASVEG No. 4**

None of the treatments had a strong influence on the *P. solanacearum* population in the soil. The general drop in population during the 17 days before transplanting was probably due to the heavy rainfall during this time (> 600 mm in 5 days). The effect of cowpea on the wilt incidence of the tomatoes cannot be explained by a reduction in the *P. solanacearum* population before transplanting the tomato seedlings. Other factors, such as drier soil or a possible deceleratic n of the root growth of the tomato plants due to the effect of the quick growing legume roots, could explain the reduction in wilt incidence over the sampling period. A species-specific factor also occurred; with a similar growth habit as soybean, only cowpea could reduce the AUDPC significantly.

Conclusions

Intercropping tomato with cowpea could be potentially used as part of an IPM program to control bacterial wilt of tomato in the tropics. However, more investigation concerning the management of this cropping system, the effect on other diseases and pests, and the competition between cowpea and tomato for water, light, and nutrients are needed before this cropping system can be incorporated into an IPM program.

Soil Science

Starter Solution Studies

Summary

Three liquid starter experiments were conducted. The first two showed little evidence of responses to either starter N or P applied to hot pepper. A third experiment in which responses by three species were compared showed large increases (in dry matter yield as well as N, P, and K uptake) to starter N but not to starter P when applied to crops that have high earlier growth rates (Chinese cabbage and eggplant). Less significant responses to N were observed when early growth rate was low (hot pepper).

Materials and Methods

Two studies were conducted on hot pepper during the spring. The first was in the AVRDC experiment station, consisting of 14 treatments in two replicates of an RCBD. The treatments and yields are summarized in table 1. Forty plants were harvested from each plot. Each plot contained two 1.5-m-wide beds of 4.5 m length, with two rows per bed. Available soil P was 33 mg/kg ($NaHCO_3$ extractant) and exchangeable K was 48 mg/kg (NH_4 acetate extractant).

The second study was conducted in a farmer's field. Plots were the same size as those in the first study. The treatments in table 2 were applied in three replicates of an RCBD. Available soil P was 43 mg/kg ($NaHCO_3$ extractant) and exchangeable K was 63 mg/kg (NH_4 acetate extractant).

Because starter effects were reported in earlier years but were not observed in the first two studies, a third study was undertaken to examine closely the effects of liquid N and P starter on three contrasting species. The surface 30 cm of soil in the field used for the study contained 20 kg inorganic N/ha, 47 kg available P/ha ($NaHCO_3$ extractant) and 27 kg exchangeable K/ha(NH_4 acetate extractant). The species, Chinese cabbage (ASVEG No. 2), eggplant (Pingtung Long), and hot pepper (Hot Beauty) were selected for early growth rate differences but similar planting geometries. Two controls were used: the full N-P basal rate and 1/3 the full N-P basal rate. The starter treatments consisted of factorial combinations of three N levels and two P levels. These six starter treatments also received a 1/3 N-P basal application. Fertilizer treatments are summarized in table 3. The starter solutions were applied in 50 ml volumes that were poured on the soil in a 2-4 cm radius around each plant on the day of transplanting. The pH and electrical conductivities of each solution are listed in table 3.

The eight fertilizer treatments were arranged in a factorial combination with the three species. Species were placed in main plots and fertilizer treatments were placed in subplots. Three replicates were transplanted on 25 August 93 in two rows on 0.2-m-high beds measuring 1.5 m between bed centers. Plant density was 30,000 plants/ha. Chinese cabbage was harvested 16 days after transplanting; eggplant and pepper were harvested 3 days later. These harvest dates occurred at approximately the date that a first topdressing would be applied.

Table 1. Total and marketable fruit yields from starter solution, basal, and total fertilizers treatments on hot pepper, AVRDC, spring 1993

Treat-ment	Cultivar	Starter fertilizer (mg/plant)			Basal fertilizer (kg/ha)			Total fertilizer (kg/ha)			Accumulated fruit yield at harvest of (t/ha)					Total yield (t/ha)	Total marketable (t/ha)
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	1st	2nd	3rd	4th	5th		
1	Chain Fair	60	120	60	0	0	0	160	40	80	1.6	2.8	7.3	5.4	5.6	24.7	18.9
2	"	240	120	60	0	0	0	160	40	80	1.6	3.1	7.8	5.0	4.7	23.3	17.4
3	"	0	0	0	80	20	40	160	40	80	1.0	2.7	6.6	5.0	5.1	21.8	16.9
4	"	60	120	60	30	60	60	190	100	140	1.9	3.7	6.4	5.4	4.9	24.2	18.0
5	"	60	120	60	60	120	120	220	160	200	1.5	3.0	7.1	5.5	4.8	23.5	18.6
6	"	240	120	60	60	120	120	220	160	200	1.9	3.8	7.3	4.8	4.2	23.0	16.8
7	"	0	0	0	60	120	120	220	160	200	1.2	2.6	5.2	5.2	5.3	21.3	15.0
8	Hot Beauty	60	120	60	30	60	60	110	80	100	0.7	6.8	5.3	1.5	1.5	16.3	15.8
9	"	240	120	60	30	60	60	110	80	100	0.6	5.7	4.6	2.0	2.0	15.4	15.0
10	"	0	0	0	30	60	60	110	80	100	0.6	5.6	4.0	2.1	2.3	15.5	14.5
11	"	60	120	60	0	0	0	160	40	80	0.6	6.9	4.9	2.2	1.9	17.2	16.4
12	"	240	120	60	0	0	0	160	40	80	0.8	5.1	4.8	2.4	1.9	15.7	14.7
13	"	60	120	60	30	60	60	190	100	140	0.8	6.3	5.9	2.0	2.1	18.0	17.2
14	"	0	0	0	60	120	120	220	160	200	0.7	5.9	4.5	2.4	2.2	16.6	15.7

Table 2. Total and marketable fruit yields from starter solution, basal, and total fertilizer treatments on hot pepper applications in farmer's field, Su-Tsu-Liao, spring 1993

Treat-ment	Cultivar	Starter fertilizer (mg/plant)			Basal fertilizer (kg/ha)			Total fertilizer (kg/ha)			Accumulated fruit yield at harvest of (t/ha)					Total yield	Total marketable
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	1st	2nd	3rd	4th	5th	(t/ha)	(t/ha)
1	Chain Fair	60	120	60	0	0	0	160	40	80	1.6	2.8	7.3	5.4	5.6	24.7	
1	PBC 374	60	240	60	0	0	0	220	160	200	3.1	5.2	5.3	1.3	2.2	18.6	16.3
2	PBC 374	240	120	60	0	0	0	220	160	200	3.4	5.2	4.8	1.0	1.2	16.7	14.6
3	PBC 374	240	120	60	0	0	0	160	40	80	1.9	3.5	3.6	0.8	1.1	11.8	9.7
4	PBC 374	240	120	60	30	60	60	190	100	140	2.1	4.5	4.6	1.0	2.0	15.8	14.2
5	PBC 374	240	120	60	60	120	120	220	160	200	3.0	6.1	5.6	1.7	1.3	19.1	16.3
6	PBC 374	240	120	60	0	120	120	160	160	200	2.3	4.9	5.4	1.3	1.6	16.8	15.2
7	PBC 374	240	120	60	30	120	120	190	160	200	2.6	5.1	6.0	1.4	1.9	18.3	16.5
8	PBC 374	240	120	60	60	0	120	220	40	200	2.3	4.7	4.9	1.7	2.2	17.5	15.5
9	PBC 374	240	120	60	60	120	0	220	160	80	2.8	5.2	5.1	1.3	1.8	17.7	15.8
10	PBC 374	240	120	60	30	0	0	190	40	80	2.9	5.7	5.7	1.2	1.8	18.4	16.5
11	PBC 374	60	120	60	60	120	120	220	160	200	2.7	6.1	6.3	1.3	2.2	20.5	18.8
12	PBC 374	0	0	0	60	120	120	220	160	200	2.0	4.6	4.9	1.6	2.2	17.2	15.8
13	Hot Beauty	240	120	60	60	120	120	220	160	200	0.9	3.3	6.6	3.2	1.8	18.2	16.7
14	Chain Fair	240	120	60	60	120	120	220	160	200	4.3	2.5	3.3	5.2	3.5	21.6	11.9

PBC 374 line from the pepper breeding unit of AVRDC.

Table 3. Fertilizer treatments, pH, and electric conductivities of starter solutions

Treatment		Starter fertilizer (mg/plant)[a]			Basal fertilizer (kg/ha)			Starter solution	
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	pH	EC (mmhos/cm)
$N_1P_0B_1$	$(NH_4)_2SO_4$ = (AS)[b]	60	0	0	30	30	120	6.5	9.7
$N_2P_0B_1$	$(NH_4)_2SO_4$	120	0	0	30	30	120	6.3	16.6
$N_3P_0B_1$	$(NH_4)_2SO_4$	240	0	0	30	30	120	6.0	30.8
$N_1P_1B_1$	$NH_4H_2PO_4$ + AS	60	120	0	30	30	120	4.8	8.0
$N_2P_1B_1$	$NH_4H_2PO_4$ + AS	120	120	0	30	30	120	4.7	15.6
$N_2P_1B_1$	$NH_4H_2PO_4$ + AS	240	120	0	30	30	120	4.6	30.4
$N_0P_0B_1$	Check 1 (distilled H_2O)	0	0	0	30	30	120	7.0	0.0
$N_0P_0B_2$	Check 2 (distilled H_2O)	0	0	0	90	90	120	7.0	0.0

[a]All nutrients were applied in a volume of 50 ml/plant.
[b]AS: ammonium sulfate, $(NH_4)_2SO_4$.

Results and Discussion

Data (hot pepper fresh weights) from accumulated yields to the third, to the fifth, and to the final harvests (including remaining full-size green fruit) were analyzed statistically. The effects of treatments on yields accumulated to the third and fifth harvests were similar to those on the total accumulated yields. Because evidence for starter effects in the earlier harvests was not detected, only the analyses from the final accumulated yield of marketable plus unmarketable fruit are discussed.

A major portion (85%) of the treatment sum of squares was accounted for by a single degree of freedom (df) for cultivar. Mean yield from cultivar Chain Fair was 22.5 t/ha (fresh fruit) and from Hot Beauty 17.4 t/ha. Single df contrasts on starter, basal, and total applied N among the 13 treatment degrees of freedom and, alternatively, as continuous variables in regression models did not expose trends attributable to fertilizer N treatments. An analysis of variance on residuals from a regression model in which the effects of cultivars and replication were removed showed no evidence that other treatment effects remained in the data.

As in the first study conducted in the AVRDC experiment station, only accumulated marketable plus unmarketable fresh fruit yields summed over all harvests are discussed for the second experiment. Analyses of earlier harvests showed similar treatment responses. A single df contrast among varieties was significant. Yields of Chain Fair, Hot Beauty, and PBC 374 from common fertilizer treatments were 29.1, 21.1, and 20.9 t/ha, respectively. A Chain Fair vs. other cultivar single df contrast accounted for 58% of the treatment sum of squares (13 df). Fertilizer effects within the 12 PBC 374 treatments were examined by regressing yields on the quantities of starter N, basal N, and total applied N. Only the coefficient of the latter variable was significant (0.048 t hot pepper/ kg N as total N increased from 160 to 220 kg N/ha, Prob>T = 0.028). The sum of squares explained by the total N variable accounted for 26% of the treatment sum of squares within the 12 PBC 374 data. Analyses of variance on residuals remaining after removal of the effects of cultivar and total applied N exhibited no evidence of other treatment effects remaining in the data.

For the third study on the effects of liquid N and P starter on three different species, no effects were visible on the plants or in the data, although pH and conductivities of the most concentrated

solutions were high. We concluded that the small amounts applied reacted rapidly with the soil and were sufficiently distant from the roots to preclude root damage.

Four attributes were determined: dry matter yield and N, P, and K uptakes. As expected, species made the largest contribution to the variability within each attribute. Starter N affected attributes significantly, although examination of the data showed that N effects within the hot pepper data were absent. Significant starter P effects were not detected, although the nutrient did increase dry matter yields and P uptake slightly.

Species and starter N effects were obvious in the dry matter yields and N uptake in fig. 1. Regression models ($Y = a + bN^{1/2} + cN$) were fitted to the data and plotted on the figure. Apparent N recoveries (N uptake/ N applied) from the 240 mg N/plant treatments were 0.89, 0.53, and 0.29 for Chinese cabbage, eggplant, and hot pepper, respectively. These recoveries were in the same ranking as mean daily posttransplanting growth rates which were 0.77, 0.34, and 0.17 g dry weight/day, respectively.

Although apparent N recoveries from the starter treatments differed between species, utilization efficiencies (g dry matter yield/mg N taken up) were less different as evidenced by the dry matter yield vs. N uptake data in fig. 2. The dry matter yield vs. N, P, and K uptake curves in the figure were estimated with square root functions. The P function for Chinese cabbage required a dummy variable to obtain good fit. The curves showed that utilization efficiency declined gradually as uptake increased. For each nutrient, all species fit the same trend except, as noted earlier, for Chinese cabbage. The significantly negative dummy variable (-3.9 g/plant) was evidence that it did not use P as efficiently as the other species did. Moreover, the positions of the full N-P basal treatments for Chinese cabbage and eggplant in fig. 2 (open boxes below the dry matter yield — N uptake regression line) are evidences that N taken up from the additional 60 kg basal N/ha was not used as efficiently as that from combinations of starter N and the 30 kg N/ha in the 1/3 N-P basal application.

The uptake curves in fig. 2 show not only that the species took up these nutrients in decreasing proportion to dry matter yield but also that the quantities taken up differed between species. Chinese cabbage took up more than two times that taken up by eggplant and five times that taken up by hot pepper. Corresponding ratios for P uptake were even larger.

The mean dry matter yields from the full basal control treatments of Chinese cabbage, eggplant, and hot pepper were 13.2, 7.0, and 2.9 g/plant. By using the dry matter yield regression curves in fig. 1, we estimated that about 4 kg/ha of starter solution N replaced 60 kg basal N/ha applied to Chinese cabbage and eggplant. The corresponding replacement for hot pepper was only 1 kg N/ha. For hot pepper, however basal fertilizer N did not promote early growth to the extent observed in the other species, and although liquid starter N did, the response was not large. An advantage from starter N appears to be greatest when early N uptake need for a crop is large because the species has a large early growth rate. Effects will be most pronounced when soil inorganic N content is low as in this study. Because fast-growing species also take up more P and K earlier than slower-growing species do, responses to P or K starter solutions are more likely to be observed on the former species when the availabilities of these nutrients are marginal. When nutrient availabilities are low, however, commercially significant responses may also occur on slow-developing species such as hot pepper.

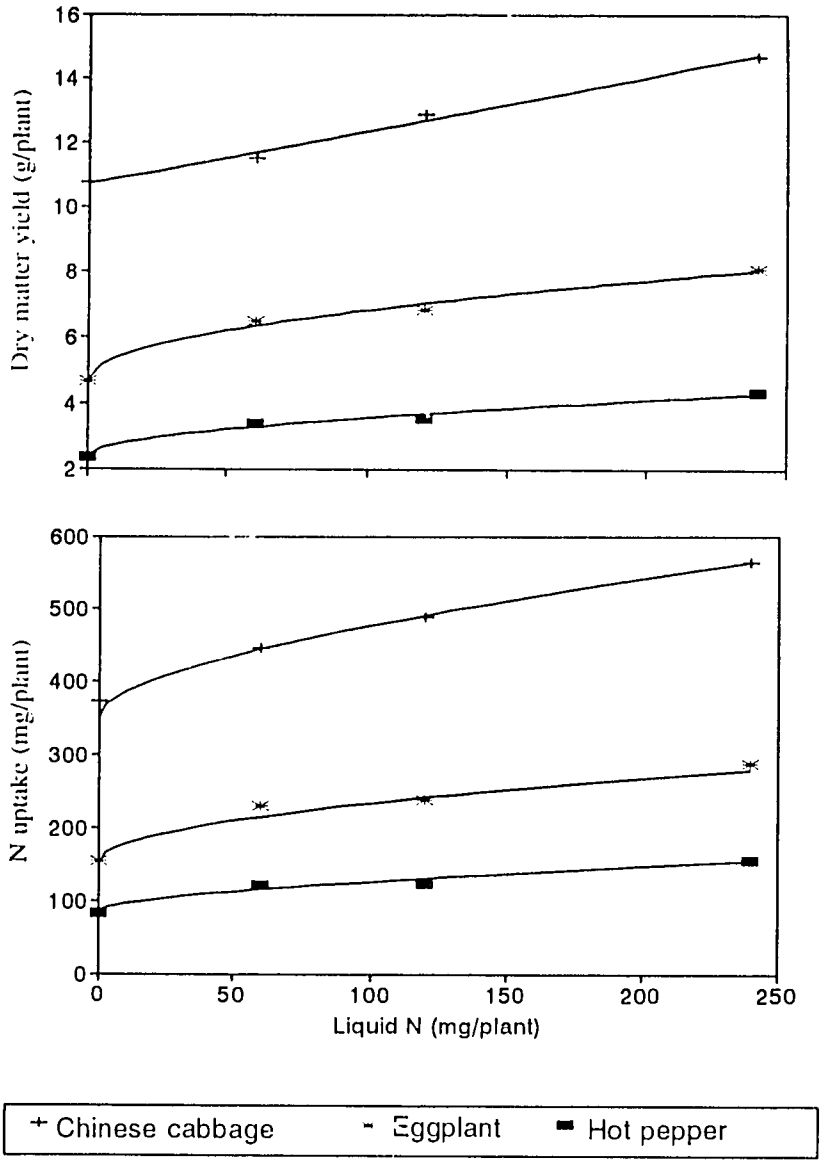

Fig. 1. Dry matter yields and N uptake by Chinese cabbage at 16 DAT, and eggplant and hot pepper at 19 DAT in response to liquid starter N applications

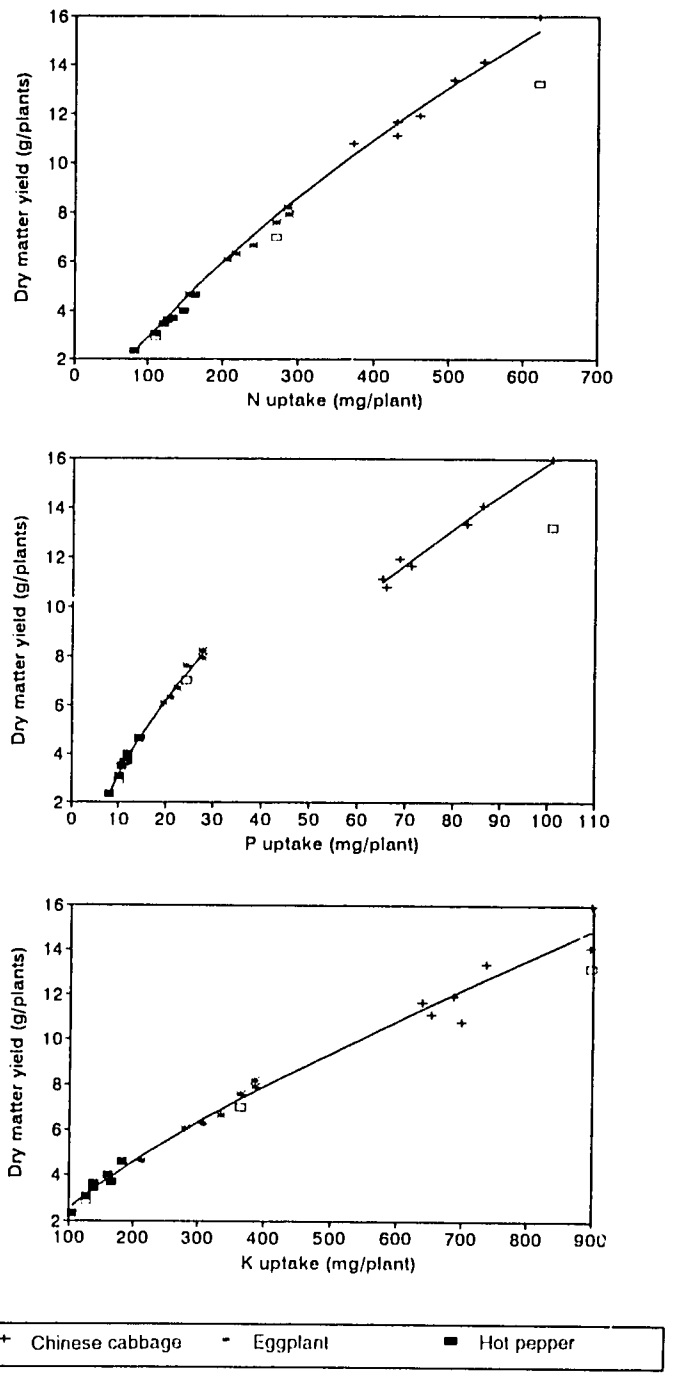

Fig. 2. Early dry matter yield of Chinese cabbage, eggplant, and hot pepper vs. N, P, and K uptakes. Equations of the form $Y = a + bX^{1/2} + cX$ were fitted to the data. A dummy coefficient was required to obtain satisfactory fit. Treatments receiving full basal applications are shown with symbols with P as the independent variable. These were excluded from the regressions

Changes in Organic C and Available P and K in AVRDC Soils

Summary

After 20 years of intensive vegetable cultivation, changes in soil organic C and available P and K are apparent. The C depletion in most soils appears to have occurred within five years of AVRDC's establishment. Liberal P and K applications have created availabilities of these nutrients well in excess of crop requirements. A combination of P applied in excess and Ca-rich irrigation water probably caused precipitation of the large quantities of immobile and unavailable Ca-PO_4 observed, but much soil P obviously was present in this form in 1972. K does not form immobile compounds and, therefore, K applied in excesses of uptake and retention has probably leached.

The Changes

Significant changes in soil organic carbon (SOC), P, and K availabilities have occurred since AVRDC fields were developed in 1973. Soil acidity (pH), total carbon, cation exchange capacity, available P ($NaHCO_3$ extractant), and exchangeable K (NH_4 acetate extractant) for a typical surface soil, from data in the AVRDC Annual Report for 1974, are listed in table 4. The low P and K availabilities were confirmed by experiments conducted in 1973 and 1974 in which large responses to liberal applications of these nutrients as well as to N were observed.

Table 4. Chemical characteristics of selected AVRDC soils in various years since 1974

Year	Block	Soil no.	pH (H_2O)	Total C (%)	CEC (+cmol/kg soil)	Olsen P (mg/kg)	Exch. K (mg/kg)
1974	Typical surface soil	-	8.6	0.93	9.2	5	24
1978	Means of 4 to 15 surface soils	-	7.5	0.72	10.2	27	75
	33	2	7.5	0.48	6.3	50	150
	79, south part	4	7.8	0.41	5.7	16	57
	98	5	8.1	1.11	14.6	11	78
1983	50	7 & 8	7.9	0.57	-	14	52
1993	Weather station	1	6.5	0.72	8.3	10	36
	33	2	7.3	0.41	6.2	34	70
	50, + compost	7	7.4	1.31	10.2	180	121
	50, - compost	8	7.7	0.60	7.5	73	94
	79, south part	4	7.4	0.56	9.3	23	94
	98	5	8.2	0.68	10.9	9	69

Means from a number of blocks sampled in 1977 showed that within four years of development large quantities of available P and K had accumulated and, also, suggested that the initially low SOC contents had declined further. Data from surface soils of four fields in 1977-78 exhibit the variation between fields in the sampling. Furthermore, the 1978 observations can be compared to observations on the same fields in 1993.

Block 33 must have received very large P and K fertilizer applications in the years just prior to the 1977-78 sampling, perhaps because the subsoil was mixed with surface soil when the block was developed. By 1993, P and K concentrations in Block 33 had declined by 32% and 53%, respectively, but remained well above availabilities reported for typical surface soils in 1974. Soils sampled from an area of the weather station immediately adjacent to the 1993 sampling area of Block 33 contained much less available P and K and had a lower pH as well. The pH difference

can be explained by lack of frequent irrigation with Ca-rich water on Block 33 and perhaps by acid rain in recent years. The large SOC difference between the weather station soil and Block 33 soil can be explained by the absence of tillage on the former. The CEC difference is attributable to the SOC difference.

Since 1991, Block 79 has been cropped three times without P and K fertilizer to reduce availabilities of these nutrients. Even with these repeated croppings, large quantities of both nutrients remain. Block 98 was included because its soil is in a series different from other fields. It is more prone to flooding than other fields and its soils shrink to create large cracks during the dry season. Therefore, Block 98 has been used almost exclusively for rice. Even so, its SOC and, therefore, CEC have decreased. P and K availabilities have remained static probably because farmers are less liberal with fertilizer applications on rice than on vegetables.

Block 50 has been used for a long-term experiment since 1983. Soil data collection started in 1984. During this period, compost was applied to half the experiment and inorganic fertilizer was applied uniformly to the entire experiment in most years. Totals of 2800 kg N/ha, 2332 kg P/ha, and 2093 kg K/ha were applied in inorganic forms to 25 soybean crops. Much larger additional nutrient quantities as well as carbon were contained in the compost (7846 kg N/ha, 3004 kg P/ha, and 5241 kg K/ha). The large increases of available P and K from these applications are evident in table 4. Considering the abundant quantities of N fertilizer applied, pH changes were small. Again the Ca-rich irrigation water probably reduced the acidifying impact of N fertilizer. To meet evapotranspiration requirements of autumn and spring soybean crops, irrigation water carrying the equivalent of about 0.5 t lime/ha was applied in most years. On plots not receiving compost, SOC changed little between 1984 and 1993 but more than doubled where compost was applied. The large SOC increase is responsible for the higher CEC where compost was applied.

The quantities of P fertilizer applied to AVRDC fields greatly exceed removal by crops. The P accumulations in Block 50 represent an extreme case. When P is applied to a deficient soil and crop growth is near its commercial potential, recovery seldom exceeds 15% of the quantity applied. Consequently, excess P accumulates and may be recovered by successive crops or may react with soil constituents. Preliminary analyses were performed to determine how selected soils differed with respect to P fractions and P sorption. Fig. 3 shows bar graphs of four fractions in each of five soils. The Resin-P fraction represents P in these soils that easily exchanges with P in soil solution. $NaHCO_3$-P is easily desorbed from soil particles as a crop depletes solution P. Together Resin-P and $NaHCO_3$-P are regarded as labile and, therefore, readily available. NaOH-P also desorbs but less readily than $NaHCO_3$-P and, therefore, is less available to meet crop needs, especially for short duration species. HCl-P represents Ca-PO_4 in various forms. Its availability is negligible when soils are neutral or alkaline.

As expected, the labile fractions were smaller than the HCl-P fractions in all soils, even in the weather station soil. The very large HCl-P accumulations in Block 50 were expected. The abundant P applications in Block 50 increased labile P fractions, especially where compost was applied, to quantities larger than detected in other blocks. The large proportion of HCl-P in Block 98 is probably due to the abundant Ca in the water used to irrigate rice twice each year.

The partitioning of applied P between the soil solution and sorption on soil particles is shown for five soils in fig. 3. The typical P range in soil solution (< 0.5 mg/l) is of most interest. Four parameters for the curves in fig. 3. are summarized in table 5. As P application increased, sorbed P increased but solution P increased at a faster relative rate. However, the P sorbed on particle surfaces was many times that in solution. All soils in fig. 3. have very low P fixing potential although differences between soils were observed. However, soils 5 and 7, from Blocks 98 and 50 (+ compost), respectively, differed from the others. In Block 98, both a higher clay content and

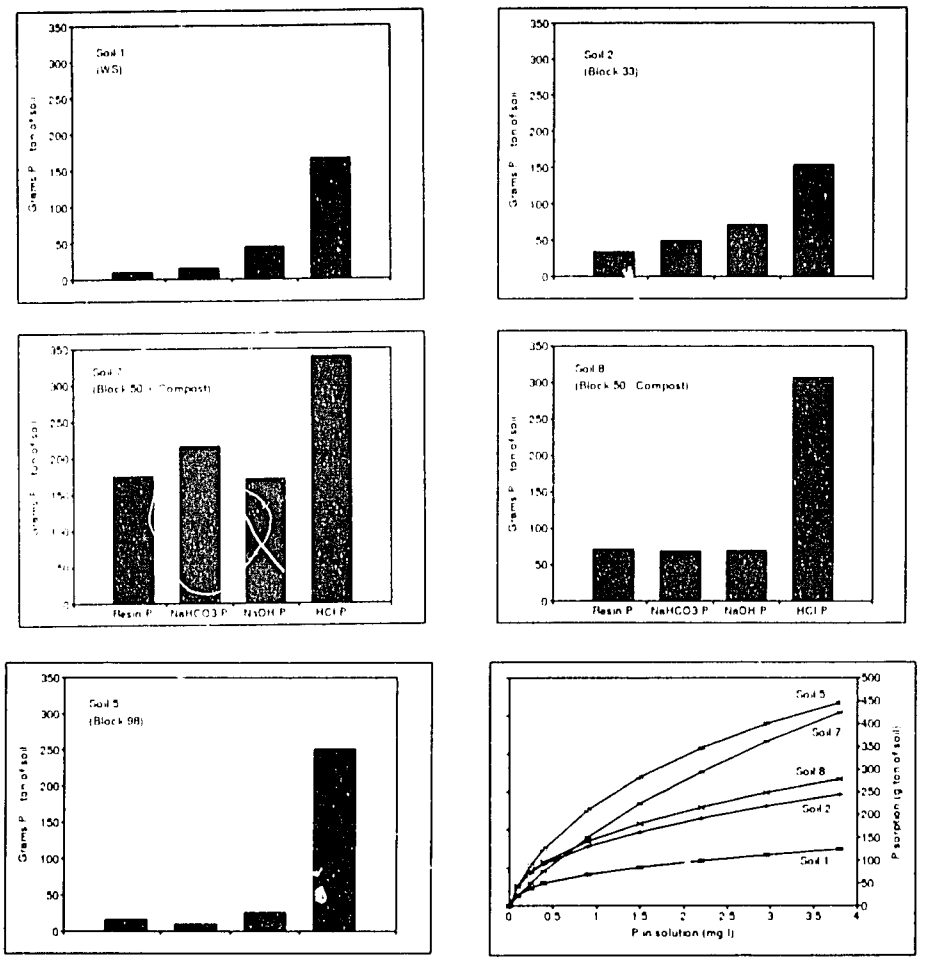

Fig. 3. Bar graphs: Fractions of Resin-P and $NaHCO_3$-P (labile P), NaOH-P (moderately labile P) and HCl-P (Ca-P) for five soils. Curves: Sorption isotherms for the same five soils

Table 5. Selected values derived from isotherms that characterize P availability in six AVRDC soils

	Labile P	P sorbed at 0.2 mg P/l soil solution	Maximum buffering capacity	Buffering capacity at 0.2 mg P/l soil solution
	(mg/kg soil)		(mg P/kg soils)/ (mg P/ml solution)	
1	26	35	346	95
2	83	39	389	106
4	54	40	389	113
5	23	45	309	173
7	389	24	132	113
8	140	40	371	115

amorphous iron, formed during frequent submergence, probably contributed to the soil's comparatively high buffer capacity at a P solution concentration of 0.2 mg/l (table 5). The large quantity of organic matter in the Block 50 soil to which compost had been applied probably blocked some sorption sites thereby decreasing maximum buffer capacity (i.e., buffer capacity at solution = 0 mg P/l, table 5).

A soil solution concentration of 0.2 mg/l is regarded as sufficient to meet the needs of most crops provided that buffering is adequate. Comparisons of measured labile P vs. estimated P sorption at 0.2 mg P/l solution showed that only in Soils 1 and 5 did the latter exceed the former, indicating that many crops should respond to applied P in these blocks. Labile P in both soils from Block 50 exceeded the quantities in equilibrium with a 0.2 mg P/l solution by severalfold.

Potassium behaves similarly to P in that applied K is partitioned between sorption on particle surfaces and solution. The characterization of sorbed K vs. K in solution, however, takes a form different from that of P. The quantity of K sorbed or released from particle surfaces is a linear function of solution K when the latter is expressed as an activity ratio (ARK). The ARK adjusts for the influence that other ions in solution have on K behavior. An example of the partitioning using Soil 1 is shown in fig. 4. Pertinent parameters from preliminary K exchange analyses are listed in table 6. Labile K, the difference on the Y axis between the intercept and the origin, is that portion of K held on nonspecific exchange sites. The difference between labile K and exchangeable K represents K held at sites specific for K ions. Comparisons of pairs of soils high and low in organic matter (Soil 1 vs. 2 and Soil 7 vs. 8) show that the former have higher buffer capacities. This is attributed to higher cation exchange capacities. The buffer capacity of the soil from Block 98 was exceptionally high. Clay mineral species and/or clay abundance differences as well as organic matter contents are implicated.

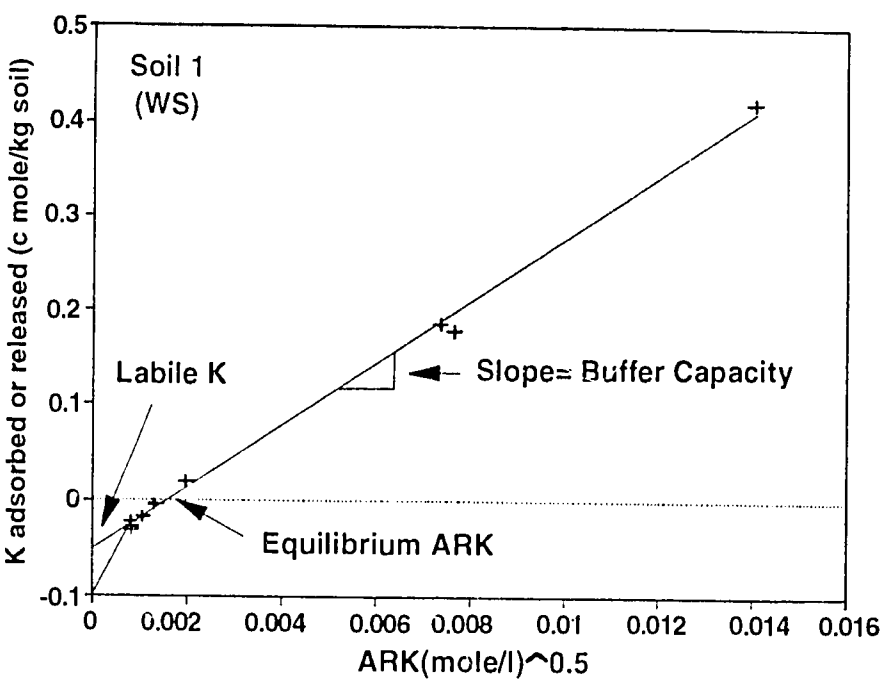

Fig. 4. K absorption or release in Soil 1 as a function K activity ratio (ARK)

Table 6. Selected values that characterize availability in six AVRDC soils

Soil no.	Labile K cmoles/ kg soil	Equilibrium activity ratio $(moles/l)^{1/2}$	Potential buffer capacity (cmoles/kg soil)/ $(moles/l)^{1/2}$
1	0.051	0.0016	32.8
2	0.064	0.0025	25.5
4	0.104	0.0029	36.4
5	0.052	0.0009	58.2
7	0.192	0.0063	30.5
8	0.038	0.0016	23.8

Soil Organic Carbon and Nitrogen Accumulations from Compost

Summary

Detailed analysis of soil data from a long-term experiment showed that sugarcane compost applications reversed soil organic carbon losses and total soil N depletion. In the experiment, compost applications, which averaged 49 t/ha/crop, more than doubled soil organic carbon. Once application and decomposition rates reached equilibrium, decomposition increased about 300 kg N/ha/crop. Simulations showed that six years of large compost applications (50 t/ha/crop in the first year, decreasing gradually to 17.5 t/ha/crop in the seventh year) can achieve a steady state equilibrium at a modest 0.75% soil organic carbon. Application of 17.5 t/ha/crop provided 120, 45, and 67 kg N, P, and K/ha/crop, respectively, as well as the carbon required to maintain the soil organic matter.

Organic Carbon

Soil organic carbon (SOC) was determined after harvest of 26 soybean crops in an experiment in which plantings were made two or three times per year. The experiment started in September 1983 and the most recent harvest was in May 1993. Some summer crops were either not planted or not harvested because of unsuitable field conditions or typhoon damage. Starting with the third crop, mushroom compost residue or sugarcane compost was applied to half the treatments. In the other treatments, mushroom compost residue was applied only on the third crop. Both series received abundant and equal quantities of inorganic N, P, and K fertilizers, averaging 104 kg N/ha, 38 kg P/ha, and 66 kg K/ha per crop.

Two forms of nonlinear models were fitted to the SOC data from the treatments to which only the single mushroom compost residue was applied to the third crop, starting with the crop to which mushroom compost was applied. The models were $SOC = \underline{a}\exp(\underline{k}t^{\underline{b}})$ and $SOC = \underline{a}\exp(\underline{k}t) + \underline{b}$. Time (t) was in months and SOC was in percent on a dry weight basis. Both models fit the data well but the coefficients of the first were estimated with less error. Moreover, the $\underline{b}$ coefficient in the exponential term in the first model adjusted the decay rate for time. The inclusion of a variable to adjust the decay rate is supported by other organic matter decay studies that have shown that the rate decreases with time. The coefficients for the model are given in table 7. SOC data points and model estimates are shown in fig. 5.

Table 7. Estimates and confidence intervals of decay model coefficients

Coefficient	Value	Confidence interval Lower	Upper
For carbon			
a	0.435	0.405	0.465
k	1.772	1.404	2.141
b	-0.581	-0.687	-0.476
For nitrogen			
a	0.062	0.0618	0.0625
k	0.967	0.946	0.987
b	-0.478	-0.426	-0.531

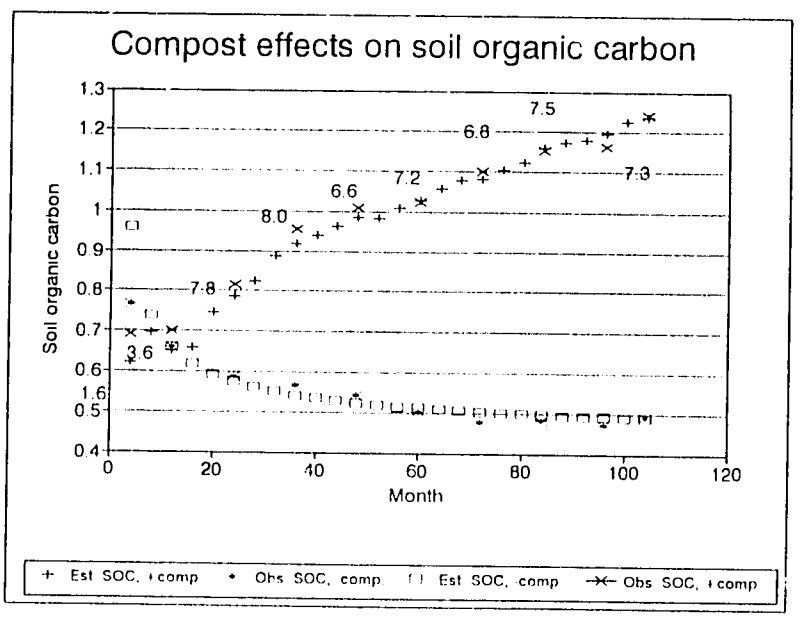

Fig. 5. Trends in observed and estimated soil organic carbon in treatments with and without compost applications, AVRDC long-term experiment, 1983-1993

Coefficients from the first model were used to estimate SOC accumulations in the treatments to which compost was applied. The decay model was used to estimate the organic carbon remaining from the carbon in each compost application. The median carbon content of the compost was 9.5% (range = 7-12%).

The decay percentages from the exponential model, however, underestimated the carbon losses during the first eight months after it was applied. The underestimation is evident in fig. 5. Therefore, humification coefficients of 76% (percentage carbon remaining) for the first 4 mo and 65% for the second 4 mo were substituted. The coefficients are in agreement with humification coefficients of readily decomposable organic carbon reported for other similar soil amendments. Coefficients from the model were used to estimate decay for all subsequent 4-mo intervals. The carbon contents remaining from each application and the original SOC were summed after each crop (4 mo steps) to obtain overall SOC percentages.

The estimates in fig. 5 exhibit the gradually increasing SOC accumulations in the data, showing minor rate changes due to compost application rates. Of the 22 seasons of SOC data in the model, only four summer determinations were made and the deviations of these data points from estimates were negative in all cases (mean = -0.05%). The mean deviations for the autumn and spring determinations were positive (mean = 0.03%). Mean monthly soil temperatures at 10 cm exceeded 30°C from June to September but declined to 20°C in February. The model could probably be improved by adjusting the humification coefficient for seasonal effects but that has not yet been attempted.

The model was used to predict SOC accumulations from 10, 20, 30, 40, and 50 t/ha sugarcane compost applications (containing 50% water content, 9.5% C on a dry weight basis) to three crops per year. Starting SOC was 0.565% and conditions during the long-term soybean experiment were assumed (fig. 6). The model showed that applications of 10 t/ha/crop barely maintained SOC over a 100-month period, whereas, 50 t/ha applications doubled the content. A strategy to increase SOC rapidly by large but diminishing application rates (50 t/ha/crop in the first year, 35 t/ha/crop in the second, 30 t/ha/crop in the third, 25 t/ha/crop in the fourth, 20 t/ha/crop in the fifth through seventh, and 17.5 t/ha/crop thereafter) should maintain SOC at about 0.75%. The application rates are large but necessary because the compost contains only modest carbon concentrations, soils are warm, and tillage is intensive (3 times per year).

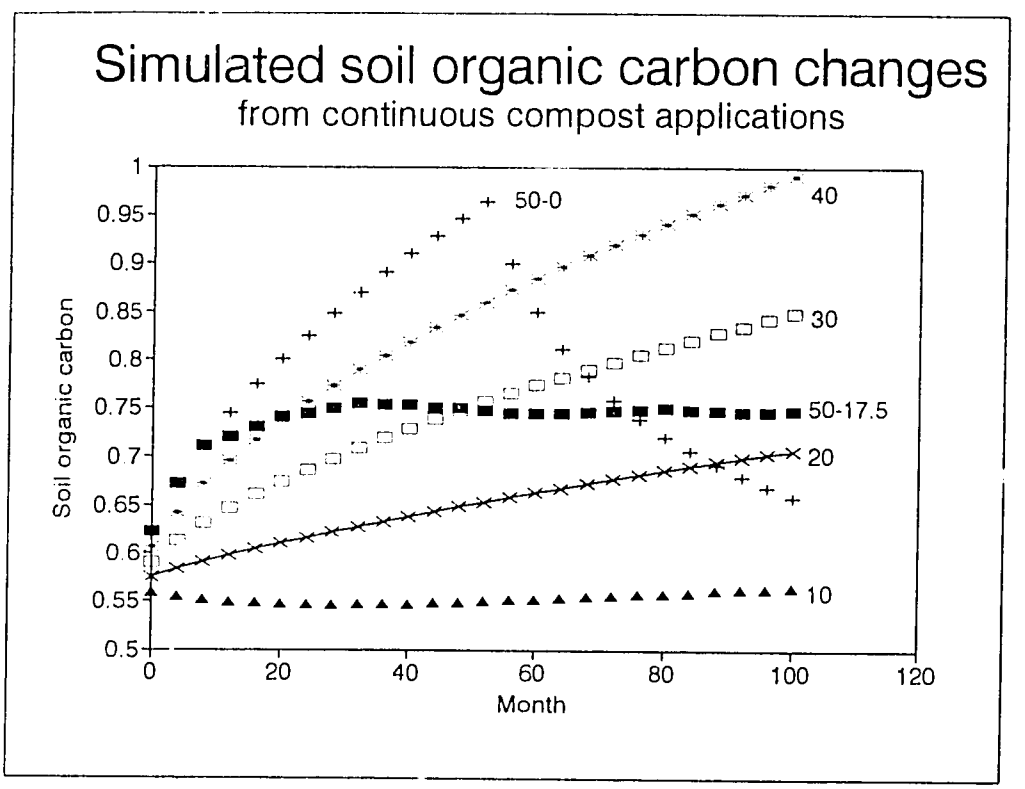

Fig. 6. Predicted soil organic carbon contents from applications of 10, 20, 30, and 40 t compost/crop for 100 months, from 50 t compost/crop for months 52 and no applications in remaining months (50-0), and from 50 t compost/crop initially, reduced gradually to 17.5 t/crop after 84 months (50-17.5)

Nitrogen

A second model was developed to estimate total soil N (TSN) accumulation with time. An equation with the same form as that used to predict carbon decay was fitted to TSN data from the treatment without compost (fig. 7). Because the C:N ratio in the data narrowed with time, ratios of estimated SOC to estimated TSN were calculated and indexed to SOC. The ratio was used to adjust for C: N ratio as decay progressed.

Decay of the initial TSN was calculated separately from the decay of N in each compost application. The N remaining from the initial TSN and from each previous compost application were summed after each season to estimate TSN changes with time. The agreement between observed and estimated TSN is apparent in fig. 7.

Estimated N mineralized during decay of TSN and applied compost are shown in fig. 8. During the first 12 mo, most of estimated N released came from the decay of initial TSN because quantities of applied N were comparatively small in the first year. By the 24th mo virtually all N came from the compost. Furthermore, by the 36th mo the amount released equaled about 90% of that in the compost. A near equality between the N released and N applied, once a steady state equilibrium has been approached, has been observed in temperate studies. In this study, the quantity of N was about 300 kg N/ha/crop, ample even for those crops that do not have symbiotic N fixation capacity.

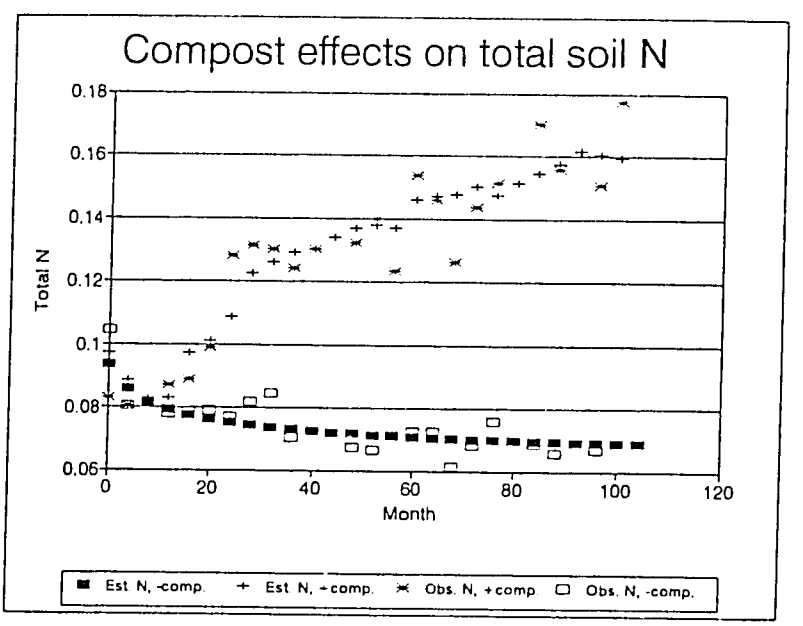

Fig. 7. Trends in observed and estimated total soil N in treatments with and without compost applications, AVRDC long-term experiment, 1983-1993

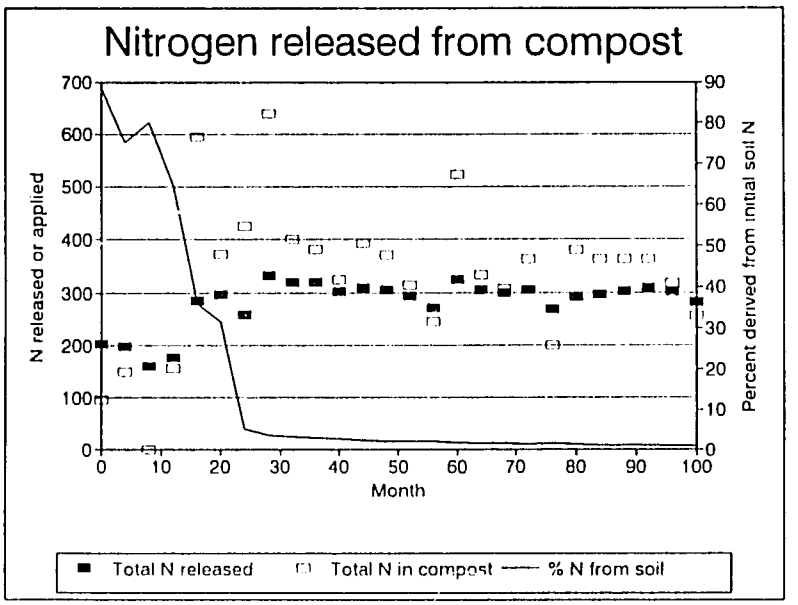

Fig. 8. Estimated N release (solid boxes) from initial total soil N and N applied in compost (open boxes). The solid line shows the proportion of derived N from initial total soil N (scale to the right)

International Cooperation Program

Training

Summary

AVRDC hosted 48 training scholars from 17 countries. Two had degree-oriented training while others undertook nondegree training. Thirty-seven percent of the scholars had special research skills training. Thirty-three percent of the trainees were women. The Crop Improvement Program had 69% of the scholars, of which 76% trained in plant breeding and plant pathology. The Production Systems Program and the International Cooperation Program had 17% and 6% of the scholars, respectively. In 1993, AVRDC provided 180.45 person-months or 15.04 person-years of training. In addition to AVRDC, 11 other donors supported the training program. The major donors were the Japan Shipbuilding Industry Foundation (JSIF), German Agency for Technical Cooperation (GTZ), Japan Special Project, and UNDP/FAO. Six scholars from six South Asian countries received training on advanced methods for virus diagnosis, specifically for geminiviruses. Another group of four trainees from AVNET participated in an AVNET-II bacterial wilt course. Through the JSIF project, seven slide sets with scripts were reprinted and a new slide set on identification of diseases in tomato has been produced. In 1993, a total of 224 slide sets with scripts and eight videos have been distributed.

Enrollment

In 1993, AVRDC had 48 training scholars from 17 countries (table 1). Two had degree-oriented training, the others had nondegree training under four different categories (table 1).

In line with the policy of the center, 37% of the training scholars underwent special research skills training. Thirty-three percent were women.

Program and Discipline Specialization

The distribution of training scholars within AVRDC programs and discipline are shown in table 2. The Crop Improvement Program had the major share of scholars with 69%. Nearly 76% of this group pursued training in plant breeding and plant pathology. The Production Systems Program and the International Cooperation Program had 17% and 6% of the total training scholars. In 1993, AVRDC provided 180.45 person-months or 15.04 person-years of training (table 3).

Special Research Skills Training Course

Six training scholars, one from each of the South Asian Vegetable Research Network (SAVERNET) countries, participated in the special purpose training on Advanced Methods for Virus Diagnosis from 22 February to 15 March 1993.

The course aimed to provide participants with knowledge on how to diagnose plant virus through immunosurbent electron microscopy (ISEM), ELISA, electrophoresis, and Western blot methods. The course included formal lectures, laboratory experience, and field trips.

Table 1. Distribution of training scholars by country and by category

Country	RF	RS	RI	SPT	UST	Total
Bangladesh				1		1
Bhutan				1		1
Ethiopia	1					1
Germany		2				2
India	1			3		4
Indonesia			1	3		4
Korea	1		2			3
Malaysia				1		1
Nepal	1			1		2
Pakistan				1		1
Philippines	3		1	2	2	8
Singapore				1		1
Sri Lanka				1		1
Taiwan					9	9
Thailand			1	2		3
Vietnam	2		2	1		5
Zambia			1			1
Total	9	2	8	18	11	48

RF = Research Fellow
RS = Research Scholar
RI = Research Intern
SPT = Special-Purpose Trainee
UST = Undergraduate Student Trainee

Table 2. Distribution of trainees by program/discipline and training period

Program/Discipline	RF	RS	RI	SPT	UST	Total	PM[a]
Crop Improvement Program							
Plant Breeding	1		4	3		8	31.3
Plant Pathology	3		1	10	3	17	30.9
Plant Physiology			1			1	6
Seed Technology (GRSU)[b]			2	3	2	7	24
Subtotal	4		8	16	5	33	92.2
Production Systems Program							
Agricultural Economics	1			2		2	15.2
Crop Management	1	2			2	3	29.0
Subtotal	2	2		2	2	8	44.2
International Cooperation Program							
Publications & Documentation	3					3	36
Analytical Laboratory					4	4	8
Total	9	2	8	18	11	48	180.4

[a]Person-month

Table 3. Distribution of grantees in each training category by sponsors

Sponsor	RF	RS	RI	SPT	UST	Total	PM
JSIF			3	2		5	18.8
AVRDC	6		2	1	11	20	101.5
AVNET				3		3	0.9
SAVERNET				5		5	3.8
E.I.D.				1		1	3
WI				1		1	2
GTZ	1	1		1		3	7.8
RMI				1		1	0.3
JSP			2	1		3	15
PPD				1		1	0.5
ZSC			1			1	5
MOC				1		1	2
UNDP/FAO	2					2	8
Self-sponsored		1				1	12
Total	9	2	8	18	11	48	180.4

JSIF – Japan Shipbuilding Industry Foundation
AVRDC – Asian Vegetable Research and Development Center
AVNET – Collaborative Vegetable Research Program for Southeast Asia, Asian Development Bank
SAVERNET – South Asian Vegetable Research Network, Asian Development Bank
E.I.D. – E.I.D. Parry (India) Ltd.
WI – Winrock International
GTZ – German Agency for Technical Cooperation
RMI – Resources Management International, Inc., Jakarta
JSP – Japanese Special Project
PPD – Primary Production Department, Ministry of National Development, Singapore
ZSC – Zambia Seed Company Ltd.
MOC – Maxworth Orchards Company, India
UNDP/FAO – United Nations Development Programme/Food and Agriculture Organization of the United Nations

Another group of four training scholars from AVNET countries participated in the training course on bacterial wilt under AVNET-II from 25 April to 3 May 1993.

The objective of this training course was to provide information on modern technology to specifically and unequivocally identify and classify pathogen types so that screening can be highly specific and interaction will be avoided. The training was conducted for 10 days for the participants to understand: (1) pathotype classification, (2) integrated disease management including screening, and (3) serology.

Production of Training Materials through JSIF Project

A slide set on Identification of Diseases in Tomato was developed in 1993 to support the training and extension programs of NARS in the collaborating countries. The set has 40 slides.

Two hundred and fifty copies of the slide sets and 500 copies of the descriptive booklet accompanying the slide set have been produced for use in training courses at AVRDC regional

programs and for distribution to national institutions organizing in-country training for extension staff and farmers.

The following seven slide sets (100 copies of each slide set) were reprinted.

Title	No. of slides per set
1. Integrated Pest Management of Sweet-Potato Weevil	38
2. Growing Vegetables Using AVRDC Hydroponic Method	43
3. Anthracnose of Pepper	24
4. Symptoms of Pepper Viruses	22
5. Bacterial Wilt of Tomato	20
6. No-Tillage Rice Stubble Soybean Cultivation	44
7. Vegetable Soybean Cultivation	49

During the year a total of 224 slide sets with scripts and eight videos have been distributed to 38 training scholars.

Information and Documentation

Summary

In 1993, a total of 1831 titles of books and crop documents, and 32 new serial publications were added to the library collection. The center's book collection has reached 15,410 titles. Serial publications totaled 1532 titles. The crop documents had 32,809 entries. The CD-ROM databases were used for more than 332 CPU hours. The Compact International Agricultural Research Library (CIARL) of CGIAR/IARCs and CD-DIS of USAID's information system were added to the CD-ROM collection. Reader services reported a small reduction in library loans but a little increase in photocopy/document delivery services.

Information Collection

Acquisitions and exchanges

A total of 317 titles of books and photocopies were ordered, and the center subscribed to 127 titles of serial publications. The average cost was US$43.66 per book and US$191.73 per serial title. A total of 413 titles of books, 120 titles of photocopies, and 356 titles of serial publications were acquired through exchange/gift from 210 institutes/organizations in 60 countries (table 1).

Table 1. Acquisitions in 1993

Title	Request for order	Ordered	Paid	Exchange
Book	179	118	93	413
Photocopy	270	253	205	120
Serial publication				
Subscription		127	127	356
CD-ROM		4	4	2
Diskette		3	3	

Documentation and in-house database development

A total of 1831 titles of books and crop documents and 32 new serial titles were catalogued and added to the library collection. The Compact International Agricultural Research Library (CIARL) of CGIAR/IARCs and the CD-DIS of USAID's Development Information System were added to the database collection on CD-ROM. Additions to the library collection and in-house database development are detailed in table 2.

Table 2. Status of library collection and retrieval system

	1993 additions	Total holdings	Retrieval system	
			Card catalog	Online DB
Books	704	15,410	9,655	5,755
Serial publication (titles)	32	1532		1532
Back volumes	341	12852		
Cassettes		52	52	
CD-ROM (discs)	25	35		
Diskettes	79	256		
Maps		84	77	7
Microforms		11		11
Documents				
Chinese cabbage	14	1501		1501
Diamondback moth	9	594	340	254
Garlic	17	211		211
Mungbean	85	4558		4558
Onion	100	813		813
Pepper	227	1216		1216
Shallot	2	43		43
Soybean	83	10158	7631	2527
Soybean rust	2	428		428
Sweet potato	34	3,885	2,566	1,319
Tomato	288	7,726	5,257	2,469
Others	266	1676		1676

Information Dissemination

Bibliography services

Eight short bibliographies retrieved from the in-house database and CD-ROM were provided for internal users (table 3).

Table 3. Bibliographies entries

Crop (database)	Total entries (title)
Colletotrichum of blackgram, mungbean & soybean (AVLIB)	45
Integrated pest management of peppers (AVLIB)	107
Macrophomina phaseolina of mungbean (AVLIB)	43
Macrophominic rot, root rot, & stem rot of mungbean (AVLIB)	144
Seed production of chili, Chinese cabbage, onion, soybean, and tomato (AVLIB)	130
Tomatoes in South Africa (AVLIB)	12
White rot of garlic, onion, and shallot (AGRICOLA, AGRIS, CAB)	135

Current awareness and SDI services

Four issues of the Library List (new acquisitions) and 15 issues of the Tropical Vegetable Information SDI Bulletin were published. The SDI bulletin was distributed to 184 partners and 5 libraries in 42 countries (table 4).

Table 4. Library list and TVIS SDI Bulletin

Topics	Issue	Entries	User	Library	Country
Library list	4	556	(staff & training scholars)		
Chinese cabbage	1	141	74	3	32
Eggplant	1	131	27	4	18
Garlic	2	171	37	3	20
Mungbean	1	95	104	4	19
Onion	2	213	46	3	22
Pepper	3	288	78	5	30
Soybean	2	245	101	4	31
Tomato	3	317	82	5	33

Reader Services

CD-ROM databases

CD-ROM databases were used for more than 332 CPU hours. The system was expanded and upgraded with support from Japan Shipbuilding Industry Foundation.

Library loans

A total of 4,459 titles of books and documents were loaned out by staff, training scholars, and external users in Taiwan.

Literature searches

A total of 70 literature searches were done for staff, training scholars, and visitors (table 5).

Table 5. Literature searches

Databases	Internal user	External user
AVLIB	18	13
AGRICOLA	11	8
AGRIS	7	8
CAB	7	8

Photocopy/document delivery

A total of 1,212 titles of documents were photocopied and sent to 49 external users and 74 libraries in 17 countries (table 6).

Table 6. Photocopy/document delivery services

	User	Library	No. of titles delivered
Cuba		1	37
India		1	5
Indonesia	1		3
Italy	1		2
Kenya		1	48
Mauritius		1	3
Niger		1	3
Papua New Guinea		1	9
Peru		1	8
Philippines		1	22
Singapore		1	2
Sri Lanka	1		1
Syria		1	20
Taiwan, ROC	42	64	1000
Thailand	1		5
USA	2		24
Vietnam	1		5

Publications and Communications

Summary

OPC managed a large workload in 1993. This was because of several factors: (1) there was no office head for most of 1992, resulting in a backlog of publications needing editing and production; (2) the demands of the 20th anniversary celebration; and (3) increased public awareness initiatives. The head of OPC was co-chairman of the 20th Anniversary Committee.

OPC implemented a public awareness strategy which resulted in AVRDC receiving notable publicity in several areas. This includes press conferences at the World Bank and the U.S. Congress; interviews with scientists on Radio Australia, the Voice of America, and the BBC; articles in Free China Review and The China Post; programming on China Public Television and China TV; and articles in numerous magazines and newspapers. Arrangements were made for several journalists from the U.K., the Philippines, USA, and Taiwan to visit the center.

But perhaps the most significant achievement was meeting the editing, production, publication, printing, and information-dissemination requirements of the center. For its size, OPC manages a publications and communications program that rivals larger international centers.

Communication Materials Production

AVRDC published 21 books and newsletters, and several training manuals/course reports with a total print run of 134,570 copies. Total number of printed pages was 3238. The list of published material is included under Appendices.

Other materials produced include:

20th anniversary materials

Exhibits in Research Laboratory Building
Building dedication citation brochures (3)
20th Anniversary Program
AVRDC brochure (Chinese)

Slide set scripts

Hybrid seed production in tomato
Vegetable nursery management techniques
Summer tomato production using hormone
Mungbean sprout production
Identification of diseases in tomato
Grafting to control soilborne diseases in eggplant

Communication Support Services

The print shop attended to 330 printing requests totaling some 402,000 pages of material.

The distribution desk disseminated 15,487 publications. Among the more frequently requested publications are the 1992 Progress Report, the Vegetable Production Training Manual, and the Pepper Field Guide. Publications were sent to 182 countries.

Graphic artwork involved making maps, figures, drawings, certificates, and designing a range of work. In all, some 243 jobs were completed.

The photo lab handled 103,100 color slides; blue slides, 1870; color prints, 3080; black and white prints, 3046. The photographer documented more than 100 visits, seminars, and events at the center, including the 20th anniversary celebration.

Promotion of Public Awareness

AVRDC's public awareness initiative during 1993 was noteworthy in several areas:

International Centers Week (ICW)

The center's biological control of diamondback moth research was showcased at a symposium at the World Bank during International Centers Week (ICW).

The selection was made on a competive basis with the other IARCs. AVRDC was one of six centers selected to present research before U.S. and foreign environmental, science, and agriculture journalists, staff from the U.S. government, NGOs, and donors.

Pre-symposium publicity resulted in Dr. N.S. Talekar being invited to present his work at a briefing at the Rayburn House Office Building (U.S. House of Representatives in Washington).

The center's publications were displayed at the International Monetary Fund during ICW.

Visiting journalists

Several writers/journalists were invited to AVRDC as part of the center's ongoing public awareness initiative. Sociologist and international agricultural research authority and writer Dr. Jim Lang of Vanderbilt University spent a month at the center gathering material for a book on vegetables. Another writer, Mr. Fred Powledge, who is collecting material for a book about international agricultural research, will visit AVRDC in early 1994.

Other writers and journalists who came to AVRDC in 1993 include Mr. Alan Fletcher (USA), who wrote The AVRDC Story as part of the 20th anniversary event; Ms. Eugenia Yun, who wrote an article on AVRDC for Free China Review (November 1993) and photographer Ms. Ching Su-Chang; and Filipino newspaper journalists Mr. Rudy Fernandez and Mr. Jose Burgos, who each wrote a series of articles about AVRDC's programs. Reporters from The China Post visited AVRDC and attended the 20th anniversary celebration program in Tainan.

International media

Voice of America agricultural programming producer Rob Sivak interviewed Dr. N.S. Talekar during ICW about his integrated pest management work with diamondback moth. The research was also covered by Radio Free Europe/Radio Liberty, the Associated Press, and the story was published in newspapers in 12 U.S. states.

The British Broadcasting Corporation (BBC), through arrangements initiated by OPC, interviewed the keynote speaker of the AVRDC-coorganized International Symposium on Alliums for the Tropics. Through similiar arrangements, Dr. David Midmore, director of the

center's Production Systems Program, was interviewed in London at Bush House by BBC World Service ("The Farming World") producer David Dixon. Programming material was obtained for five broadcasts. Dixon will visit AVNET projects in the Philippines in early 1994.

Dr. Jaw-fen Wang, AVRDC pathologist, was interviewed three times (twice in English, once in Mandarin) by Radio Australia.

AVRDC's collaboration with the Philippine national agricultural system received extensive coverage in the Philippine press, radio, and television.

Articles were also published in Ag Sieve (2), Seed World (2), Diversity, Biotechnology and Development Monitor, Arab World Agribusiness, IBPGR Newsletter, Crawford Fund Newsletter, Free China Review, and The China Post (2).

Other articles and photos about AVRDC are known to have been published in agricultural magazines and newspapers in Hungary, Thailand, the USA, Taiwan, Australia, the Philippines, and Bangladesh.

News releases and the AVRDC publication Centerpoint were sent to some 35 U.S.-based journalists who cover science, agriculture, and development matters. Publicity given to Taiwan Green, a high-yielding mungbean variety, in Centerpoint generated much demand for the cultivar in Asia.

Local media

As part of the publicity for AVRDC's 20th anniversary, arrangements were made for two television programs produced by Public Broadcasting and China TV in Taiwan. China TV spent several days at AVRDC and sent a production team to Bangkok to cover the work of the Asian Regional Center as well.

The 20th anniversary celebration was covered by the national radio, including International Community Radio Taiwan (ICRT) which broadcasts in English.

Some 25 journalists from Taiwan were invited to the anniversary celebration and press kits were provided to them in advance. Numerous articles about AVRDC and its anniversary appeared in the national press.

Collaborative Vegetable Research Program in Southeast Asia — Phase II

Summary

The joint planning meeting of the second phase of the Collaborative Vegetable Research Program in Southeast Asia (AVNET-II) was held in September 1992 in conjunction with the final workshop of AVNET-I. The Technical Assistance Agreement was approved by the Asian Development Bank (ADB) in March 1993. Research activities under AVNET-II have been divided into two subnetworks: subnetwork I — field evaluation and technology packaging for selected vegetables; and subnetwork II — disease and pest management with components on bacterial wilt, major viruses of peppers, and IPM of crucifers. A bacterial wilt training course was held at AVRDC from 25 April to 23 May 1993 attended by a researcher each from the four collaborating countries, namely, Indonesia, Malaysia, the Philippines, and Thailand. Thailand took responsibility in organizing the training course on nonradioactive DNA probe diagnosis of leaf curl virus held at Kasetsart University on 9-16 June 1993. Five participants from Thailand and one each from Indonesia, Malaysia, and the Philippines attended the training course.

Joint Planning Meeting

The joint planning meeting of the Collaborative Vegetable Research Program in Southeast Asia — Phase II (AVNET-II) was organized and conducted on 24-26 September 1992 in conjunction with the final workshop of AVNET-I.

Based on the achievements of AVNET-I, members of each subnetwork and of units within each subnetwork discussed in detail the proposed work plan. A jointly prepared proposal was submitted to the Asian Development Bank for financial support. ADB approved the proposal to establish AVNET-II on 12 March 1993. The approved T. A. document No. 5517 was distributed to all country coordinators; they were asked to share the document with each unit's leaders and researchers.

Subnetworks

AVNET-II has two subnetworks: subnetwork I — field verification and technology packaging for selected vegetgables; and subnetwork II — disease and pest management.

Subnetwork II on disease and pest management has the following three components:

- bacterial wilt disease management
- management of major viruses of peppers
- IPM of crucifers

Training

A bacterial wilt training course was held at AVRDC from 25 April to 23 May 1993. Dr. Niphone Thaveechai from Kasetsart University, Bangkok, Thailand, was invited as a resource person for the training. One researcher from each of the four collaborating NARS participated in the training. Seven lectures and nine laboratory sessions combined with a field visit provided the training scholars an excellent opportunity to learn and plan jointly their proposed research. The training was coordinated by Dr. Jaw-fen Wang, assistant plant pathologist at AVRDC. The training course report has been completed.

A training course on nonradioactive DNA probe diagnosis of leaf curl virus was held at Kasetsart University on 9-16 June 1993. The course included five lectures and four laboratory sessions and a field trip. One researcher each from Malaysia, Philippines, and Indonesia and five from Thailand participated in the training. Drs. Sutevee Sukprakarn and Pissawan Chiemsombat coordinated the training course; there were four other resource persons. The training course report has been completed.

South Asian Vegetable Research Network

Summary

The South Asian Vegetable Research Network (SAVERNET) was established with the signing of the Technical Assistance Agreement (TA) between the Asian Development Bank (ADB) and AVRDC. The establishment of SAVERNET was formally recommended during the South Asia Vegetable Research Planning and Consultation Workshop held on 24-29 September 1990 jointly sponsored by ADB and AVRDC and hosted by the Pakistan Agricultural Research Council at Islamabad, Pakistan. The implementation of this ADB-financed project (ADB T.A. No. 5461) began in November 1991.

The SAVERNET steering committee is composed of a representative each from the member countries who also serves as the technical coordinator. Seven AVRDC senior scientists also participate in the implementation of SAVERNET as lead persons and program coordinator.

A joint planning meeting was organized to develop a work plan for the implementation of SAVERNET research activities. A total of 36 scientists from the six collaborating countries and four AVRDC scientists participated in the joint planning meeting held at the Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh, on 24-27 February 1992.

Subnetwork I on the exchange and evaluation of elite varieties primarily aimed to: assemble, multiply, maintain, distribute, and evaluate elite local cultivars (improved cultivars and breeding lines) of identified priority vegetable crops; strengthen the research capability of the NARS and accelerate the development of improved vegetable cultivars through the sharing of such materials; and facilitate sharing of information for varietal evaluation in similar agroecological environments within the region by using a uniform varietal evaluation procedure. A large number of varieties of 12 different vegetables exchanged among the South Asian countries already stands as a major achievement. Due to lack of seeds, out of 121 entries agreed for exchange in the work plan, only 69 varieties of 13 vegetables have been received by the network coordinator. The participating countries agreed to provide the rest of the varieties in their next shipment. In accordance with the work plan, the vegetable seeds for trial by each member country were either hand-carried or distributed via airmail. It took some time for each of the countries to collect and send the seeds for evaluation. As a result, shipment of seeds to each participating country has been delayed. Due to this delay, the seeds were not planted in the winter season of 1992. First planting was carried out with selected summer crops and the trials are now in progress. The 1993 winter trial results are expected to show the potential of some of the introduced varieties.

Subnetwork II on crop and pest management research aims to: assemble, disseminate, and assess available technology and information at AVRDC and the NARS of the participating countries on topics such as bacterial wilt resistance in tomato and chili, leaf curl resistance in tomato and chili, and integrated pest management of crucifers with emphasis on diamondback moth; train researchers from the participating countries in the above areas to create a mass of

trained people to undertake collaborative research activities using commonly accepted procedures; develop new technology through collaborative or contract research on the above components with a view to share the new technology among the NARS; and exchange materials, methods, and expertise among the NARS and AVRDC.

A bacterial wilt training course was organized from 5 October to 16 November 1992 at AVRDC attended by representatives from each of the six collaborating countries. In Bangladesh, various chemical control measures have been tried against bacterial wilt but the results were not encouraging. Tomato lines sent by AVRDC to the Bangladesh Agricultural Research Institute (BARI) will be screened following the method agreed upon by the SAVERNET countries. In Bhutan, sites for the bacterial wilt resistance screening nursery (BWRSN) have been selected. An extensive survey of bacterial wilt in major pepper, tomato, eggplant, and potato growing areas has also been conducted. In India, a literature survey on bacterial wilt of solanaceous crops (other than potato and tobacco) is in progress. Since December 1992, a total of 275 references have been collected. Cataloging started in February 1993. A nondestructive method of detecting *Pseudomonas solanacearum* in tomato seedlings by immunosorbent techniques (dot-blot and ELISA) and for the rapid identification of wilt-resistant/tolerant seedlings in the nursery has also been developed. In Nepal, tomato varieties from the collaborating countries have been sent to different locations for field testing. A survey of bacterial wilt of tomato, capsicum, and eggplant in different localities and districts in Nepal was also carried out. In Pakistan, a detailed bacterial wilt survey plan was developed. In Sri Lanka, bacterial wilt disease surveys were conducted at 10 locations in Bandarawela. Data on disease incidence (percentage of wilted plants at flowering and harvesting stages), cultivar names, and environmental data were collected. Diseased plant tissues (samples) were also gathered for isolation of the pathogen for identification.

Tomato leaf curl virus (TLCV) is one of the major constraints in tomato and chili production in South Asia. A training course on advanced methods for virus diagnosis was conducted from 22 February to 16 March 1993 at AVRDC. In Bangladesh, 29 tomato hybrids were screened for resistance to TLCV. Three lines showed tolerant reaction. The experiment will be repeated to confirm the results. A thorough leaf curl virus survey was conducted in Bhutan throughout the major pepper, eggplant, and tomato growing areas of the country in June 1993. In India, 75 isolates/diseased samples of tomato were collected from different infected fields and planted in the sick plot for further multiplication of the viruses. The infected plants exhibited curling, mottling, thickening, puckering, and stunting of the leaves. Tomato and chili breeding materials have been generated and screened for resistance against TLCV. In Nepal, a survey of tomato, chili, and sweet pepper growing areas showed the presence of leaf curl symptoms. Infected leaf samples were collected and preserved in $CaCl_2$ and stored at low temperature (5-10°C) for identification. In Pakistan, following the training at AVRDC, a detailed plan for the leaf curl virus survey in tomato and chili was drawn up. In Sri Lanka, an extensive survey was undertaken during the 1993 yala (dry) season in the low country dry zone to record various symptoms associated with chili and to collect samples of diseased plants for identification of viruses associated with the crop.

Integrated pest management of cruciferous crops with emphasis on diamondback moth aims to achieve the following: low-cost control of DBM with a concomitant reduction in health hazards associated with excessive use of pesticides which are harmful to the environment; an updated assessment of DBM and other vegetable insect pest problems and national research and

development efforts to combat these pests; insights into pesticide registration and use for vegetable crops and environmental assessment programs of concerned NARS; enhancement of capabilities of the NARS' research personnel through training at AVRDC and in-country training; and appliction of the concept of IPM by researchers for the control of other major pests of agricultural and horticultural commodities.

In addition to the release of parasites, judicious use of trap crop shall also be promoted. Training on the mass rearing of parasites of diamondback moth was conducted at AVRDC from 22 April to 22 June 1992.

In Bangladesh, a comprehensive field survey of the seasonal abundance of DBM (*Plutella xylostella* L.) during the rabi 1992-93 in major cruciferous vegetable growing areas of Joydebpur, Jessore, Rajshahi, and Bogra was conducted. In Bhutan, parasite rearing facilities for DBM will be constructed at the National Plant Protection Centre (NPPC) complex in Simtokha, Thimphu. Surveys of local parasites of DBM were carried out in and around Thimphu (Yusipang); a few parasites of DBM were collected and sent to AVRDC for identification. In India, a survey of the pilot project site in Ooty, Nilagiris district, Tamil Nadu state (representing the highlands) was carried out. A simple technique to collect a large number of eggs of diamondback moth has also been developed, as well as a computer software called Cabbage Pest Expert Ver. 1.0 which can be used by researchers, students, and extension workers involved in pest management. In Pakistan, the parasite rearing facility will be established at the National Agricultural Research Centre (NARC). A survey for the presence of DBM and its parasitoids will be conducted at Peshawar, Khanpur, Islamabad, Rawalpindi, Murree Hills, Multan, and Hyderabad. In Sri Lanka,a building plan for a parasite-rearing facility has been approved. The dynamics of cabbage caterpillars is also being studied under this IPM component.

The management of heat, moisture, and other physical stress factors, and the technology available in each of the NARS shall be reviewed and a consolidated procedure shall be developed for adoption. In Bangladesh, an experiment using polyethylene sheets to protect tomato crop from excessive rains and other stress factors was initiated. In India, plant stress management activities include: screening techniques for drought and heat tolerance; application of growth hormones in tomato and chili to improve fruit set at high temperature conditions; response of tomato to moisture stress-plant water balance and yield; and effects of heat stress on photosynthesis and dry matter distribution in tomato. In Pakistan, a work plan primarily focused on the collection of germplasm and heat and moisture stress trials in tomato and chili has been drawn up. In Sri Lanka, research on plant stress management will commence in the wet season of 1993-94.

Three major constraints hampered the smooth progress of the network activities. First, exchange of germplasm from different countries was delayed and, hence, the planting season in most countries was also delayed. Second, staff members assigned to spearhead the projects had to be replaced for one reason or another. As a result, new persons had to be identified and familiarized with the projects. The third and most critical constraint was funding. Although the checks from AVRDC had been sent to the SAVERNET NARS as early as August-October 1992, it took 5-8 months for the funds to be released to the scientists.

As part of the monitoring activities, the network coordinator visited the participating countries on several occasions to meet with researchers, inspect key research sites, and examine research facilities.

Introduction

SAVERNET was established with the signing of the Technical Assistance Agreement (TA) between ADB and AVRDC. The implementation of this ADB-financed project (ADB T.A. No. 5461) began in November 1991.

Project Management

The SAVERNET steering committee is represented by a member from each of the six collaborating countries, who also serves as the technical coordinator.

Country	Steering Committee members
Bangladesh	Dr. M.H. Mondal, Mr. S.N.H. Arangzeb
Bhutan	Miss Chime P. Wangdi, Mr. Thinlay
India	Dr. K.L. Chadha
Nepal	Dr. R.K. Raut
Pakistan	Mr. M.H. Bhatti
Sri Lanka	Dr. S. Nagarajah

Seven AVRDC senior scientists also participate in the implementation of SAVERNET as lead persons and program coordinater.

Dr. S.K. Green	Virologist
Dr. L.M. Engle	Head, Genetic Resources and Seed Unit
Dr. J.M. Poulos	Pepper Breeder
Dr. J.F. Wang	Plant Bacteriologist
Dr. N.S. Talekar	Entomologist
Dr. P. Hanson	Tomato Breeder
Dr. S. Shanmugasundaram	SAVERNET Coordinator

The establishment of SAVERNET was formally recommended during the South Asia Vegetable Research Planning and Consultation Workshop held on 24-29 September 1990 and jointly sponsored by ADB and AVRDC and hosted by the Pakistan Agricultural Research Council at Islamabad, Pakistan. For the implementation of this collaborative undertaking, the six participating countries entered into a Memorandum of Understanding (MOU).

Financial statements from the six countries have yet to be received. As a result of stringent financial procedures, disbursement of funds advanced to them from AVRDC for the researchers has been delayed. Consequently, this unduly hampered the implementation of the different project components.

Joint Planning Meeting

A joint planning meeting was organized to develop a work plan for the implementation of SAVERNET research activities. A total of 36 scientists from the six collaborating countries and four AVRDC scientists participated in the joint planning meeting held at BARC, Dhaka,

Bangladesh on 24-27 February 1992. The meeting was inaugurated by BARC Executive Vice Chairman M.S.U. Chowdhury.

The first session of the joint planning meeting was devoted to the presentation of country reports on vegetable research and development by each of the technical coordinators. The rest of the sessions were devoted to group discussions on priority research areas such as exchange and evaluation of elite varieties, bacterial wilt of tomato and chili, leaf curl of tomato and chili, integrated pest management, and management of heat, moisture, and other plant stresses.

The group discussions concluded with a plenary session held on the last day of the meeting. Recommendations were presented by the chairman of each group, and were then approved for implementation.

Along with the joint planning meeting, a steering committee meeting was held on 24 February 1992. The committee elected BARI Director General M.H. Mondal as chairman for 1992. For 1993, Indian Council of Agricultural Research (ICAR) Deputy Director General (Horticulture) K. L. Chadha was elected as chairman.

The next meeting of the steering committee will be held in Bangalore, India, in 1994. Funding for the organization of this meeting will be borne entirely by the ADB. ICAR/Government of India will provide facilities and other local arrangements.

Research Progress

Subnetwork I - Exchange and evaluation of elite varieties

The following are the major objectives of subnetwork I:

(1) To assemble, multiply, maintain, distribute, and evaluate the elite local cultivars (improved cultivars and breeding lines) of identified priority vegetable crops;
(2) To strengthen the research capability of the NARCs and accelerate the development of improved vegetable cultivars through sharing of such materials; and
(3) To facilitate sharing of information for varietal evaluation in similar agroecological environments within the region by using a uniform varietal evaluation procedure.

A list of seeds of different varieties of various crops received from the network member countries is presented in table 1. This large number of varieties of 12 different vegetables exchanged among the South Asian countries already stands as a major achievement. Out of 121 entries agreed for exchange in the work plan, only 69 varieties of 13 vegetables have been received by the network coordinator. The participating countries agreed to provide the rest of the varieties in their next shipment.

In accordance with the work plan, the vegetable seeds for trial by each member country were either hand-carried or distributed via airmail. The list of seeds distributed as of 14 April 1993 is presented in tables 2-7.

Table 1. Vegetable seeds received from SAVERNET countries as of April 1993

	Crop	Variety name	Seeds received (g)
Bangladesh	Cabbage	Probhati	60
	Eggplant	Uttara	75
		Khafkhati	64
		Islampuri	62
	Onion	Taherpuri	40
	Tomato	Manik	30
		Ratan	36
Bhutan	Cabbage	Copenhagen Market	100
	Cauliflower	White Top	100
	Chili	Sha Ema	100
	Cucumber	S-Genchu	100
	Eggplant	PP Comg	100
	Onion	Kyoju	100
	Tomato	Roma	100
India	Brinjal	Pant Samrat	455
		KT 4	455
		P.P. Long	450
		Pant Rituraj	610
		Pusa Kranti	250
	Cabbage	Pusa Makta	484
	Capsicum	California Wonder	480
	Cauliflower	Pant Shubhra	480
		Pusa Snow Ball-I	478
		Pusa Deepali	500
		Pusa Snow Ball K-1	474
	Chili	Pusa Jawala	250
	Muskmelon	Wara Madhu	300
		Pusa Sharbati	300
		Pusa Madhuras	300
	Onion	Agrifound Dark Red	2000
		Pusa Madhui	1000
		Arka Niketan	500
		Pusa Red	2000
	Pumpkin	Pusa Vishwas	258
		Arka Chandan	300
	Tomato	Pusa Ruby	500
		Arka Vikas	500
		Pant Bahr	165
		Pusa Gaurau	500
		PED (Pusa Early Dwarf)	500
		Pb. Chhuhara	500
	Watermelon	Arka Manik	300
		Sugar Baby	300
Nepal	Cabbage	Copenhagen Market	206
	Cauliflower	Kathmandu	191
		Pusa Deepali	119.5
	Chili	Yatsufusa	104.2
		Surya Mukhi	199.6

Table 1. Continued.

	Crop	Variety name	Seeds received (g)
	Eggplant	Lurke	234.6
		Nurki	215
		Pusa Purple Long	194
	Onion	Red Creole	2000
	Sweet pepper	California Wonder	50
	Tomato	Monprecus	100.8
Pakistan	Cabbage	Golden Acres	70
	Cauliflower	Champa	64.4
		Chinolate	58.5
		1st Early	68.1
		2nd Early	69.6
Sri Lanka	Bitter gourd	Thinnevelly White	269
		MC 43	300
	Brinjal	Thinnevelly Purple	52.4
		SM-164	56.6
	Capsicum	CA-8	65.6
	Chili	MI-2	58.1
		KA-2	50
	Cucumber	Ly-58	255.7
	Okra	MI-5	585
		MI-7	605
	Pumpkin	ANK-1	204.9
	Tomato	T 245	54.9
		T 89	55.9
		K.W.R.	55.6
	Watermelon	Sugar Baby	298.6

Table 2. Seeds distributed to Bangladesh as of 14 April 1993

Crop	Variety name	Origin	Amount (g)
Eggplant	Uttara	Bangladesh	7
Eggplant	Khatkhati	Bangladesh	7
Eggplant	Islam Puri	Bangladesh	7
Onion	Taherpuri	Bangladesh	7
Chili	Sha Ema	Bhutan	10
Brinjal	P.P. Long	Bhutan	10
Welsh onion	Kyoju	Bhutan	10
Brinjal	Pant Samrat	India	91
Brinjal	KT 4	India	89
Brinjal	P.P. Long	India	87
Brinjal	Pant Rituraj	India	122
Brinjal	Pusa Kranti	India	44.8
Capsicum	California Wonder	India	80
Chili	Pusa Jamala	India	39
Onion	Agrifound Dark Red	India	158
Onion	Pusa Madhui	India	163

Table 2. Continued.

Crop	Variety name	Origin	Amount (g)
Onion	Arka Niketon	India	74.5
Onion	Pusa Red	India	325
Chili	Yatsufusa	Nepal	14.9
Chili	Surya Mukhi	Nepal	33
Eggplant	Lurke	Nepal	46.5
Eggplant	Nurki	Nepal	43
Eggplant	Pusa Purple Long	Nepal	38.5
Onion	Red Creole	Nepal	339
Sweet pepper	California Wonder	Nepal	7.1
Bitter gourd	Thinnevelly White	Sri Lanka	65.5
Bitter gourd	MC 43	Sri Lanka	50
Brinjal	Thinnevelly Purple	Sri Lanka	9.4
Brinjal	SM-164	Sri Lanka	10
Capsicum	CA-8	Sri Lanka	10
Chili	MI-2	Sri Lanka	8.8
Chili	KA-2	Sri Lanka	6

Table 3. Seeds distributed to Bhutan as of 14 April 1993

Crop	Variety name	Origin	Amount (g)
Cabbage	Probhati	Bangladesh	10.3
Cabbage	Cop. Market	Bhutan	10
Cauliflower	White Top	Bhutan	10
Chili	Sha Ema	Bhutan	10
Cabbage	Pusa Makta	India	121
Capsicum	California Wonder	India	80
Cauliflower	Pant Shubhra	India	98
Cauliflower	Pusa Snow Ball I	India	96
Cauliflower	Pusa Deepali	India	95
Cauliflower	Pusa Snow Ball K-1	India	93.8
Chili	Pusa Jawala	India	42
Cabbage	Copenhagen Market	Nepal	51
Cauliflower	Kathmandu	Nepal	38
Cauliflower	Pusa Deepali	Nepal	39.5
Chili	Yatsufusa	Nepal	14.9
Chili	Surya Mukhi	Nepal	33
Sweet pepper	California Wonder	Nepal	7.5
Cauliflower	Champa	Pakistan	8.7
Cauliflower	Chinolate	Pakistan	7.2
Cauliflower	1st Early	Pakistan	8.8
Cauliflower	2nd Early	Pakistan	9
Capsicum	CA-8	Sri Lanka	10
Chili	KA-2	Sri Lanka	6
Chili	MI-2	Sri Lanka	8.8

Table 4. Seeds distributed to India as of 14 April 1993

Crop	Variety Name	Origin	Amount (g)
Cabbage	Probhati	Bangladesh	10.3
Eggplant	Uttara	Bangladesh	12.5
Eggplant	Khafkhati	Bangladesh	10.6
Eggplant	Islam Puri	Bangladesh	10.3
Onion	Taherpuri	Bangladesh	66
Tomato	Manik	Bangladesh	5
Tomato	Ratan	Bangladesh	6.2
Brinjal	P.P. Long	Bhutan	10
Cabbage	Market	Bhutan	10
Cauliflower	White Top	Bhutan	10
Chili	Sha Ema	Bhutan	10
Cucumber	S-Genchu	Bhutan	10
Onion	Kyoju	Bhutan	10
Tomato	Roma	Bhutan	10
Brinjal	Pant Samrat	India	91
Brinjal	KT 4	India	91
Brinjal	P.P. Long	India	85
Brinjal	Pant Rituraj	India	122
Brinjal	Pusa Kranti	India	44.8
Cabbage	Pusa Makta	India	121
Capsicum	California Wonder	India	80
Cauliflower	Pant Shubhra	India	96
Cauliflower	Pusa Snow Ball-I	India	95.6
Cauliflower	Pusa Deepali	India	95
Cauliflower	Pusa Snow Ball K-1	India	94.8
Chili	Pusa Tawala	India	39
Muskmelon	Wara Madhu	India	94.6
Muskmelon	Pusa Sharbati	India	89.6
Muskmelon	Pusa Madhuras	India	87.2
Onion	Agrifound Dark Red	India	158
Onion	Pusa Madhvi	India	167
Onion	Arka Niketan	India	74.5
Onion	Pusa Red	India	327
Pumpkin	Pusa Vishwas	India	86
Pumpkin	Arka Chandan	India	95
Tomato	Pusa Ruby	India	68.5
Tomato	Arka Vikas	India	69
Tomato	Pant Bahr	India	32.8
Tomato	Pusa Gaurav	India	68.5
Tomato	PED (Pusa Early Dwarf)	India	96
Tomato	Pb. Chhuhara	India	92
Watermelon	Sugar Baby	India	87
Watermelon	Arka Manik	India	89.6
Cabbage	Copenhagen Market	Nepal	51
Cauliflower	Kathmandu	Nepal	38
Cauliflower	Pusa Deepali	Nepal	39.5
Chili	Yatsufusa	Nepal	14.9
Chili	Surya Mukhi	Nepal	33
Eggplant	Lurke	Nepal	46.5
Eggplant	Nurki	Nepal	43

Table 4. Continued.

Crop	Variety name	Origin	Amount (g)
Eggplant	Pusa Purple Long	Nepal	38.5
Onion	Red Creole	Nepal	333
Sweet pepper	California Wonder	Nepal	7.1
Tomato	Monprecus	Nepal	7
Cabbage	Golden Acres	Pakistan	9
Cauliflower	Champa	Pakistan	8.7
Cauliflower	Chinolate	Pakistan	8.5
Cauliflower	1st Early	Pakistan	8.8
Cauliflower	2nd Early	Pakistan	9
Bitter gourd	Thinnevelly White	Sri Lanka	65.5
Bitter gourd	MC 43	Sri Lanka	50
Brinjal	Thinnevelly Purple	Sri Lanka	9.4
Brinjal	SM-164	Sri Lanka	10
Capsicum	CA-8	Sri Lanka	10
Chili	MI-2	Sri Lanka	8.8
Chili	KA-2	Sri Lanka	6
Cucumber	Ly-58	Sri Lanka	83
Okra	MI-5	Sri Lanka	145.2
Okra	MI-7	Sri Lanka	149
Pumpkin	ANK-1	Sri Lanka	66
Tomato	T 245	Sri Lanka	10
Tomato	T 89	Sri Lanka	10.4
Tomato	K.W.R.	Sri Lanka	10
Watermelon	Sugar Baby	Sri Lanka	98

Table 5. Seeds distributed to Nepal as of 14 April 1993

Crop	Variety name	Origin	Amount (g)
Onion	Taherpvri	Bangladesh	7
Tomato	Manik	Bangladesh	7
Tomato	Ratan	Bangladesh	7
Cauliflower	White Top	Bhutan	10
Onion	Kyoju	Bhutan	10
Tomato	Roma	Bhutan	10
Cauliflower	Pant Shubhra	India	96
Cauliflower	Pusa Snow Ball-1	India	95.6
Cauliflower	Pusa Deepali	India	95
Cauiiflower	Pusa Snow Ball K-1	India	93.8
Onion	Agrifound Dark Red	India	158
Onion	Pusa Madhvi	India	163
Onion	Arka Niketan	India	74.5
Onion	Pusa Red	India	325
Tomato	Pusa Ruby	India	69.2
Tomato	Arka Vikas	India	69
Tomato	Pant Bahr	India	32.8
Tomato	Pusa Gaurav	India	68.5
Tomato	PED (Pusa Early Dwarf)	India	96
Tomato	Pb. Chhuhara	India	92
Onion	Red Creole	Nepal	339
Tomato	Monprecus	Nepal	8.1
Cauliflower	Chinolate	Pakistan	8.5
Cauliflower	Champa	Pakistan	8.6
Cauliflower	1st Early	Pakistan	8.8
Cauliflower	2nd Early	Pakistan	9.0
Tomato	T 245	Sri Lanka	10
Tomato	T 89	Sri Lanka	10
Tomato	K.W.R.	Sri Lanka	10

Table 6. Seeds distributed to Pakistan as of 14 April 1993

Crop	Variety name	Origin	Amount (g)
Cabbage	Probhati	Bangladesh	10.3
Eggplant	Uttara	Bangladesh	12.5
Eggplant	Khafkhati	Bangladesh	10.6
Eggplant	Islam Puri	Bangladesh	10.3
Onion	Taherpuri	Bangladesh	66
Tomato	Manik	Bangladesh	5
Tomato	Ratan	Bangladesh	6.2
Brinjal	P.P. Long	Bhutan	10
Cabbage	Market	Bhutan	10
Cauliflower	White Top	Bhutan	10
Chili	Sha Ema	Bhutan	10
Cucumber	S-Genchu	Bhutan	10
Onion	Kyoju	Bhutan	10
Tomato	Roma	Bhutan	10
Brinjal	Pant Samrat	India	91
Brinjal	KT 4	India	91
Brinjal	P.P. Long	India	85
Brinjal	Pant Rituraj	India	122
Brinjal	Pusa Kranti	India	44.8
Cabbage	Pusa Makta	India	121
Capsicum	California Wonder	India	80
Cauliflower	Pant Shubhra	India	96
Cauliflower	Pusa Snow Ball-I	India	95.6
Cauliflower	Pusa Deepali	India	95
Cauliflower	Pusa Snow Ball K-1	India	94.8
Chili	Pusa Tawala	India	39
Muskmelon	Wara Madhu	India	94.6
Muskmelon	Pusa Sharbati	India	89.6
Muskmelon	Pusa Madhuras	India	87.2
Onion	Agrifound Dark Red	India	158
Onion	Pusa Madhvi	India	167
Onion	Arka Niketan	India	74.5
Onion	Pusa Red	India	327
Pumpkin	Pusa Vishwas	India	86
Pumpkin	Arka Chandan	India	95
Tomato	Pusa Ruby	India	68.5
Tomato	Arka Vikas	India	69
Tomato	Pant Bahr	India	32.8
Tomato	Pusa Gaurav	India	68.5
Tomato	PED (Pusa Early Dwarf)	India	96
Tomato	Pb. Chhuhara	India	92
Watermelon	Sugar Baby	India	87
Watermelon	Arka Manik	India	89.6
Cabbage	Copenhagen Market	Nepal	51
Cauliflower	Kathmandu	Nepal	38
Cauliflower	Pusa Deepali	Nepal	39.5
Chili	Yatsufusa	Nepal	14.9
Chili	Surya Mukhi	Nepal	33
Eggplant	Lurke	Nepal	46.5
Eggplant	Nurki	Nepal	43
Eggplant	Pusa Purple Long	Nepal	38.5

Table 6. Continued.

Crop	Variety name	Origin	Amount (g)
Onion	Red Creole	Nepal	333
Sweet pepper	California Wonder	Nepal	7.1
Tomato	Monprecus	Nepal	7
Cabbage	Golden Acres	Pakistan	9
Cauliflower	Champa	Pakistan	8.7
Cauliflower	Chinolate	Pakistan	8.5
Cauliflower	1st Early	Pakistan	8.8
Cauliflower	2nd Early	Pakistan	9
Bittergourd	Thinnevelly White	Sri Lanka	65.5
Bittergourd	MC 43	Sri Lanka	50
Brinjal	Thinnevelly Purple	Sri Lanka	9.4
Brinjal	SM-164	Sri Lanka	10
Capsicum	CA-8	Sri Lanka	10
Chili	MI-2	Sri Lanka	8.8
Chili	KA-2	Sri Lanka	6
Cucumber	Ly-58	Sri Lanka	83
Okra	MI-5	Sri Lanka	145.2
Okra	MI-7	Sri Lanka	149
Pumpkin	ANK-1	Sri Lanka	66
Tomato	T 245	Sri Lanka	10
Tomato	T 89	Sri Lanka	10.4
Tomato	K.W.R.	Sri Lanka	10
Watermelon	Sugar Baby	Sri Lanka	98

Table 7. Seeds distributed to Sri Lanka as of 14 April 1993

Crop	Variety name	Origin	Amount (g)
Eggplant	Uttara	Bangladesh	12.5
Eggplant	Khafkhati	Bangladesh	10.6
Eggplant	Islam Puri	Bangladesh	10.3
Onion	Taherpuri	Bangladesh	6.6
Tomato	Manik	Bangladesh	5
Tomato	Ratan	Bangladesh	6.2
Chili	Sha Ema	Bhutan	10
Eggplant	P.P. Long	Bhutan	10
Tomato	Roma	Bhutan	10
Welsh onion	Kyoju	Bhutan	10
Brinjal	Pant Samrat	India	93
Brinjal	KT 4	India	89
Brinjal	P.P. Long	India	85
Brinjal	Pant Rituraj	India	122
Brinjal	Pusa Kranti	India	44.8
Capsicum	California Wonder	India	80
Chili	Pusa Jawala	India	29
Onion	Pusa Red	India	325.
Onion	Pusa Madhvi	India	163
Onion	Arka Niketon	India	74.5
Onion	Agrifound Dark Red	India	158
Tomato	Pusa Ruby	India	68.5
Tomato	Arka Vikas	India	69
Tomato	Pant Bahr	India	28.5

Table 7. Continued.

Crop	Variety name	Origin	Amount (g)
Eggplant	Uttara	Bangladesh	12.5
Tomato	Pusa Gaurav	India	68.5
Tomato	PED (Pusa Early Dwarf)	India	96
Tomato	Pb. Chhuhara	India	92
Chili	Yatsufusa	Nepal	14.9
Chili	Surya Mukhi	Nepal	33
Eggplant	Lurke	Nepal	48.6
Eggplant	Nurki	Nepal	43
Eggplant	Pusa Purple Long	Nepal	38.5
Onion	Red Creole	Nepal	303
Sweet pepper	California Wonder	Nepal	7.5
Tomato	Monprecus	Nepal	14
Brinjal	Thinnevelly Purple	Sri Lanka	99.4
Brinjal	SM-164	Sri Lanka	10
Capsicum	CA-8	Sri Lanka	10
Chili	KA-2	Sri Lanka	6
Chili	MI-2	Sri Lanka	8.8
Okra	MI-5	Sri Lanka	144
Okra	MI-7	Sri Lanka	149
Tomato	T 245	Sri Lanka	10
Tomato	T 89	Sri Lanka	10
Tomato	K.W.R.	Sri Lanka	10

It took some time for each of the countries to collect and send the seeds for evaluation. As a result, shipment of seeds to each participating country has been delayed. Due to this delay, the seeds were not planted in the winter season of 1992. First planting was carried out with selected summer crops and the trials are now in progress. The 1993 winter trial results are expected to show the potential of some of the introduced varieties.

Bangladesh. By the last week of February 1993, BARI received seeds of 11 varieties of eggplant (brinjal), 5 onion, 4 chili, 3 sweet potato, 1 bitter gourd, and 1 Welsh onion from the network coordinator. Brinjal has already been planted and the trial is in progress. All other vegetables were planted during the 1993 winter.

Bhutan. In February 1993, seeds of 5 varieties ofchili, 3 sweet pepper, 4 cabbage, and 11 cauliflower were received. These will be evaluated at the Center for Agricultural Research and Development (CARD), Wangdi; Yusipang; and Khangma/Tashigang. The National Plant Protection Center will organize and conduct the trials.

India. Evaluation of elite varieties will be conducted at the Indian Institute of Horticultural Research (IIHR), Bangalore; and at the Project Directorate of Vegetable Research (PDVR), Varanashi.

The following scientists are in charge of the evaluation at the different sites: Dr. R.M. Pandey, director, IIHR, Bangalore; Dr. Kalloo, director, PDVR, Varanashi; and Dr. H.S. Gill, head, Vegetable Crops, Indian Agricultural Research Institute (IARI), New Delhi.

India provided provided the network with seeds of a total of 29 varieties of 10 vegetable crops (onion, tomato, brinjal, cauliflower, cabbage, chili, watermelon, muskmelon, pumpkin, and sweet pepper).

Due to nonavailability, seeds of varieties N-53 (onion); Aruna (brinjal); Early Kunhavi and Pusa Shukra (cauliflower); Ambali (pumpkin); Andhra Jyoti, J-218, Bhaskar, Musalwadi and K-2 (chili); and Sel-2 and P-7 (okra) will be provided in the next season.

Nepal. Sites for crop evaluation and the cooperators who will be involved have been identified.

Tomato will be evaluated at the Horticulture Centre, Mawalpur, Sarlahi. Mr. Fuleshwor Singh, vegetable development officer and acting farm manager, will be responsible for the implementation of the project.

Cauliflower will be evaluated at the Vegetable Seed Production Centre, Khumaltar, with Mr. Devkota as the lead person.

The evaluation of onion will be at the Vegetable Seed Production Centre, Rukum, Mushikot. Mr. K.P. Adhikari, acting farm manager, will be responsible for the trials. Rukum is a major onion growing area in Nepal.

Pakistan. Seeds for the crop evaluation were received from the network coordinator in April 1993 and were planted in the middle of that month at the National Agricultural Research Centre (NARC), Islamabad, for preliminary evaluation. More than half of the seeds received were saved for the following summer planting for evaluation in the summer of 1994.

Muskmelon. The three muskmelon varieties that were planted flowered in 50-55 days. Only Wara Madhu (India) matured in 70 days. One fruit per plant weighed 1.6 kg.

Fruitfly attack severely damaged both Pusa Madharas and Pusa Sharbati.

Okra. Varieties M1-5, M1-7 (Sri Lanka), and Pusa Green (Pakistan) were planted for evaluation. All varieties flowered in 50-55 days and matured in 65-70 days. Pusa Green had the highest number of pods/plant (12). Sri Lankan varieties had 7-8 pods/plant. Germination of Sri Lankan varieties was poor and plants were stunted.

Pumpkin. All three varieties, Pusa Vishwas, Arka Chandan (India), and ANK 1 (Sri Lanka), flowered in July but had no fruit.

Cucumber. All three varieties, LY-58 (Sri Lanka), S. Ghenchu (Bhutan), and Sailkot Local (Pakistan) had very poor germination. Due to high temperature, 95% of the plants died.

Watermelon. Sugar Baby (Indian and Sri Lankan varieties) and Arka Manik (Indian variety) were planted; all three varieties flowered in 55-58 days and matured in 75-80 days (table 8). Sugar Baby had two fruit/plant while Arka Manik had only one fruit/plant. Arka Manik, however, was heavier than Sugar Baby although it was not as sweet.

Table 8. Information recorded for watermelon varieties planted in Pakistan

Varieties	Days to flowering	Days to maturity	No. of fruit/plant	Single fruit wt (kg)
Sugar Baby (India)	55	75	2	2.2
Sugar Baby (Sri Lanka)	55	75	1.6	2.8
Arka Manik (India)	58	80	1	3.4

Bitter gourd. Variety Thinnevelly took 48 days to flower and 65 days to mature, but was 100% susceptible to fruitfly.

Cabbage and cauliflower. For the winter trial, both cabbage and cauliflower have been planted in the nursery.

Sri Lanka. In March 1993, seeds of 44 varieties of different vegetable crops were received from the network coordinator.

Thirteen tomato varieties and three sweet pepper varieties are being evaluated at the Regional Agricultural Research Centre (RARC), Bandarawela, with Mr. E.M. Balasubramaniam, research officer in charge.

At the RARC in Maha Illuppallama, 2 okra varieties, 14 eggplant varieties, and 5 chili varieties are being evaluated. Ms. A.M. Perera, research officer, is in charge of the trials.

Seven onion varieties are also being evaluated at the RARC in Maha Illuppallama with Mr. K.A. Methananda in charge. Varieties Taherpuri and Agrifound Dark Red had poor germination.

Subnetwork II - Crop and pest management research

The subnetwork on crop and pest management research aims primarily to:

(1) assemble, disseminate, and assess available technology and information on the following topics at AVRDC and the NARS of the participating countries:
- bacterial wilt resistance in tomato and chili;
- leaf curl resistance in tomato and chili;
- integrated pest management of crucifers with emphasis on diamondback moth; and
- management of heat, moisture, and other stress factors in tomato and chili.

(2) train researchers from the participating countries in the above areas to create a mass of trained people to undertake collaborative research activities using commonly accepted procedures;

(3) develop new technology through collaborative or contract research on the above components with a view to share the new technology among the NARS; and

(4) exchange materials, methods, and expertise among the NARS and AVRDC.

Bacterial wilt resistance in tomato and chili

Bacterial wilt (BW) caused by *Pseudomonas solanacearum* is one of the most damaging diseases of tomato in the lowland tropics and subtropics. Estimates of yield loss due to this disease range from 15 to 95% worth about US $25-158 million.

The objectives of the bacterial wilt component of the SAVERNET are to:

(1) survey the strategic tomato and chili growing areas in each of the countries in the region and identify the race, biovar, and pathotypes of the pathogen;

(2) utilize available resistant materials from AVRDC and from each of the countries to determine the potential resistant sources for breeding; and

(3) understand the host, pathogen, and environmental factors and their interactions on disease severity, disease expression, and breakdown of resistance.

The main strategies are to understand the variability in the pathogen and in the host, and the role of environment in disease epidemics. Utilizing improved germplasm resources from subnetwork I, plant breeders are encouraged to work collaboratively with plant pathologists to develop bacterial wilt-resistant tomato and chili.

The goal is to devise a bacterial wilt control method that employs genetic resistance. In the event that genetic resistance is not sufficient, the control method should make use of reliable, efficient, and economical ways of managing the disease given the available resistance level

The methodology for the survey, pathogen identification, screening, resistance rating, and host genotypes should all be agreed upon by the collaborating countries. Such common methodology is expected to facilitate a meaningful understanding of the pathogen and the host response to the pathogen and in devising appropriate control measures.

A bacterial wilt training course was organized from 5 October to 16 November 1992 at AVRDC. Participants to the training included Mr. Md. Abdur Rahman (Bangladesh), Mr. Thinlay (Bhutan), Dr. Roopali Singh (India), Dr. D.B. Kelaniyangoda (Sri Lanka), Mrs. Kurshed Burney (Pakistan), and Mr. P.R. Bhurtyal (Nepal). The training scholars likewise benefited from an international bacterial wilt symposium organized by AVRDC from 28-30 October 1992. A number of authorities on bacterial wilt who participated in the symposium were requested to give lectures and demonstrations to the training scholars. Resource persons from the U.K., Australia, and France shared valuable knowledge with the training scholars.

Bangladesh. Bacterial wilt has been limiting production of solanaceous vegetables in Bangladesh. Various chemical control measures have been tried at BARI farms but the results were not encouraging. Tomato lines sent by AVRDC to BARI will be screened following the method agreed to by the SAVERNET collaborating countries. The bacterial wilt survey was conducted during the peak tomato growing season in 1993.

Bhutan. Bacterial wilt is an important disease of tomato and potato in warm subtropical areas of Bhutan. However, no proper survey of incidence and severity has been carried out mainly due to lack of knowledge of the methodology.

Following the training at AVRDC, the phytopathologist who participated in the training toured the country for the selection of sites for bacterial wilt resistance screening nursery (BWRSN).

An extensive survey of bacterial wilt in major pepper, tomato, eggplant, and potato growing areas was conducted in June 1993. Due to the current social unrest, the major tomato growing areas in the southern part of the country was not included in the survey. The areas surveyed are presented in table 9.

Table 9. Areas surveyed for bacterial wilt in chili and eggplant

Date collected	Place	Dzongkhag	Sample no.	Mem. no.	Elev. (cm)	Crop	Symptoms
20/6/93	Langthel	Tongsa	Nil	Nil	900	Chili	Wilting
21/6/93	Kabjisa	Punakha	Nil	Nil	1000	Eggplant	Wilting
13/6/93	Lungtenzamp	Tashigang	Nil	Nil		Chili	Wilting

Positive symptoms of bacterial wilt were observed in chili var. Lungtenzamp and Langthel and in eggplant var. Kabjisa. In all the places surveyed, bacterial wilt of tomato was not observed.

The BWRSN will be set up at Kabjisa under Punakha Dzongkhag. The place is ideal for the nursery due to its high temperature and humidity and to the presence of severe bacterial wilt on eggplants. Screening for resistance will be from December 1993 to February 1994, the normal season for eggplant, tomato, and chili growing at Kabjisa.

India. Bacterial wilt is a major disease of tomato and chili in India. Although considerable research has been done on the disease, there is a need to: identify different isolates of the pathogen present in the major tomato and chili growing areas; understand the environment and host-pathogen factors for disease severity and expression or breakdown of resistance; and utilize the above information and develop stable bacterial wilt-resistant tomato and chili varieties.

The IIHR in Bangalore has been selected as the agency responsible for the conduct of research on bacterial wilt. The scientists responsible for the implementation of the project are: Drs. N. Anand, A.T. Sadasiva, K. Madhavi Reddy, Roopali Singh, and K.S. Mohan.

A literature survey on bacterial wilt of solanaceous crops (other than potato and tobacco) is in progress. The following topics are covered in the literature survey:

- crop improvement - including sources of resistance, varieties developed, genetics of resistance, genotype x environment interaction, stability of resistance, and factors influencing susceptibility;
- basis of resistance - biochemical, biophysical;
- disease management - chemical and biological control;
- weed and collateral hosts;
- biotechnological aspects; and
- pathogen classification, serological identification, genetics of virulence, and biotechnological approaches.

Since December 1992, a total of 275 references have been collected. Cataloging started in February 1993.

The bacterial wilt survey, which will commence as soon as funds are released from ICAR, will be conducted in the following areas:

State	Places
Kerala	Trichur
Karnataka	Dharwar, Doddaballapur, Anekal, Nelamangala
Maharashtra	Akola, Parbhani
Bihar	Ranchi
Meghalaya	Shillong
Assam	Jorhat
Himachal Pradesh and Orissa	Palampur
	Bhubaneshwar

A nondestructive method of detecting *Pseudomonas solanacearum* in tomato seedlings by immunosorbent technique (dot-blot and ELISA) and for the rapid identification of wilt-resistant/tolerant seedlings in the nursery has been developed. This is expected to facilitate the elimination of seedlings which harbor the pathogen but do not show symptoms. This screening system is especially useful in breeding programs.

The local isolate of *P. solanacearum* was grown on nutrient agar plates and the biovar specific glycoprotein (associated with the murein layer) was extracted and purified. Polyclonal antibodies were raised in rabbits against the purified glycoprotein antigen. The procedure for the detection of *P. solanacearum* in tomato seedlings is still being standardized. This technique would help detect *P. solanacearum* cells within the petiole tissue of seedlings.

To evolve a technique for screening against *P. solanacearum* at the seedling stage, seedlings of two resistant and two susceptible lines were dipped in different concentrations of bacterial ooze. At 0.3 O.D. the susceptible lines succumbed to the disease but not the resistant lines. However, this reaction was temperature-specific (30±2°C). Further studies to develop and refine this technique using leaf petioles are in progress.

To acquire highly resistant lines (12) and advanced breeding resistant lines (12) identified at AVRDC, a permit to import seeds has been acquired through the National Bureau of Plant Genetic Resources (NBPGR).

Nepal. Due to a reorganization, Mr. P.R. Bhurtyal who participated in the bacterial wilt training course at AVRDC has been transferred to another office. In his place, Mrs. Ram Devi Dhawa took over as the lead person in the implementation of the project.

Tomato varieties sent to Nepal from the collaborating countries have been sent to the following locations for field testing:

Research farm	**Responsible officer**
Lumle Regional Agricultural Research Center	Mr. K. Budhathoki
Pakhribas Agricultural Center	Mr. S. Gautam
Agricultural Research Station, Surkhet	Mr. S.K. Pant

A survey of bacterial wilt of tomato, capsicum, and eggplant in different localities and districts in Nepal was conducted from 7 to 13 February 1993. Bacterial wilt-infected samples were collected from Bhaktepur, Kathmandu, Jhapa, Sarlahi, Sunsari, and Janakpur. The samples will be evaluated in the laboratory by Mrs. Ram Devi Dhawa.

Pakistan. Based on the work plan, a detailed bacterial wilt survey plan was developed. It proposed to conduct surveys in different areas (table 10).

Table 10. Proposed bacterial wilt survey plan in Pakistan

Locations	No. of locations to be surveyed	
	Chili	Tomato
Punjab		
Sheikhpura	3	3
Kasur	3	1
Okara	4	1
Sahiwal	3	2
Sindh		
Tharparker	4	2
Hyderabad	4	3
Badin	4	2
Balochistan		
Quetta	-	4
Loralai	4	4
N.W.F.P.		
Peshawar	1	2
Mardan	1	2
Swat	-	4
Malakand	1	4

Surveys will be conducted during the peak tomato and chili growing season.

The senior officer in charge of the project is Mr. Khalid M. Kohokkor; Mrs. Khurshed Burney, a participant of the bacterial wilt training course at AVRDC, conducts all the research activities.

Sri Lanka. Bacterial wilt disease surveys were conducted at 10 locations in Bandarawela. Data on disease incidence (percentage of wilted plants at flowering and harvesting stages), cultivar names, and environmental data were collected. Diseased plant tissues (samples) were also collected for isolation of the pathogen for identification.

In the laboratory, selected plant tissues collected from the survey were used for the isolation of bacteria in TZC medium. A fluidal typical single colony was selected from the TZC plate and multiplied in rich media (523 or NA). After multiplication, the bacteria mass was transferred into sterilized tubes containing sterilized distilled water at room temperature to serve as long-term storage.

In the field 40 different lines/varieties were tested. The bacterial wilt incidence was low. Therefore, no reliable conclusion was drawn.

An international bacterial wilt disease nursery was established in two locations.

In Sri Lanka the released tomato cultivar, Katungastota wilt resistant (KWR) remains highly resistant to bacterial wilt. However, its fruit quality and yield are unacceptable to most farmers.

In a resistance screening conducted by Dr. I.J. De Zoysa of the Central Agricultural Research Institute, Gannoruwa using root and stem inoculation with a highly virulent culture of *P. solanacearum* (10^8 cfu/ml), a number of tomato and capsicum germplasm resistant to bacterial wilt have been identified. However, none of the eggplant germplasm showed resistance.

In another field screening, a naturally infected plot was developed and all crops of the tomato variety Marglobe succumbed to bacterial wilt 2 months after planting.

Leaf curl virus resistance evaluation in tomato and chili

Leaf curl disease of tomato and chili is one of the major constraints in tomato and chili production in South Asia. Leaf curl is caused by a whitefly-transmitted nonpersistent virus.

A training course on advanced methods for virus diagnosis was conducted from 22 February to 16 March 1993 at AVRDC. The objectives of this training were to:

- provide researchers in the developing countries hands-on experience in the effective screening methodologies for host resistance; and
- provide training in the use of recent diagnostic techniques for identification of these viruses and use in resistance screening.

The topics covered in the training course were: (1) techniques for virus identification such as Enzyme Linked Immunosorbent Assay (ELISA), Immunosorbent Electron Microscopy (ISEM), use of polyclonal antisera and monoclonal antibodies, nucleic acid hybridization, and electroblot immunoassays; and (2) screening protocols for evaluating host resistance.

The course was conducted by the AVRDC virology staff. Other resource persons included: Dr. D.E. Lesemann and H.J. Vetten (Federal Institute of Agricultural Research, Germany), Dr. J. Cho (University of Hawaii Manoa), and Dr. D. Maxwell (University of Wisconsin).

The course was attended by the following: Dr. P.M. Wijerantne Banda (Sri Lanka), Mr. Shahid Hameed (Pakistan), Dr. Md. Ashraf Khan (Bangladesh), Mr. Ugyen Penjore (Bhutan), Mr. Frederick Salal Rajan (India), and Mrs. Krishna Kumari Shreshtha (Nepal). Dr. S.J. Singh (India) will be trained in early 1994.

Bangladesh. Tomato leaf curl virus (TLCV) disease caused by a geminivirus transmitted by whitefly, *Bemisia tabaci* Genn., is a major tomato production problem in Bangladesh. The disease has caused up to 50-60% yield loss. Experiments have shown that indeterminate tomato varieties are more resistant to TLCV than determinate ones.

Twenty-nine tomato hybrids were screened for resistance to TLCV. Three lines showed a tolerant reaction. The experiment will be repeated to confirm the results.

Bhutan. A thorough leaf curl virus survey was conducted throughout the major pepper, tomato, eggplant, and tomato growing areas of the country in June 1993. Many typical leaf curl virus symptoms were observed on pepper throughout the country; however, symptoms on tomato appeared to be different.

The decision to include screening for leaf curl virus among the activities under this component will depend on the diagnostic results from AVRDC's survey samples from Bhutan. The places surveyed and the date samples were collected are given in table 11.

India. Leaf curl is an important disease of tomato and chili in India.

Two centers will be involved in the leaf curl virus resistance research. IIHR in Bangalore with Dr. S.J. Singh as the lead person will deal with virological studies. At the Project Directorate of Vegetable Research at Varanashi, Dr. Kalloo will spearhead studies on virus strain identification and will develop host differentials, strain confirmation, multilocation testing, and testing of advanced breeding lines.

Table 11. Leaf curl virus areas surveyed in Bhutan

Date collected	Place	Dzongkhag	Sample no.	Mem. no.	Elev. (m)	Crop	Symptoms
13/6/93	Jomtsang	Tashigang	1	1,2,3,4	1,200	Chili	SP,LC
17/6/93	Chali	Mongar	2	1,2,3,4		Chili	LC
19/6/93	Chamkhar	Bumthang	3	1,2,3,4	2,340	Chili	YL,SP,LC
20/6/93	Langthel	Tongsa	4	1,2,3,4	900	Chili	LC,PL,YL,W
20/6/93	Tikay Zam	Wangdi	5	1,2,3,4	1,100	Chili	YL,LC,SP,PL
21/6/93	Wokuna		6	1,2,3,4	1,100	Chili	YL,LC,SP,PL
22/6/93	Lorina		7	1,2,3,4	1,100	Chili	LC,SP,YL
17/6/93	Autsho	Lhuntshi	8	1,2,3,4	700	Chili	LC,SP,YL
21/6/93	Kabjisa	Punakha	9	1,2,3,4	1,000	Chili	LC,PL,YL,SP
13/6/93	Lungtenzamp	Tashigang	10	1,2,3,4		Chili	LC,YL,SP
20/6/93	Langthel	Tongsa	11	1,2,3,4	860	Chili	LC,YL,SP
21/6/93	Wokuna		12	1,2,3,4	1,100	Chili	LC,YL,SP,PL
13/6/93	Rongtong	Tashigang	13	1,2,3,4	1,500	Chili	LC
17/6/93	Lhuntshi	Lhuntshi	14	1,2,3,4	1,300	Chili	LC,YL,SP
24/7/93	Thimphu	Thimphu	15	1,2,3,4		Chili	LC
29/7/93	Chapey	Haa	16	1,2,3,4	2,500	Chili	LC,SP
29/7/93	Balamna	Haa	17	1,2,3,4	2,300	Chili	LC,YL
17/6/93	Tangmachu	Lhuntshi	1	5	1,000	Tomato	YL,LC
13/6/93	Pam	Tashigang	2	5	960	Tomato	YL,LC
22/6/93	Bajo	Wangdi	3	5	1,060	Tomato	LC,YL,SP
29/7/93	Balamna	Haa	4	5	2,300	Tomato	LC,YL
29/7/93	Haa	Haa	5	5	2,100	Tomato	LC,YL

LC = leaf curling; YL = yellowing of leaves; PL = puckering of leaves; SP = stunted plant growth.

Strain identification. Seventy-five isolates/diseased samples of tomato were collected from different infected fields and planted in the sick plot for further multiplication of the viruses. The infected plants exhibited curling, mottling, thickening, puckering, and stunting of the leaves. Infected plants exhibited extremely poor flowering and no fruiting. Infection at the early stage resulted in no fruiting. Late-infected plants produced few but unmarketable fruit.

Disease severity in chili was low with only 20 infected samples collected; morphological characteristics of these samples have been identified. There was curling and stunting of the leaves. In spite of infestation, the plants bore fruit.

The virus strains will be identified using differentials. An attempt is being made to develop differentials on the basis of degree of resistance in the plants/lines. Breeding populations/lines have been planted in the field and observations on the disease incidence/severity are being recorded. On the basis of these observations, differentials will be developed. Such lines will be used to identify strains of TLCV. Identification of strains under laboratory conditions will also be tried. Laboratory facilities and probes are being developed for this purpose.

Screening of breeding material. Tomato breeding materials have been generated with the hybridization of *Lycopersicon esculentum* x *Lycopersicon hirsutum* f. *glabratum* and *Lycopersicon esculentum* x *Lycopersicon pimpinellifolium*. *Lycopersicon hirsutum* f. *glabratum* and *Lycopersicon pimpinellifolium* were found resistant to TLCV. Advanced progenies have been developed using these sources. Such progenies were planted in the field on 28 August 1992 and observations on the disease have been recorded. The number of resistant plants selected from the different populations is presented in table 12.

Table 12. Number of resistant tomato plants selected from the different populations

S. no.	Accession no.	Total no. of plants	No. of resistant plants selected
	L. esculentum x *L. hirsutum* f. *glabratum*		
1	BC_1-BC_2 bulk (1)	57	5
2	BC_1-BC_2 bulk (2)	368	10
3	H-86-1	15	2
4	H-86-2	217	8
5	H-86-3	62	2
6	H-86-9	3	-
7	86-24-1	19	2
8	86-24-2	73	5
9	H-86-82	134	6
10	H-88	194	10
11	H-88-1	86	5
12	H-88-2	275	10
13	H-88-3	32	-
14	H-88-4	182	10
15	H-88-78	1	1
16	24-1 Large fruited		
	Cross: *L. esculentum* x *L. pimpinellifolium*		
17	P-2-21	73	2
18	P.B. (13)	45	4
19	BC-4 F_4 Bulk hybrids/varieties	210	10
20	Pant Bahar-AC-238	74	0
21	D.T.-10	22	0
22	Anand T-1	50	0
23	Supriya hybrid	20	0
24	Pant T-4	70	0
25	A.T.V.-2	52	0
26	Century-12	18	0
27	BT (12-2)	72	0
28	HOE-909	7	0
29.	NDT-96	31	0
30	COTH-2	20	0
31	K.S.-17	15	0
32	Lerica	5	0
33	NDM-1	26	0
34	DTH-6	9	0
35	BSS-39	12	0
36	BSS-20	9	0
37	NDTH-6	10	0
38	NDTH-1	6	0
39	Arth-3	6	0
40	TC-16-15	3	0
41	BT-12	26	0

An experiment on chili hybrid evaluation/screening was conducted on 20 November 1992 in 3.6 x 3.0 m plots with 60 x 20 cm distance in a randomized block design.

The disease incidence will be recorded after appearance of the symptoms. The following accessions were used:

1. Sonali
2. Padmaraj
3. Swarna
5. Param Mitra
6. Century-12
7. Rupali
8. Naveen
9. Ajanta
10. Kalyani
11. MT-6
12. PTH-103
13. XLE-006
15. ARTH-3
16. TC-104
17. NH-25
18. NH-38
19. Sel-16
20. Hybrid No.-37

Breeding materials involving the cross of cultivated and wild chili species (resistant) (total 12 entries) were transplanted in the field on 24 January 1993 at a distance of 60 x 45 cm. Resistant plants will be selected when disease symptoms have appeared. The details are given in table 13.

Table 13. Resistant chili plants selected

S. no.	Accession no.	Total no. of plants	No. of resistant plants selected
1	Faizabadi Long Green	125	0
2	HOE-808	307	0
3	JCA-283	416	0
4	BC-14-2	95	0
5	BC_1-21-2	16	0
6	CA-219	57	0
7	LCA-206	273	0
8	LCA-304	156	0
9	LCA-305	220	0
10	PKM-1	135	0
11	Pusa Jwala	148	0
12	Suryamukhi	78	0

Evaluation of advanced lines. Two varieties developed with the hybridization of *Lycopersicon esculentum* and *Lycopersicon hirsutum* f. *glabratum* have been transplanted along with susceptible varieties Selection-7 (Hisar Arun) and Sel-18 at a distance of 60 x 45 cm.

The data obtained from this experiment are presented in table 14.

Table 14. Evaluation of advanced tomato lines

S. no.	Accession no.	Total no.	No. of susceptible plants	Rating
1	H-24	155	4	Resistant
2	H-36	156	2	Resistant
4	Sel. 7 check	50	40	Susceptible
5	Sel-18 check	54	41	Susceptible

Varieties H-24 and H-36 have shown resistance, whereas, checks were found to be susceptible. Seeds of H-24 and H-36 are being multiplied for distribution to the farmers. These varieties are expected to show promise in the farmers' fields.

Nepal. A survey of tomato, chili, and sweet pepper growing areas showed the presence of leaf curl symptoms. The disease was suspected to be due to a geminivirus; whitefly, the vector normally associated with this virus, was not observed.

Infected leaf samples were collected and preserved in $CaCl_2$ and stored at low temperature (5-10°C) for identification. Samples were collected from Sarlahi, Chitran, Lalitpur, and Kathmandu districts; some of the samples were sent to the Danish Government Institute of Seed Pathology in Denmark for identification. None of the samples showed virus particles when subjected to electron microscope examination.

Following the survey carried out by Mrs. Ram Devi Dhawa and Mrs. Krishna Shrestha, about 40 tomato samples have been collected from different parts of the country, e.g., Chitwam, Newalparasis, Nepalgunj, Punchkhal, Kathmandu Valley, and Sarlahi districts. All samples have been preserved in calcium chloride. Twenty selected samples were squashed onto a nylon membrane. Whiteflies have been multiplied on eggplant and tomato inside insect-proof cages for transmission studies.

Pakistan. Following the training at AVRDC, a detailed plan for the leaf curl virus survey in tomato and chili was drawn up. The provinces and districts to be surveyed are as follows:

Province	**Districts**
Punjab	Sheikhupura, Kasur, Okara, Sahiwal, Faisalabad, T.T. Singh, Khanewal, Multan, Rahim Yar Khen
Sindh	Tharparkar, Mirpur Khas, Badin, Hyderabad, Karachi
NWFP	Swat, Malakand
Baluchistan	Loralai, Quetta

The survey will be conducted during the tomato and chili growing seasons in 1993. Mr. Asif Khan of the National Agricultural Research Center will be responsible for the implementation of the project. Research activities will be spearheaded by Mr. Shahid Hameed.

Sri Lanka. An extensive survey was undertaken during the 1993 yala (dry) season in the low country dry zone to record various symptoms associated with chili and to collect samples of diseased plants for identification of viruses associated with the crop. The following major chili growing areas were visited and on-site inspection of chili fields exhibiting leaf curl symptoms were made:

Anuradhapura district - Nachchaduwa, Rajangane, Katitigollawa, and Mahawali II area
Polonnamwa district - Bakamuna

Eleven samples were subjected to laboratory assay. These samples will be sent to Wisconsin and AVRDC for pathogen identification.

At the RARC in Bandarawela, five tomato varieties were evaluated in the field for leaf curl and other virus symptoms. Two local hybrids, Vihara I and Vihara II, exhibited lower virus infection and higher yield compared to other varieties.

At Girandumkotte, the planting trial time suggested that leaf curl virus symptoms tended to increase from June onwards (during the dry period). At Bandarawela, leaf curl virus incidence was less compared to Girandumkotte; however, incidence of other virus diseases (yellowing, etc.) was high in the former which also tended to increase during the dry spell. Mr. M.G. Dhanapala will be in charge of the tomato trial in Girandumkotte, while Dr. P.H. Wijeratne Banda will be responsible for chili trial in Maha Illupallama.

Integrated pest management of cruciferous crops

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 of the diamondback moth (DBM), *Plutella xylostella*.

Farmers in South Asia have been using 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 such as predators and parasites which otherwise help check the natural population of DBM and other pests.

Alternative measures to control DBM have been developed. Scientists have found a bacteria, *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. Recently, the chemical industry has come up with selective chemicals which are safe for the natural enemies of DBM. AVRDC has also been working on several parasites of DBM.

The NARS of South Asia have unanimously agreed to accord high priority to the transfer of integrated pest management (IPM) technology.

The goal of the IPM of DBM subnetwork is to transfer the concept and the technology of IPM to cruciferous vegetable scientists in South Asia. Specifically, the subnetwork aims to achieve the following:

- Low-cost control of DBM with a concomitant reduction in health hazards associated with excessive use of pesticides which are harmful to the environment;
- An updated assessment of DBM and other vegetable insect pest problems and national research and development efforts to combat these pests;
- Insights into pesticide registration and use for vegetable crops and environmental assessment programs of concerned NARS;
- Enhancement of capabilities of the NARS' research personnel through training at AVRDC and in-country training; and
- Application of the concept of IPM by researchers for the control of other major pests of agricultural and horticultural commodities.

In addition to the release of parasites, judicious use of trap crop shall also be promoted.

Training on the mass rearing of parasites of diamondback moth was conducted at AVRDC from 22 April to 22 June 1992. The training course was attended by Mr. Chencho Dorji (Bhutan), Mr. P.N. Krishna Moorthy (India), Mrs. Shashi Adhikari (Nepal), Mr. Saifullah Talpur (Pakistan), and Mr. G. Ratnasinghe (Sri Lanka). Mr. Ibrahim Ali (Bangladesh) was given a special training from 15 October to 9 December 1992.

Bangladesh. A comprehensive field survey of the seasonal abundance of DBM (*Plutella xylostella* L.) during the Rabi 1992-93 in major cruciferous vegetable growing areas of Joydebpur, Jessore, Rajshahi, and Bogra was conducted.

In Joydebpur, farmers' cabbage fields in Koddah, Kashimpur and plots of the Horticulture Development Center, Bangladesh Agricultural Development Corporation (BADC) in Kashimpur were visited. No serious infestation of DBM on cabbage (*Brassica oleracea* var. *capitata* L.) and other crucifer vegetables was noted. Some farmers reported having noted some infestation during the early season but which disappeared after insecticide spraying. Most farmers apply insecticides on cabbage regularly at fortnightly intervals as a prophylactic measure against the insect pest. In the BADC farm, a serious outbreak of DBM on cabbage occurred in 1985-86 which was almost unmanageable. Since then, no serious infestation of DBM has been observed. During the 1985-86 season, a serious infestation of DBM occurred at the research farm of BARI in Joydebpur, Gazipur.

In Jessore, farmers' cabbage fields near the Barobazzar area were visited and a high level of infestation was noted in all the fields. Farmers reported that DBM infestation occurs yearly throughout the growing season. As a control measure, they follow a calendar-based fortnightly prophylactic spray schedule of insecticides against the DBM and other cabbage pests. During late January, Dr. M.A. Karim, Chief Scientific Officer, Entomology Division, BARI, visited these areas and noticed similar DBM infestation.

In Bogra, farmers' cabbage fields at Naruli and Gabtali were visited. Serious infestation of DBM was noted in some plots. Farmers reported that the infestation of DBM has become a regular problem in recent years; hence, they needed to regularly spray against the pest.

In Rajshahi, a serious infestation on radish (*Raphanus sativus*) pods and cabbage heads was observed at the Horticulture Development Center (BADC) farm in Naudapara. DBM larvae had almost skeletonized the radish pod. A cabbage field near the radish field was abandoned due to DBM infestation. According to a farm authority, they were unable to control the pest even with the application of three sprays of Ekalux (Quinalphos), one spray of Malathion, two sprays of Ngos (dichlorvos), and one spray of Dimecron (phophamidon) throughout the season. DBM infestation started during the seedling stages at the nursery and continued throughout the season. This year due to pest problems, farmers were unable to produce cauliflower (*B. oleracea* var. *campestris* L.) seed. A serious DBM infestation was also noted on cabbage in farmers' fields at Baro Banogram areas; farmers were unable to manage the pest even by repeated spraying of different kinds of insecticides.

In the infested cabbage field, a large number of adults and pupae of *Cotesia plutellae* and *Diadegma semiclausum* parasitoids were observed. These specimens were sent to C.A.B. International Institute of Entomology (CABIIE), London for identification. Aside from these, predaceous coccinellid beetles, *Coccinella transversalis*, *Chelomene sexmaculata*, *Micraspis discolor*, staphylinid beetle, *Paederus fuscipes*, and spiders were found. *C. plutellae* and *D. semiclausum* are recognized as parasitoids of DBM on cabbage growing areas worldwide. The relationship of the above mentioned predators with DBM is not yet known. However, their presence in such a large number in the cabbage field suggests a functional relationship between them and the DBM larvae.

Besides DBM, tobacco caterpillar (*Spodoptera litura* F.), a polyphagous insect, was considered a major pest of cabbage, cauliflower, and other vegetables in Bangladesh. The infestation of this pest was noted in all the plots visited. As a control measure, farmers apply prophylactic sprays of insecticides. Ali reported some effective natural enemies of the tobacco caterpillar from Bangladesh. Among them, a nuclear polyhedrosis virus was found to cause up to 43% larval

mortality while the parasitoids, *Microplitis similis* Lyle and *Chelonus* sp. inflicted up to 84.5% and 14.5% larval mortality, respectively.

Although DBM and the tobacco caterpillar are considered major insect pests of cruciferous vegetables in Bangladesh, tobacco caterpillar infestation is the most regularly occurring. The occurrence of DBM has been erratic in some locations. However, the severity of the DBM infestation has been growing in recent years. This is attributed to the excessive use of chemical insecticides on crucifer vegetables. DBM has developed resistance against almost all groups of insecticides in many countries. A related species of the tobacco caterpillar (*S. littoralis* Boisd.) has also developed resistance against some insecticides. By adopting the integrated pest management approach, farmers need not solely rely on chemical insecticides for the control of these pests.

Bhutan. The National Plant Protection Center (NPPC) of the Department of Agriculture initiates and implements the SAVERNET IPM program in Bhutan. The parasite rearing facilities for DBM will be constructed at the NPPC complex in Simtokha, Thimphu.

Surveys of local parasites of DBM were carried out in and around Thimphu (Yusipang); a few parasites of DBM were collected and sent to AVRDC for identification.

Construction of the parasite rearing house is almost completed. Equipment to control the temperature inside the rearing house has been requested.

Initial baseline surveys of local parasites of DBM have been conducted since May 1993 to:

(1) identify and differentiate the various parasites attacking DBM in Bhutan. This would help establish their abundance and relative economic importance; and

(2) examine the degree of parasitism from parasite, host emergence, and mortality. Sampling will be carried out in the eastern zone of the country, composed of five districts, namely, Thimphu, Punakha, Paro, Haa, and Wangdiphodrang. The activities mainly include:

- collection of fourth and fifth instar larvae.
- collection of DBM pupae.
- larval dissection and collection of other parasites pupating outside the host body.

Some of the cooling and warming equipment for the parasite rearing house will be purchased through the EC funds.

India. Diamondback moth is a major pest of crucifers in India. The IIHR in Bangalore is responsible for the implementation of the program. Dr. K. Srinivasan and Mr. P.N. Krishna Moorthy are the lead persons.

Establishment of parasitoid culture. Twenty insect rearing cages have been fabricated especially for rearing parasitoids. With the import permit from the government of India secured, a nucleus culture of *D. semiclausum* and *T. bactrae* has been acquired from AVRDC, Taiwan. Both parasitoids are being quarantined at the National Centre for Integrated Pest Management (NCIPM) in Bangalore. *D. semiclausum*, though, has already been cultured at IIHR. The parasitoids are surviving at room temperature ranging from 15 to 27°C. *C. plutellae* was not imported since it is available both in the lowlands and highlands of India.

Survey of highland pilot project sites. A survey of the pilot project site in Ooty, Nilagiris district, Tamil Nadu state (representing the highlands) was made in November 1992. The local strain of *D. semiclausum* is already available at Ooty in the cabbage/cauliflower ecosystem. The identity of *D. semiclausum* has also been confirmed by Dr. Chandra Mohan, Professor of Entomology, Regional Research Station of Tamil Nadu Agricultural University, Vijayanagar, Ooty. According to Dr. Mohan, *D. semiclausum* is dominant during winter (November-January) exercising 50-60% parasitism at temperatures ranging from 3 to 20°C. This local strain appears to have evolved over several years and could have delayed density dependent regulation. Hence, it was proposed that the Indonesian strain of *D. semiclausum* obtained from AVRDC be tried in isolated pockets at Ooty to evaluate its performance the following year.

Proposed studies in the lowlands (summer/rainy season 1993). The following field experiment was proposed either for the summer (April-June) or the rainy season (July-September) at the experiment station of IIHR.

Design: Exploded block

Treatments:

- Releases of *C. plutellae* under IPM using Indian mustard as a trap crop.*
- Releases of *C. plutellae* on cabbages alone.*
- IPM using Indian mustard as a trap crop with recommended 4% neem seed kernel extract (NSKE) sprays.
- Cabbage sprayed with 4% NSKE sprays as recommended under the IPM with mustard as a trap crop.
- Insecticide sprays at weekly intervals on cabbages.
- Unsprayed cabbages.

* Treatments 1 and 2 will be tried in separate blocks.

Plot size: 100 m^2 per plot.

Observations were made on the following:

(1) Population of DBM, leafwebber, *Croccidolomia pavonana*, Web worm, *Hellula undalis*, aphids, *Brevicoryne brassicae*, gram caterpillar, *Helicoverpa armigera* on cabbages.
(2) Percent parasitism due to *C. plutellae* on DBM.
(3) Percent marketable heads of cabbage.

A simple technique to collect large number of eggs of diamondback moth was developed by Mr. P.N. Krishna Moorthy and Dr. K.N. Srinivasan as described below:

A cotton plug is wrapped around a tender cabbage leaf 4-6 in. in length and inserted in a 100-ml conical flask containing water. The cotton plug is kept in constant touch with the water to maintain leaf turgidity. Tissue paper, 6 x 4 in. is folded to get a 1-in. strip. It is gently crumpled by hand and fastened around the neck of the conical flask with a rubber band in such a way that half of the strip comes in contact with the leaf. The flask is then kept inside the DBM oviposition cage containing 150-500 adults. After 24 hours of exposure the tissue paper is separated by cutting the rubber band. About 300-1500 eggs with yellow tinge can be obtained on the tissue paper per

day. Crumpling causes undulations in the tissue paper in which adult moths readily oviposit. Few eggs are found on the tender leaf. In this method 20-100% more eggs can be obtained as compared to exposing the whole plant for oviposition. After 2-3 days, eggs laid on the tissue paper turn black. The tissue paper is then cut into pieces and pinned on the tender leaves of potted plants for subsequent larval development. This way, all the eggs laid by DBM could be successfully utilized for rearing. This method of egg collection also opens up the possibility of using them for direct parasitization by the egg parasitoid, *Trichogrammatoidea bactrae*, instead of the present method of exposing them to eggs of meal moth, *Corcyra cephalonica*. It also enables easy shipment of DBM culture along with pupae of their parasitoids from one place to another. The eggs collected on tissue paper can also be stored under refrigeration (5-7°C) without mortality for about 10 days.

The IIHR IPM team has also developed a computer software called Cabbage Pest Expert Ver. 1.0, the features of which are described below:

Several researchers across the globe are working on pests of crucifers and their management. Quite often difficulty is experienced in getting access to comprehensive information on work done by other researchers. The printing of annotated bibliographies and organization of meetings ease the exchange of information and ideas. However, these are increasingly becoming costly and take a considerable amount of time. To fill up this gap and provide need-based information for researchers, the IIHR has come up with an expert system available in diskette form. This system entitled "Cabbage Pest Expert Ver 1.0" was developed by P.R. Ramachander, K. Srinivasan, P.N. Krishna Moorthy, and K. Gopalakrishna Pillai. It was partly financed by a grant from the United States Department of Agriculture under the U.S. India Fund. Information contained in this system is supported with literature citations and, hence, can be used by researchers, students, and extension workers involved in pest management. The Cabbage Pest Expert has the following major menus:

- International pest scenario
- Biology of major pests
- Parasitoids and predators
- Economic and action thresholds
- Insecticide resistance in diamondback moth
- Host plant resistance to diamondback moth
- Microbial control of pests
- Use of pheromones to control diamondback moth
- Major IPM components in different countries
- IPM with Indian mustard as a trap crop

This expert system is IBM-PC compatible and is available in high density diskette (5-1/4") and occupies approximately 800 KB. It has been developed in basic language in GWBASIC formation. Through SAVERNET the diskette is provided free to all participating members and others who request it.

Nepal. Areas frequently surveyed in Kathmandu valley included Bhaktapur, Thimi, Swayambhu, Kuleshwor, and Kabre. So far, no severe DBM infestation has been observed in these areas. Some occasional parasites, which could be *Apanteles* sp., were noted.

Stock culture of DBM has been maintained since 4 April 1993 on cabbage seedlings in cages of 50 x 50 x 50 cm under laboratory conditions. At present fourth generation DBM are being maintained. The growth period from egg to pupa ranged from 15 to 21 days, with 3-5 days for egg stage, 9-12 days for larval stage, and 3-5 days for pupal stage.

Pakistan. The parasite rearing facility will be established at the National Agricultural Research Centre (NARC).

A survey for the presence of DBM and its parasitoids will be conducted at Peshawar, Khanpur, Islamabad, Rawalpindi, Murree Hills, Multan, and Hyderabad. Dr. Ali Asghar Hashmi, Director of Entomology, Research Laboratory at NARC will take the lead in the implementation of this project.

Sri Lanka. The IPM of DBM project will be conducted at RARC, Bandarawela. Mrs. I. Wahundeniya and Mr. G. Ratnasinghe will spearhead the implementation of the program. Since Mr. Ratnasinghe has gone abroad for postgraduate training, Mr. M.G. Dhanapala has taken over his work.

A building plan for a parasite rearing facility was approved in March 1993. Construction is now being supervised by the RARC, Bandarawela.

The dynamics of cabbage caterpillars are also being studied under this IPM component.

Management of heat, moisture, and other physical stress factors

High temperature and excessive or insufficient moisture are some of the major problems besetting tomato and chili production in the lowlands of the tropics and subtropics. To overcome these constraints, management practices for heat, moisture, and other stress factors have to be developed and standardized. Contract research in specific countries will be conducted to evaluate different management methods to overcome the problem of heat, moisture and other stress factors, and to assess the economic viability of such methods for farmer adoption.

The technology available in each of the NARS will be reviewed and a consolidated procedure shall be developed for adoption.

Mulching with rice straw or other types of organic materials or plastics is becoming very popular to control weeds, conserve soil moisture, provide appropriate micro-environments for optimum growth and production, and protect the plants from damaging diseases. Different types of mulches will be evaluated for selected priority vegetables such as tomato, chili, and onion; and the results will be shared to be able to come up with appropriate recommendations for the farmers. Pilot farmer sites may be chosen for on-farm evaluation of selected mulches to determine the economic feasibility and social acceptability of the technology.

Simple plastic rain-shelters to alleviate stress induced by excessive summer rainfall shall also be evaluated experimentally, and, if proven successful, will be tested under farmer conditions.

Preliminary efforts in this area will be spearheaded by Bangladesh, India, Pakistan, and Sri Lanka.

Bangladesh. An experiment using polyethylene sheets to protect tomato crops from excessive rains and other stress factors was initiated.

India. IIHR in Bangalore will implement this project component. Dr. N.K. Srinivasan Rao will be the lead scientist. A detailed research plan has been drawn up:

First year

- Application of growth hormones in tomato and chili to improve fruit set at high temperatures.
- Physiological studies on fruit set in chili at high temperatures.
- Screening techniques for drought and heat tolerance.

Second year

- Screening of chili cultivars for drought and heat tolerance.
- Documentation of existing management practices in chili (survey work).

Third year

- Demonstration of the developed technology in the farmers' field based on the results of two years of research.

The following research results have so far been obtained:

Screening techniques for drought and heat tolerance. In tomato when the tissue is injured by exposure to high temperatures, the cellular membrane permeability is increased and electrolytes diffuse out of the cells. Cell membrane stability utilizing the conductivity method in four cultivars of tomato was recorded. Percent injury in leaf tissues by heat stress (45°C) was well correlated with cell membrane stability. The percent relative injury was less in IHR-1224 compared to cultivars Arka Saurabh, Pusa Ruby, and Sioux. This technique can be used to screen germplasm for high temperature tolerance.

Application of growth hormones in tomato and chili to improve fruit-set at high temperature conditions. An experiment was conducted to determine the effect of tomatotone on percent fruit-set, fruit growth rate, and its effect on some physiological processes like photosynthetic rate, stomatal conductance, and proline content in flower buds. Two cultivars of chili (Arka Lohit and Byadagi) and six cultivars of tomato (Arka Saurabh, Pusa Ruby, IHR-1224, and three AVRDC heat-tolerant lines) were used. Tomatotone was sprayed on individual flower clusters. Temperature during flowering and fruit setting was maintained at 35°C during the day and 25°C at night. Experiments were carried out under controlled conditions.

Responses of tomato to moisture stress-plant water balance and yield. The response of 20 selected cultivars to moisture stress imposed at vegetative and fruiting stages and complete stress after establishment was studied during the summer of 1992. Osmotic potential, leaf water potential, and relative water content were measured. In plants stressed at the vegetative stage, water potential values were less negative and showed good recovery after relief from stress. As plant water potential became more negative, osmotic potential values also became more negative in some of the cultivars like Arka Saurabh, P.E.D., KT-2 Sioux, and Redrock indicating higher turgor potential compared to other cultivars. These cultivars had maximum fruit size and gave higher fruit yield under water stress. Water stress during fruit development accelerated the process of fruit drop before ripening. In the completely stressed plants, about 20-50% fruit drop was observed in the different cultivars. Water stress accompanied by higher temperatures, above 28°C, during fruiting induced about 30-45% flower drop. The percent yield decrease in the different cultivars varied from 1.3 to 52 % in the plants stressed at the vegetative stage, 0-70% in the plants stressed at the fruiting stage, and 27-82% in the completely stressed plants.

Effects of heat stress on photosynthesis and dry matter distribution in tomato. Photosynthesis rate, growth rate, and dry matter production were studied in two cultivars of tomato, IIHR-1224 and Arka Saurabh, under high temperature stress conditions (35/20 and 35/27°C day/night). There was a reduction in photosynthesis in both cultivars at 27°C night temperature. IHR-1224 had maximum biomass of 35.7g/plant at 27°C night temperature. Prehardening of plants of IHR-1224 for 2 h at 45°C resulted in higher relative growth rate (RGR), net assimilating rate (NAR), and crop growth rate (CGR). Maximum flower drop was observed in Arka Saurabh at both temperatures. There was no fruit-set in Arka Saurabh at high night temperature. IHR-1224 recorded a 1% fruit set at 27°C indicating high temperature tolerance.

Pakistan. Dr. Abdul Jabbar is in charge of this component on plant stress management with Mrs. Naheed Akhtar and Mr. M. Faroog as researchers. As of December 1992, the following work plan has been proposed:

Tomato

- Collection of germplasm;
- Trials on evaluation for heat stress;
- Trials for moisture stress;
- Survey of local farmers' practices to overcome heat and moisture stress;
- Trials on the use of plastic mulches for moisture conservation and weed control;
- Establishment of shade house.

Chili

- Collection of germplasm;
- Documentation of existing management practices by farmers;
- Survey of the local farmers' practices to overcome heat and moisture stress;
- Trials for heat stress.

Sri Lanka. Research on plant stress management will be conducted at RARC, Maha Illuppallama. Research work will commence in the wet season of 1993-94 with Mr. S.N. Jayawardana, agronomist, as the implementor.

Constraints

Three major constraints hampered the smooth progress of the network activities. First, exchange of germplasm from different countries was delayed. The seeds were repacked and distributed immediately, but arrival of the seeds did not meet the planting season in most countries. Also, seeds of some of the varieties for exchange were not available at the time of exchange.

Second, staff members assigned to spearhead the projects had to be replaced for one reason or another. As a result, new persons had to be identified and familiarized with the projects.

The third and most critical constraint was funding. Although the checks from AVRDC had been sent to the SAVERNET NARS as early as August-October 1992, it took 5 to 8 months for the funds to be released to the scientists.

The network coordinator made visits to the NARS and had discussions with the financial officials and the steering committee members to ensure that the problems are resolved.

Monitoring Visits

The network coordinator visited all SAVERNET countries member in 1992 and 1993 and met with SAVERNET researchers in each country, visited key research sites, and examined research facilities. Discussions were held with high level administrators and financial section staff to facilitate fiscal matters.

Philippines-AVRDC Outreach Program

Mungbean Preliminary Yield Trial

Summary

The study was conducted to identify mungbean lines with high bean yield potentials, desirable agronomic characters, and disease resistance, particularly to Cercospora leaf spot (CLS) and powdery mildew (PM).

A total of 68 entries were evaluated in three sets of trials during crop year 1992-93. The grand mean yields of all the trials were generally low due to the unfavorable climatic and soil conditions. Moisture stress and lack of good irrigation facilities during the dry season and continuous rain and strong winds which occurred at flowering and maturity stages of the crop caused pod abortion and bean sprouting during the wet season. However, three lines, namely, VC 4297-1-B-7, VC 4216-2, and VC 3732-B-3-B-2-B, produced mean yields greater than the check. Most of the test lines were moderately resistant to CLS and virus disease compared to the susceptible check variety BPI-Mg9.

Twelve most promising lines that have completed four season trials were selected and elevated to the general yield trials (GYT).

Introduction

Selected lines with desirable agronomic characters (high bean yield potentials, early and uniform maturity, resistance to common pests and diseases, and tolerance to lodging), acceptable eating and processing qualities, and having homozygosity were evaluated in the preliminary yield trials (PYT) to identify those adapted to local agro-climatic conditions. After two to four seasons of PYT, the most promising lines were elevated to the GYT.

Materials and Methods

For 1992-93, three sets of trials were evaluated. Sets 1 (24 entries) and 2 (20 entries) were planted during the dry season and Sets 2 and 3 (20 entries) during the wet season. Set 1 was in its last season of PYT, while Sets 2 and 3 were in their first and third seasons of trial. In all the trials, the entries were sown on 4-row, 5-m-long subplots distributed in RCBD, and replicated three times. The rows were spaced at 0.5 m.

Cultural management and data collection were based on the standard procedure suggested by AVRDC in its International Cooperators' Guide for Mungbean Evaluation Trial.

Results and Discussion

Set 1. During the dry season, the bean yield ranged from 0.3 t/ha for the check Pag-asa 7 to 1.0 t/ha for VC 4140-B-5 with a grand mean of 0.5 t/ha for the 24 entries. Although significant

differences were observed among entries, only the high yielding line VC 4140-B-5 significantly outyielded the check BPI-Mg9 with 0.6 t/ha. Lines VC 4195-B-5 and VC 4195-B-4, both with 5.6 g/100 seeds, produced the largest seeds.

Slight infections of CLS and virus were recorded during the later growth stages of the crop.

After collating the performance of the entries in four-season trials, 12 promising lines were selected and elevated to the GYT. Selection was based on the yield, 100-seed weight, disease reaction, and other important agronomic characteristics.

Set 2. The average yield of the 20 entries was 0.5 t/ha during the dry, and 0.8 t/ha during the wet season. None of the test lines outyielded the check BPI-Mg9 during the dry season, but 10 lines outyielded the same check during the wet season. However, the differences were not statistically significant. Two lines (VC 4297-1-B-7 and VC 4216-2) produced yields of more than 1 t/ha during the wet season. Most of the test lines were moderately resistant to CLS and virus diseases compared to the susceptible check BPI-Mg9.

Set 3. Only line VC 3732-B-3-B-2-B with a bean yield of 1.0 t/ha slightly outyielded the check Pag-asa 7 with 0.9 t/ha. However, differences among the 24 entries were not significant. The grand mean yield was 0.8 t/ha. All the entries flowered in 35 days and matured in 57 days from planting. So far, two lines showed a high level of resistance to CLS and eleven to mungbean virus.

Mungbean General Yield Trial

Summary

Thirty-four advanced mungbean breeding lines selected from the previous PYT were evaluated in the GYT in three sets of trials together with two check cultivars.

Bean yields from the dry season trials were very low, ranging from 0.4 to 0.6 t/ha due to soil moisture stress and severe infestation of leaf miner. During the wet season, grand mean yields of .7 t/ha from Set 2 and 1.0 t/ha from Set 3 were obtained. Lines VC 4477 A, VC 4499 A, VC 3963-B-3, and VC 4531 A yielded significantly higher than the check BPI-Mg9 in Set 2. VC 4195-B-5 with 1.2 t/ha outyielded the check in Set 3, but the difference was not significant.

Most of the breeding lines were rated intermediate to CLS, while two lines (VC 4190-B-1 and VC 3510-B-1) were highly resistant to mungbean virus.

Most promising lines that have completed the 2-year GYT were elevated to the regional yield trials (RYT).

Introduction

The study was designed to further screen selected lines from the PYT for yield, adaptability to local agro-climatic conditions, and reactions to common pests and diseases. Results obtained from this trial serve as the basis for selecting entries for inclusion in the RYT or the National Cooperative Test (NCT).

Materials and Methods

Forty entries were evaluated in three sets of GYT during the crop seasons of 1992-93. Set 1 with 12 entries was planted (last trial) on 11 January 1993 (DS); Set 2 with 14 entries on 11 January 1993 (DS) and 15 July 1993 (WS); and Set 3 with 14 entries (newly selected from the

previous PYT trials) on 15 July 1993. A randomized complete block design (4-row plot, 5-m-long) with three replications was used in all sets of trials. The AVRDC suggested cultural management and data collection guides were used.

Results and Discussion

Set 1. The top yielders were VC 3876-2B-1-2 (.7 t/ha) followed by VC 3890-B-3-1, and VC 3995-B-1. VC 3560-B-4-4 produced the largest seed (6.8 g/100 seed) (table 1). Slight infection of virus was observed.

After the four-season trials of the 12 entries, the three most promising lines were selected and recommended for inclusion in the RYT. The lines were VC 3876-2B-1-2 as EGM 3876, VC 3995-B-1 as EGM 3995, and VC 2764 (Yellow Sel as EGM 2764 [Y]).

Set 2. The data from the dry season trial were not validated due to the low mean yield of .4 t/ha caused by unfavorable climatic and soil conditions and high levels of leaf miner infestation.

The wet season trial performed relatively better than the dry season, although the average yield of .7 t/ha was rather low (table 2) due to frequent heavy rains that occurred from flowering to maturity stages of the crop and severe infection of CLS and mungbean virus. Six lines outyielded the check cultivar BPI-Mg 9, but the yield difference was statistically significant for four lines, namely, VC 4477 A, VC 4499 A, VC 3963-B-3, and VC 4531 A, with mean yields of 1.0, .9, .9, and .9 t/ha, respectively.

Set 3. The grand mean of the 14 new entries was 1.0 t/ha (table 3). Two test entries outyielded the check BPI-Mg9, but the differences were not statistically significant. The highest yielder was line VC 4195-B-5 with 1.2 t/ha. All the entries had intermediate levels of resistance to CLS. Two lines, VC 4190-B-1 and VC 3510-B-1, were identified as resistant to mungbean virus.

Table 1. Summary data of promising entries under the GYT (Set 1) during the dry season, 1993[a]

Entry	Yield (t/ha)	100-seed weight (g)	Days to maturity	Plant height (cm)	No. of pods/ plant	No. of seeds/ pod	Virus[b] rating
VC 3876-2B-1-2	0.7 a	5.8 d	58 a	43 a	9 a	11	1.5
VC 3890-B3-1	0.7 b	5.2 h	57 b	37 a-c	9 a	11	1.5
VC 3995-B-1	0.7 b	5.7 e	57 b	38 ab	8 ab	10	2.0
VC 3995-B-7	0.6 bc	5.5 g	56 c	35 b-d	8 ab	11	1.0
VC 3530-B-1-1	0.6 cd	5.7 e	56 c	29 d	8 ab	11	1.0
VC 3998-B-3	0.6 c-e	5.8 b	57 b	37 a-c	8 ab	11	1.8
VC 2764 (Yel Sel)	0.6 d-f	4.9 i	56 c	38 ab	8 ab	11	1.3
BPI-Mg9 (ck)	0.6 d-f	6.0 c	56 c	39 ab	8 ab	11	1.0
Grand mean	0.6	5.7	56.7	35.4	7.6	10.7	1.4
c.v. (%)	7.4	1.1	1.0	11.1	12.5	4.2	32.4

[a]Planted 11 January 1993 and harvested 8-22 March 1993. Data means of 5.0 m^2 subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1-5, where 1 = highly resistant and 5 = highly susceptible.

Table 2. Field performance of promising entries evaluated under the GYT (Set 2) during the wet season, 1993[a]

Entry	Yield (t/ha)	100-seed weight (g)	Days to flower	Days to maturity	Plant height (cm)	No. of pod/ plant	No. of seeds/ pod	Disease rating[b] CLS	Virus	Lodging
VC 4477 A	1.0 a	5.9 ab	39 b	61 cd	78 c-e	13 ab	10 b	4.8 ab	3.8	2.5
VC 4531 A	0.9 ab	4.8 h	39 b	61 cd	83 a-c	14 a	11 ab	5.0 a	3.5	1.8
BPI-Mg 9 (ck)	0.7 cd	5.8 bc	39 b	60 d	79 b-e	13 ab	11 ab	5.0 a	4.3	2.0
VC 3963-B-3	0.9 ab	5.8 bc	40 a	62 bc	88 a	10 c	12 a	4.0 c	3.0	3.3
VC 4499 A	0.9 a	4 2 j	39 b	61 cd	74 e	14 a	11 ab	4.8 ab	3.8	2.5
Grand mean	0.7	5.4	39.4	61.7	80.4	11.8	11	4.7	3.7	2.4
c.v. (%)	12.1	1.5	1.5	1.3	4.8	14.2	6.0	7.8	12.4	30.8

[a]Planted 15 July 1993 and harvested 13-27 September 1993. Data means of 5.0 m² subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1-5, where 1 = highly resistant and 5 = highly susceptible.

Table 3. Field performance of the new mungbean entries evaluated under the GYT (Set 3) during the wet season, 1993[a]

Entry	Yield (t/ha)	Days to flower	Days to maturity	Plant height (cm)	No. of pods/ plant	No. of seeds/ pod	Disease rating[b] CLS	Virus	Lodging
VC 4195-B-5	1.2 a	33 cd	55 ef	71 de	10 cd	12	3.0 bc	2.0 a-c	1.0 d
VC 4140-B-1	1.1 ab	34 bc	56 c-e	68 de	13 ab	11	3.8 a	1.5 cd	1.5 cd
BPI-Mg9 (ck)	1.1 a-c	33 cd	53 fg	73 d	11 b-d	12	3.8 a	2.0 a-c	2.0 bc
VC 4190-B-1	1.1 a-c	33 cd	53 fg	71 de	10 cd	12	3.0 bc	1.0 d	2.0 bc
VC 4150-B-2	1.1 a-c	33 cd	59 ab	75 cd	11 b-d	12	3.0 bc	2.5 ad	1.5 cd
VC 4195-B-1	1.1 a-c	34 bc	58 a-c	74 cd	10 cd	11	2.8 c	2.0 a-c	1.3 d
VC 4140-B-3	1.1 a-c	34 bc	57 b-d	72 de	11 b-d	11	3.5 ab	1.8 b-d	1.0 d
VC 4146-B-3	1.0 bc	35 ab	59 ab	80 bc	14 a	12	3.5 ab	2.8 a	2.5 ab
Pag-asa 7 (ck)	1.0 bc	35 ab	58 a-c	84 ab	[illegible] ab	12	3.3 a-c	2.5 ab	1.5 cd
Grand mean	1.0	33.5	56.5	74.8	[illegible]	11.5	3.2	2.1	1.6
c.v. (%)	11.5	3.2	2.3	5.8	14.2	4.7	14.0	24.4	22.4

[a]Planted 11 June 1993 and harvested 9-23 August 1993. Data means of 5.0 m² subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1-5, where 1 = highly resistant and 5 = highly susceptible.

International Mungbean Nursery

Summary

Twenty-two elite mungbean varieties/accessions were evaluated during the 1993 wet season for their performance under Philippine conditions.

Mean bean yield ranged from 0.5 t/ha (ML 267) to 1.5 t/ha (Chun Nam 4) with a grand mean of 0.9 t/ha. A significant difference was observed only between highest yielding entry Chun Nam 4 and the check BPI-Mg7. Chun Nam 4 was also rated moderately resistant to mungbean virus.

Introduction

The International Mungbean Nursery (IMN) is an international cooperative trial on mungbean currently coordinated by AVRDC. The entries are elite cultivars/accessions from different countries of origin assembled by AVRDC and sent to different cooperators representing a wide range in latitudes. The objectives of the trial are to provide information on the range of adaptation of the subspecies and specific cultivars, and the characteristics of the mungbean plant influencing adaptation. It also serves as a means of disseminating superior cultivars to research workers.

Materials and Methods

Twenty elite mungbean cultivars/accessions were planted on 15 July 1993 (WS) together with two local checks. Each entry was sown in 4-row subplots distributed in RCBD, replicated three times. Rows were 5 m long, spaced 0.5 m apart.

Cultural requirements and data collection were based on the standard procedures suggested in the AVRDC International Cooperators' Guide for Mungbean Evaluation Trial.

Results and Discussion

The yield performance of the 22 entries is presented in table 4.

The grand mean yield ranged from 0.5 t/ha (ML 267) to 1.5 t/ha (Chun Nam 4) with a grand mean of 0.9 t/ha for the 22 entries. Only Chun Nam 4 significantly outyielded the check BPI-Mg7 (1.1 t/ha). The same line also had the highest number of pods/plant and the lowest rating on virus infection.

Table 4. Field performance of the mungbean entries under the 19th IMN during the wet season, 1993[a]

Entry	Yield (t/ha)	100-seed weight (g)	Days to flower	Days to maturity	Plant weight (cm)	No. of pods/ plant	No. of seeds/ pod	Disease rating[b] CLS	Disease rating[b] Virus	Lodging
Chun Nam 4	1.5 a	4.3 i	37 c	58 de	83 a-d	20 a	11 d	4.3	2.0 d	3.0 a
VC 1973 C	1.3 ab	5.9 cd	38 bc	60 bc	86 ab	16 b	11 b	4.7	2.7 b-d	2.3 a-c
VC 1973 A	1.1 bc	5.7 e	38 bc	58 de	84 a-c	14 bc	11 b	5.0	2.7 b-d	2.3 a-c
BPI-Mg7 (ck)	1.1 b-d	5.8 de	38 bc	58 de	82 a-e	13 b-d	11 b	4.7	2.3 cd	2.7 ab
VC 4386 A	1.0 c-f	6.2 b	39 ab	60 bc	79 b-g	13 b-d	11 b	4.3	3.3 a-c	2.7 ab
VC 3541 A	0.6 jk	6.9 a	40 a	62 a	69 i	9 d	11 b	4.0	3.3 a-c	1.3 cd
Grand mean	0.9	5.2	38.3	59.7	75.0	12.9	11.0	4.6	3.1	2.1
c.v. (%)	13.8	1.8	2.4	1.2	5.4	17.1	4.4	10.7	18.0	30.9

[a]Planted 15 July 1993 and harvested 13-27 September 1993. Data means of 5.0 m^2 subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1 - 5, where 1 = highly resistant and 5 = highly susceptible.

Mungbean Regional Yield Trial

Summary

For 1992-93, nine entries were evaluated in the RYT during the dry season and 10 during the wet season. The study was designed to evaluate the performance of the promising lines/varieties in the different regions of the Philippines in terms of bean yield potential and reaction to major pests and diseases.

During the dry season only line EGM 3890 (0.8 t/ha) significantly outyielded the national check BPI-Mg9 (0.5 t/ha). Among the 10 new entries evaluated during the wet season, two lines (EGM 2764 [Y] and IPB 83-80-26) yielded higher than the check MG50-10A, although their means were not statistically different. There were also significant differences among entries on the different yield parameters measured in both wet and dry seasons.

Introduction

The RYT for mungbean under upland monoculture conditions was conducted in cooperation with the Institute of Plant Breeding (IPB) and other institutions involved in the varietal improvement of field legumes. The test was conducted in eight to nine locations to evaluate the performance of the promising strains compared to the national check under different conditions in various regions of the country. The results from the RYT were used as basis for recommending to the Philippine Seedboard varietal release for regional or national production.

Materials and Methods

The promising lines selected in the PYT or GYT were submitted to the National Legume Technical Committee of the Philippine Seed Board for inclusion in the RYT. Accepted entries were evaluated for four to six seasons in different cooperating stations. The performance of the varieties were reviewed by the Technical Committee each year. The entries that consistently surpassed the yield or other characteristics of the standard checks were submitted to the Philippine Seedboard for approval, while those inferior to the checks were dropped from the trial after four seasons.

For 1992-93, the nine entries evaluated included lines developed by the Bureau of Plant Industry-Los Baños National Crop Research and Development Center (BPI-LBNCRDC) and IPB and two check varieties, BPI-Mg9 (national check) and MG50-10A (regional check). Each entry was planted in 10-m^2, four-row subplots distributed in RCBD and replicated four times. The cultural management and data collection were based on the Guidelines of the Upland Crop National Cooperative Trial (UCNCT) of the Philippine Seed Board.

This report presents only the results obtained from BPI-LBNCRDC.

Results and Discussion

The results from the dry season trial are presented in table 5. Among the six test entries evaluated, only three lines with yields ranging from 0.7 t/ha (IPB M79-13-45) to 0.8 t/ha (EGM 3890) outyielded the regional check MG50-10A with 0.6 t/ha. However, only the yield of the high-yielding line EGM 3890 was statistically significant over the check. It also produced the biggest seeds (5.6 g/100 seed). Almost all the entries were rated moderately resistant to CLS and virus diseases.

As agreed upon by the members of the Legume Technical Working Group, all the dry season entries were frozen from the NCT. A combined analysis across locations will be done by the secretariat and reviewed during the next Seed Board meeting.

A new set of entries was evaluated during the wet season. The entries were composed of four BPI and four IPB lines and three check cultivars. The average bean yield of the 10 entries was 0.9 t/ha (table 6). The yield ranged from 0.7 t/ha for IPB 83-33-20 to 1.2 t/ha for EGM 2764 (Y). Entries EGM 2764 (Y) (1.2 t/ha) and IPB 83-80-26 (1.1 t/ha) outyielded the regional check MG50-10A (1.0 t/ha), but their differences were not statistically significant. Line EGM 3902

produced the biggest seed with 6.7 g/100 seeds. Mean plant height was 83.4 cm. Number of days to maturity ranged from 51 to 59 days after planting.

All the entries were infected with Cercospora leaf spot. EGM 3902 had the lowest disease score of 2.5 (moderately resistant), while the regional check MG50-10A had the highest score of 5.0 (highly susceptible).

Table 5. Field performance of nine mungbean entries in the RYT conducted at BPI-LBNCRDC during the dry season, 1992[a]

Entry	Yield (t/ha)	100-seed weight (g)	Days to flower	Days to maturity	Plant weight (cm)	No. of pods/ plant	No. of seeds/ pod	Disease rating[b] CLS	Disease rating[b] Virus
EGM 3890	0.8 a	5.6 a	39 b	61 ab	45 ab	11 a	12 a	1.8 b	1.5
EGM 3541	0.7 ab	5.5 ab	39 b	61 ab	45 ab	11 a	12 a	1.8 b	1.8
IPBM 79-13-45	0.7 a-c	5.4 b	39 b	61 ab	42 bc	8 bc	12 a	2.0 b	1.5
MG50-10A (R ck)	0.6 b-d	5.5 ab	38 c	59 c	48 a	11 a	12 a	3.0 a	1.3
EGM 3901	0.6 c-e	5.5 ab	40 a	60 bc	41 b-d	8 bc	12 a	2.3 b	1.5
BPI-Mg9 (N ck)	0.5 c-e	5.5 ab	39 b	61 ab	45 ab	9 b	12 a	2.3 b	1.5
Pag-asa 7 (N ck)	0.5 de	5.5 ab	39 b	60 bc	36 de	7 cd	11 b	2.0 b	1.8
IPBM 79-22-108	0.5 e	5.0 c	39 b	61 ab	38 c-e	8 bc	11 b	2.0 b	1.5
EGM 3827	0.4 e	5.5 ab	40 a	62 a	33 e	6 d	11 b	2.0 b	1.3
Grand mean	0.6	5.4	39.2	60.6	41.3	8.7	11.6	2.1	1.5
c.v. (%)	15.3	1.6	1.2	1.3	8.7	11.6	3.9	16.2	25.3

[a]Planted 16 October 1992 and harvested 14-28 December 1992. Data mean of 5.0 m^2 subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1-5, where 1 = highly resistant and 5 = highly susceptible.

Table 6. Field performance of 10 mungbean entries in the RYT during the wet season, 1993[a]

Entry	Yield (t/ha)	100-seed weight (g)	Days to flower	Days to maturity	Plant height (cm)	No. of pods/ plant	No. of seeds/ pod	Disease rating[b] CLS	Disease rating[b] Virus	Lodging
EGM 2764 (Y)	1.2 a	4.7 h	32 d	54 c	82 c-e	10 bc	12 a	3.8 bc	1.8	2.0 d
IPB 83-80-26	1.1 ab	5.0 g	32 d	52 d	70 g	11 ab	12 a	3.3 c	2.0	1.8 d
MG 50-10A (ck)	1.0 ab	6.1 d	32 d	51 d	79 d-f	11 ab	11 b	5.0 a	2.0	2.3 cd
EGM 3902	0.9 bc	6.7 a	34 b	56 b	71 fg	10 bc	11 b	2.5 d	1.8	1.0 e
EGM 3995	0.9 bc	5.2 f	35 b	59 a	90 bc	9 c	12 a	4.0 b	2.0	2.8 bc
BPI-Mg9 (ck)	0.9 bc	5.9 c	33 c	52 d	75 e-g	11 ab	12 a	3.8 bc	2.3	1.8 d
EGM 3876	0.9 bc	5.6 d	35 b	58 a	93 b	11 ab	12 a	3.8 bc	2.3	3.8 a
IPB 85-4-11	0.8 bc	5.2 f	35 b	59 a	89 bc	12 a	11 b	3.5 bc	2.8	2.8 bc
IPB 83-46-31	0.7 c	5.3 ef	35 b	58 a	85 b-d	11 ab	12 a	3.3 c	2.5	3.0 b
IPB 83-33-20	0.7 c	5.4 e	36 a	59 a	101 a	12 a	12 a	3.8 bc	2.3	3.0 b
Grand mean	0.9	5.5	33.9	55.7	83.3	10.8	11.7	3.6	2.2	2.4
c.v. (%)	16.9	1.7	1.9	1.5	6.1	9.3	3.9	12.2	23.8	18.8

[a]Planted 9 June 1993 and harvested 6-20 August 1993. Data mean of 5.0 m^2 subplots distributed in RCBD and replicated four times. Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

[b]Rated on a scale of 1-5, where 1 = highly resistant and 5 = highly susceptible.

Soybean Preliminary Yield Trial

Summary

Twenty-six promising soybean lines/accessions from AVRDC and other sources were evaluated in the PYT during the dry and wet seasons to identify those with high bean yield potentials, low sensitivity to photoperiodism, resistance to common pests and diseases, and other desirable characters.

Although there were significant differences in bean yield among the entries in the dry season trial, none significantly outyielded the check UPL-Sy4 with 1.9 t/ha.

For the wet season, lines GC 50227-3-3, TGX 239-250-18, GC 50227-3-5, and GC 50227-3-1 gave bean yields comparable to UPL-Sy4 (ck) which produced 3.0 t/ha. No significant mean difference in bean yield among entries was observed.

Introduction

Promising AVRDC lines/accessions were evaluated in the PYT during the dry and wet seasons to identify lines/accessions with high bean yield potentials, low sensitivity to photoperiodism, resistance to common pests and diseases, and other desirable characters.

Materials and Methods

Twenty-six test entries were evaluated against the standard checks, BPI-Sy4 and UPL-Sy4, during the dry and wet seasons. Plantings were made on 11 December 1992 for the dry season and 15 June 1993 for the wet season. In both trials, the entries were drilled in two-row, 5-m^2 subplots, distributed in RCBD, and replicated three times. Complete fertilizer at 30-30-30 kg/ha was applied at planting. AVRDC evaluation procedure for soybean was followed in conducting the trials.

Results and Discussion

During the dry season, none of the test entries outyieded the highest yielding check UPL-Sy4 with 1.9 t/ha. The average bean yield of the 26 entries ranged from 1.1 to 1.9 t/ha with a grand mean of 1.4 t/ha. Significant mean differences among entries in 100-seed weight and days to maturity were noted. All entries were rated resistant to leaffolder and mites.

In the wet season trial, lines GC 50227-3-3, GC 50227-3-5, TGX 239-250-18, and GC 50227-3-1 gave comparable bean yields to UPL-Sy4 (ck) with 3.0 t/ha. No significant mean yield difference among entries was observed. All entries were rated resistant to moderately resistant to bacterial pustules and purple seed stain.

Soybean General Yield Trial

Summary

The general yield trial was conducted to further verify the yield potentials and resistance to common pests and diseases, and to identify the desirable agronomic characters of the lines selected from the PYT.

Of the 15 test entries evaluated during the dry season, only G 0062 outyielded the check variety UPL-Sy4 with 1.6 t/ha, but the difference was not statistically significant. All entries were early maturing, ranging from 75 to 80 days from planting.

During the wet season, three test entries outyielded the highest yielding check variety — BPI-Sy4 with 2.5 t/ha, but the difference was not statistically significant.

Introduction

Promising lines selected from the PYT were further tested in GYT for their bean yield potentials and reactions to major pests and diseases, and to determine 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

Fifteen and 11 test entries were evaluated against the standard checks, BPI-Sy4 and UPL-Sy4, during the dry and wet seasons, respectively. The dry season trial was planted on 11 December 1992 and the wet season trial on 15 June 1993. In each trial, the entries were sown in 4-row, 10-m² subplots, distributed in RCBD, and replicated three times. Complete fertilizer at 30-30-30 kg/ha 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 trials.

Results and Discussion

Bean yield ranged from 1.1 to 1.6 t/ha with a grand mean of 1.4 t/ha (table 7). All entries were rated resistant to leaffolder and mites.

During the wet season trial, five test entries outyielded the highest yielding check variety BPI-Sy4 with 2.5 t/ha, but the difference was not statistically significant. The entries matured from 91 to 97 days after sowing. All the entries were rated resistant to moderately susceptible to bacterial pustule and purple stain.

Table 7. Mean bean yield and other agronomic characters of selected soybean lines under the GYT during the dry and wet seasons, 1992-93[a]

Entry	Bean yield (t/ha)		100-seed weight (g)		Days to maturity		Disease and pest rating[b]			
							Mites-leaffolder		BP	P. stain
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS
G 0062	1.6 a	-	13.5 cd	-	79 b	-	1.7	1.6	-	-
SJ 4	1.6 ab	2.3	13.2 de	15.5 d	78 bc	97 b	1.9	1.6	3.0	1.7
UPL-Sy 4 (ck)	1.6 ab	2.3	12.7 d-f	16.8 c	80 a	95 d	1.5	1.4	1.0	1.5
BPI-Sy 4 (ck)	1.3 c-e	2.5	12.3 e-g	17.2 c	78 bc	92 g	1.8	1.7	3.5	1.8
Grand mean	1.4	2.5 (ns)	12.7	16.7	78	95	1.8	1.6	2.9	1.9
c.v. (%)	7.3	14.3	4.2	3.4	0.9	0.3	7.7	10.2	17.3	10.4

[a]DS planted 11 December 1992 and WS 15 June 1993. Data mean of 5 m² subplots distributed in RCBD with three replications. Means followed by the same letter are not significantly different at 5% level (DMRT).

[b]Rated on a scale of 1-5, with 1 = highly resistant, and 5 = highly suceptible.

Soybean Regional Yield Trial

Summary

Eight and 11 entries including the national and regional checks were elevated to RYT during the dry and wet seasons, respectively. The study was designed to verify the performance of promising strains/varieties in the different regions of the Philippines for yield potentials, reactions to major pests and diseases, and desirable eating and processing qualities.

Results from BPI-LBNCRDC during the dry season showed that only IPB-Sy 201-013 had significantly higher yield over the highest yielding regional check BPI-Sy4 (1.6 t/ha).

During the wet season, LGSy 12-12 outyielded the highest yielding national check PSB-Sy1 with 3.2 t/ha, but the difference was not statistically significant. Four test entries, namely, IPB Sy 201-013, EGSy 93-147, EGSy 93-18-7, and LGSy 5-8 produced bean yields comparable to the highest yielding national check PSB-Sy1.

Introduction

The regional yield trial for soybean was conducted in cooperation with the University of the Philippines Los Baños' (UPLB), Institute of Plant Breeding (IPB) and other institutions involved in the soybean varietal improvement program. Coordinated by the Field Legumes Technical Working Group of the Philippine Seed Board, promising entries from various national breeding programs were 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. To regionalize varietal recommendation, promising soybean entries in the RYT in a given region were further evaluated for two seasons in the technology adaptation (TA) trial before being released in the region.

Materials and Methods

Eight and 11 soybean entries including the national and regional checks were evaluated in six cooperating stations during the dry and wet seasons of 1992-93. In both trials, each entry was planted in 4-row, 12 m^2 subplots distributed in RCBD, and replicated four times. The standard procedures for evaluating soybean prescribed in the UCNCT of the Philippine Seed Board was followed by all cooperating stations in conducting the test.

Results and Discussion

Out of the eight entries evaluated during the dry season, IPB-Sy 201-013 gave significantly higher bean yield of 1.6 t/ha over the highest yielding check, BPI-Sy4 (table 8). Significant differences on 100-seed weight and days to maturity among entries were noted. All the entries were rated resistant to leaffolder and mites.

During the wet season, LGSy 12-12 outyielded the highest yielding national check PSB-Sy1 with 3.2 t/ha, but the difference was not statistically significant. Entries were rated resistant to moderately resistant to bacterial pustule and purple seed stain.

Table 8. Mean bean yield and other agronomical characters of selected soybean lines under the RYT during the dry and wet seasons, 1992-93[a]

Entry	Bean yield (t/ha)		100-seed weight (g)		Days to maturity		Disease and pest rating[b]			
							Mites-leaffolder		BP	P. stain
	DS	WS	DS	WS	DS	WS	DS	DS	WS	WS
IPB Sy 201-013	2.0 a	3.1 ab	12.8 a	17.5 d	83 a	98 e	1.5	1.2	1.7	2.6
BPI-Sy4 (ck)	1.6 b	2.6 bc	12.3 ab	16.4 e	77 c	91 g	1.7	1.5	3.5	1.5
PSB-Sy1(ck)	1.5 bc	3.2 ab	12.0 bc	18.1 cd	77 c	106 b	1.5	1.5	1.0	3.0
EG Sy 93-147	-	3.0 ab	-	19.1 b	-	93 f	-		2.2	3.0
Eg Sy 93-18-7	-	3.1 ab	-	20.3 a	92 fg	-	-	3.0	2.0	
LG Sy 5-8	-	3.0 ab	-	18.3 b-d	93 f	-	-	1.2	3.0	
LG Sy 12-12	-	3.6 a	-	18.6 bc	-	93 f	-	-	1.0	3.0
Grand mean	1.5	2.8	10.9	16.9	78	99	1.6	1.4	1.9	2.2
c.v. (%)	12.0	14.4	3.4	2.7	1.0	0.8	9.7	8.1	22.4	7.9

[a]DS planted 11 December 1992 and WS 15 June 1993. Data mean of 5 m² subplots distributed in RCBD with three replications. Means followed by the same letter are not significantly different at 5% level (DMRT).

[b]Rated on a scale of 1 - 5, with 1 = highly resistant and 5 = highly susceptible.

Preliminary Yield Trial of Vegetable Soybean

Summary

Nine AVRDC vegetable soybean accessions were evaluated under the PYT on 11 December 1992 (dry season) and on 15 June 1993 (wet season) to determine their yield potentials, eating qualities, and reactions to pests and diseases under local climatic conditions.

The grand mean of the fresh pod yield of the nine entries during the dry season trial was 5.4 t/ha. The highest yielding entry was AGS-186 (6.8 t/ha). Almost all yield components measured showed significant mean differences among entries.

During the wet season trial, the highest yielder was G-10503 with fresh bean yield of 11.5 t/ha; the grand mean for the nine entries was 10.3 t/ha.

Introductior

There is an increasing demand for vegetable soybean for domestic consumption and for export. Because of its high nutritional value and ease of production (can be grown even in backyard gardens), vegetable soybean has been included as one of the priority crops in the nutrition program of the local municipal government. To support this program, promising lines of vegetable soybean from AVRDC are being evaluated at the station for yield potentials, eating qualities, and reactions to pests and diseases under local climatic conditions.

Materials and Methods

Nine entries were evaluated during the wet and dry seasons. Each entry was sown in 4-row, 5-m-long subplots distributed in RCBD, and replicated three times. The rows were spaced 50 and 60 cm apart for dry and wet seasons, respectively. AVRDC standard cultural practices for soybean were followed in raising the crop.

Results and Discussion

The grand mean yield of fresh pod evaluated during the dry season was 5.4 t/ha. The highest yielding entry was AGS-186 with fresh pod yield of 6.8 t/ha (table 9). Line AGS-191 gave the highest seed weight of 64.0 g. Seed size ranged from 46.2 to 64.0 g/100 seeds with a grand mean of 51.6 g/100 seeds. All entries were rated resistant to moderately resistant to soybean rust infection and mite infestation.

For the wet season trial, line G-10503 gave the highest fresh bean yield of 11.5 t/ha. Fresh bean yield ranged from 8.6 to 11.5 t/ha with a grand mean of 10.3 t/ha (table 9). Lines G-10478, G-42, and G-10142 had comparable fresh bean yields. All entries were rated resistant to moderately susceptible to purple seed stain.

AGS-186, AGS-190, and AGS-191 had the best eating quality as boiled green pods.

Table 9. Preliminary yield trial of the AVRDC vegetable soybean accessions during the dry and wet seasons, 1992-93[a]

Entry	Fresh pod yield (t/ha)		100-seed weight (g)		Days to maturity		Disease and pest rating[b]		
							Rust	Mites	Purple stain
	DS	WS	DS	WS	DS	WS	DS	DS	WS
AGS-186	6.8 a	8.6 c	47.0 c	44.7 d	70 a	77	2.3	1.8	3.5
G-10478	6.5 a	11.3 ab	48.3 bc	55.0 c	62 c	63	3.0	1.5	2.0
G-10500	6.3 ab	9.9 a-c	48.5 bc	53.3 c	62 c	63	3.0	1.9	2.0
G-42	5.9 a-c	10.9 ab	46.2 c	53.7 c	62 c	63	3.0	1.7	2.5
G-10503	5.2 b-d	11.5 a	46.2 c	60.7 b	62 c	63	3.0	1.5	2.0
AGS-190	5.1 b-d	10.0 a-c	60.7 a	69.3 a	70 a	86	3.0	1.6	3.5
AGS-191	4.9 cd	9.4 bc	64.0 a	70.3 a	70 a	86	3.0	1.6	3.5
G-10494	4.4 ce	10.0 a-c	53.3 b	50.7 c	63 b	63	2.3	1.9	2.5
G-10142	3.6	10.9 ab	50.7 bc	62.5 b	62 c	63	3.0	1.7	2.5
Grand mean	5.4	10.3	51.6	57.8	65	70	2.8	1.7	2.3
c.v. (%)	11.4	10.2	5.2	4.7	0.3	-	9.5	7.7	-

[a]DS planted 11 December 1992 and WS 15 June 1993. Data mean of 5 m^2 subplots distributed in RCBD with three replications. Means followed by the same letter are not significantly different at 5% level (DMRT).

[b]Rated on a scale of 1-5, with 1 = highly resistant and 5 = highly susceptible.

Tomato Preliminary Yield Trial

Summary

Fifteen indeterminate fresh-market tomatoes were compared to Pope during the dry and wet seasons to identify lines with heat tolerance, high yield potential, acceptable eating and processing qualities, and resistance to diseases. The grand mean yields of the entries were 24.8 and 3.0 t/ha for the dry and wet seasons, respectively. Low yield during the wet season was due to high incidence of bacterial wilt and tobacco mosaic virus. Six entries did not survive the unfavorable conditions.

The 10 processing tomatoes were compared to Mapula during the dry season and yielded from 10.6 to 24.7 t/ha.

Introduction

The preliminary yield trial on fresh market determinate and indeterminate tomatoes was conducted in both dry and wet seasons. During the wet season, screening for heat-tolerant lines/ varieties was given emphasis for off-season production in the tropics. The screening of 10 processing types undertaken during the dry season aimed to identify entries with high yields, acceptable processing qualities, and resistance to diseases.

Materials and Methods

Sixteen indeterminate fresh market tomatoes from AVRDC and 11 processing tomatoes (6 AVRDC, 2 French, and 2 U.S. hybrids) were evaluated in the PYT during the wet and dry seasons of 1992-93. The indeterminate entries were transplanted on 15 December 1992 (DS) and 22 June 1993 (WS); the processing tomatoes on 27 November 1992. A subplot of 5 m^2 with 12 plants per row was used for each entry. The subplots were distributed in RCBD and replicated three times. The AVRDC cultural requirements were followed in raising the crops. The indeterminate tomato crops were provided with trellis, and all sets of trials were mulched with rice straw at about 5 t/ha.

The indeterminate fresh market tomatoes were harvested at green ripe stage and the processing type at red ripe stage. Total and marketable yields were taken during the dry season and potential yields during the wet season. Important horticultural traits and reactions to pests and diseases were also noted. All data were analyzed statistically.

Results and Discussion

Indeterminate fresh market tomato

Of the 15 test entries compared to Pope in both seasons, six entries did not survive the wet season due to adverse climatic conditions.

FMTT 18 gave the highest total yield of 32.6 t/ha during the dry season, and FMTT 115 with 5.4 t/ha during the wet season. However, there were no significant differences in the total and marketable yield among the entries in both seasons. The low yields during the wet season were due to high incidence of bacterial wilt (BW) and tomato mosaic virus (ToMV), and lack of heat tolerance in the test entries.

Fruit size produced during the dry season significantly varied among the entries with the biggest fruits observed in FMTT 4 (99 g) and FMTT 23 (98 g). During the wet season, fruit size ranged from 14.3 g to 33 g, but differences were insignificant among entries.

Days to flowering varied in both seasons with significant differences during the dry season. Variety Pope flowered the earliest at 24 days during the dry season, and FMTT 115 at 22 days during the wet season.

The incidence of BW was lower during the dry season. The reaction of the entries was significant with the highest score of 2.7 observed on FMTT 77 in the dry season. During the wet season, the hot-wet conditions favored the development of BW and ToMV organisms. The entries showed varied reactions, but the differnces were statistically insignificant.

Fruit worms were more severe during the dry season, affecting the entries at various degrees of severity. However, the differences among entries were statistically insignificant.

Percent survival was highest (83%) in FMTT 18 and FMTT 264 during the dry season, and in FMTT 19 and FMTT 115 during the wet season (61%).

Processing tomato

Entry Re 1805 F_1 from France produced the highest total yield of 24.7 t/ha which was not significant compared to the check Mapula (18.0 t/ha) and six AVRDC hybrids with yields ranging from 18.3 to 21.9 t/ha. Fruit size varied among entries, but the differences were statistically insignificant. The entry with the biggest fruit was Re 1805 F_1 (58 g), while the smallest was Mapula (43 g). The earliest to flower was PT-4098 (21.3 days), and the earliest to mature was Butte (66 days). Bacterial wilt was observed on all test lines at varying degrees of severity, but its effect was insignificant. The least infected were PT-4066 and Mapula (score: 2.3), and the most susceptible was Butte (score: 4.0).

Tomato General Yield Trial

Summary

Thirty fresh market determinate tomatoes were compared to checks, Pope and Maigaya, in three sets of trials during the dry season. Promising lines were: Alton, CLN 698 BC_1F_2-517-OP-5, CLN 229 BC_1F_2-12-5-3-12-12, CLN 657 BC_1 F_2-206, and CL 143-0-10-3-1-0-1-10.

During the wet season, Maigaya outperformed the 19 entries evaluated in two sets of plantings.

In the processing tomato trial, PT-1599 F_1 had the highest total yield of 30.1 t/ha.

Introduction

Tomato lines/varieties selected from the preliminary trials were further evaluated in the general yield trial. For the determinate fresh market tomatoes, screening for off-season production during the wet season was given emphasis to identify entries with high yield potentials, heat tolerance, and pest and disease resistance.

The processing tomatoes were screened during the dry season to evaluate the yield and processing qualities of the entries.

Materials and Methods

1991-93 dry season

The 30 determinate tomatoes evaluated during the DS 1992-93 were divided in three sets of planting. Set 1 was composed of 10 entries (seven AVRDC OP lines, one from China, one Fiji variety, and two checks); Set 2 with 12 entries (10 AVRDC hybrids and two checks); and Set 3 with 11 entries (nine AVRDC OP lines, one Fiji variety, and one check). Sets 1 and 2 were transplanted on 24 November 1992 and harvested seven times from 22 January to 22 February 1993, while Set 3 was transplanted on 15 December 1992 and harvested four times from 18 February to 15 March 1993.

1993 wet season

Nineteen determinate lines selected from the dry season trial were evaluated during the wet season in two sets of planting. The first set was composed of four AVRDC OP lines, and one Fiji variety compared to the checks Pope and Maigaya, while the second set was composed of 11 AVRDC hybrids and three OP lines compared to Maigaya.

In both seasons, the entries were distributed in RCBD with four replications. A subplot of 5 m^2 with 12 plants per row was used for each entry. Triple 14 fertilizer was used as basal, applied at 1 tbsp per hill or at the rate of 600 kg/ha. The plants were side-dressed 10 and 20 days after transplanting with equal proportions of urea, solophos and muriate of potash at the rate of 1 tbsp per hill. The total NPK applied was equivalent to 168-164-324 kg/ha. The plants were sprayed at weekly intervals against pests and diseases.

Total and marketable yields, important horticultural characters, and reactions of the test entries to pests and diseases were recorded and analyzed statistically.

Results and Discussion

Dry season trial

Fresh market tomato (Set 1). The Fiji variety, Alton, gave the highest total yield of 35.6 t/ha which was comparable to Maigaya (29.3 t/ha) and CLN 95-280 D_5-1-7 (27.0 t/ha), but significantly different from the rest of the test lines. Flowering among entries significantly varied with Maigaya, the earliest to flower at 24 days, and CL 5915-206 D3-2-4-0, the latest at 29 days. Peak of harvest varied from 7 to 79 days but differences were insignificant. Smallest fruit (14 g) was produced by Maigaya, and the biggest (56 g) by CL 5915-206 D_4-2-4-0. Fruit worms and blossom end rot (BER) were observed on CL 4657-9-0-4R-NR-0 (score: 3.7).

Fresh market tomato (Set 2). Three hybrids outperformed Maigaya, but the total and marketable yield differences were insignificant.

The most promising entry was CL 698 BC_1F_2-517-OP-5 which produced 38.3 and 34.9 t/ha, total and marketable yield, respectively. Entry CLN 229 BC_1F_2-12-5-3-12-10 had the earliest peak of harvest at 67 days. Maigaya produced the smallest fruit size (17 g), while the biggest (65 g) was observed on CLN 229 BC_1F_2-12-5-3-12-10 and CLN 657BC_1F_2-206-0-0. Slight BW infection was observed among test lines, but the reaction was insignificant.

Fresh market tomato (Set 3). Total and marketable yields of 32.6 and 30.6 t/ha, respectively, were highest on CL 143-0-10-3-1-0-1-10 outyielding the check, Maigaya; but differences were insignificant (table 10). All entries had a comparable peak of harvest which ranged from 71 to 77 days except for CLN 484 BC_1F_3-58-5-4-0 with 84 days. Fruit size significantly varied with smallest fruit (20 g) produced by Maigaya, and the biggest (79 g) by CLN 65-349 D5-2-0. The entries showed moderate resistance to BW, fruit worm (FW), sun scald (SS), and BER.

Processing tomato. Total yields of the processing tomatoes were not significantly different among the entries. The grand mean marketable yield was 25.2 t/ha. Entry PT-1599 F1 (28.4 t/ha) was comparable to the check and the three East/West hybrids. Fruit size significantly varied among entries and ranged from 25 g (PT-1017 F_1) to 51 g (PT-1600). Maturity ranged from 77 to 85 days, but was not significant among the entries. Entry PT-1599 F_1 was the most susceptible to BW infection with a score of 2.5.

Wet season trials

Fresh market tomato (Set 1). The check Maigaya significantly outperformed the other test lines in total and marketable yields. Total yield ranged from 1.7 to 11.9 t/ha, while marketable

Table 10. Yield, horticultural characters, pest, disease, and physiological disorders of determinate fresh-market tomatoes in dry season, 1992-93[a]

Entry	Yield (t/ha) Total	Yield (t/ha) Marketable	Days to Flowering	Days to Peak of harvest	Fruit size (g)	Rating[b] BW	Rating[b] FW	Rating[b] SS	Rating[b] BER
Alton	29.9 a-c	25.4 a-c	29 b-d	77 b	32 e	1.0	1.8	1.3	1.3
CL 1131-0-0-13-0-6	24.3 a-d	21.8 a-d	27 d	71 b	32 e	2.0	2.0	1.0	1.0
CL 143-0-10-3-1-0-1-10	32.6 a	30.6 a	29 b-d	76 b	29 e	2.0	1.3	1.0	1.0
CL 5915-223 D_4-2-1-0	21.3 b-e	18.9 b-e	30 a-c	76 b	61 b-d	2.0	2.0	1.0	1.0
CL 5915-93 D_4-1-0-1-2	22.0 b-e	18.7 b-e	31 ab	71 b	75 ab	1.8	1.8	1.3	1.0
CLN 65-349 D_5-2-0	22.0 b-e	19.5 b-d	30 a-c	76 b	79 a	1.8	1.8	1.3	1.0
CLN 698 BC_1 F_3-512-0-12	22.1 b-e	19.4 b-e	30 a-c	76 b	62 b-d	2.0	2.0	1.3	1.0
CLN 484 BC_1 F_3-58-5-4-0	12.9 e	10.2 e	32 a	84 a	68 a-c	2.3	1.8	1.3	1.0
CLN 475 BC_1 F_3-265-12-9-1	19.3 de	16.3 c-e	30 a-c	71 b	56 c-d	2.3	1.8	1.0	1.3
CL 5915-93 D_4-1-0-3	19.8 c-e	15.5 d-e	29 b-d	77 b	53 d	1.8	1.8	2.0	1.0
Maigaya (ck)	30.6 ab	28.1 ab	28 cd	76 b	20 e	1.0	1.3	1.0	1.0
Grand mean	23.3	20.4	30	75	52	1.5	1.73	1.2	1.0
c.v. (%)	25.9	27.9	4.6	5.2	16.5	40.5	24.5	31.2	24.4

[a]Transplanted 15 December 1992 and harvested four times from 18 February to 15 March 1993.
[b]Rating scale of 1 = none to 5 = severe.
Note: Means followed by the same letter in each column are not statistically different at 5% level (DMRT).

yield ranged from 1.4 to 9.6 t/ha. Flowering ranged from 22 to 30 days but differences were insignificant. The first harvest at 64 days was made on Maigaya, which differed significantly from the rest of the entries. Fruit size ranged from 15 g (Maigaya) to 30 g (CL 5915-93 D_4-1-0-C-2), which significantly varied among entries. Bacterial wilt infected the entries. Maigaya was the least susceptible (score: 2.0) while Alton was the most susceptible (score:4.75). ToMV was noted in all entries, but differences were insignificant.

Fresh market tomato (Set 2). Maigaya with a total yield of 13.5 t/ha and marketable yield of 12.6 t/ha significantly outyielded the 14 AVRDC test lines (table 11). Flowering ranged from 23 (Maigaya) to 33 days (CLN 657 BC_1 F_3-267-0-3-1-4). First harvest was from 67 (Maigaya) to 77 days. The smallest fruit (12 g) was produced by Maigaya, and the biggest (39 g) by CL 5915-93 D_4-1-0-L-2. High incidence of BW and TMV was observed in all entries with a grand mean of 3.5 and 3.7, respectively.

Table 11. Yield, horticultural characters, and disease ratings of selected fresh-market tomatoes during the wet season, 1993[a]

Entry	Yield (t/ha) Total	Yield (t/ha) Marketable	Days to Flowering	Days to First harvest	Fruit size (g)	Rating[b] BW	Rating[b] TMV
CLN 5915-223 D_4-2-1-0	8.2 b	7.6 b	31 a-c	75 ab	30 a-e	3.3	4.0
CLN 229 BC_1-12-5-3-12-10	8.7 b	8.0 b	27 b-d	75 ab	37 ab	3.5	3.8
CLN 657 BC_1-209-0-0	7.5 b-d	7.1 b-d	30 a-c	72 bc	26 c-f	3.0	3.8
Maigaya (ck)	13.5 a	12.6 a	23 c	67 c	12 g	2.8	3.8
Grand mean	5.7	5.2	29.0	75.4	26.5	3.5	3.7
c.v. (%)	31.4	32.3	10.5	3.8	19.6	21.7	23.7

[a]Transplanted 23 June 1993 and harvested two times from 24 August to 3 September 1993.
[b]Rating scale of 1 = none to 5 = severe.
Note: Means followed by the same letter in each column are not statistically different at 5% level (DMRT).

Tomato Regional Yield Trial

Summary

Entry DSF-82352 produced the highest total yield of 34.8 t/ha during the dry season which was comparable to the seven test lines including the check, Maigaya. During the wet season, the check (Maigaya with 18.4 t/ha) significantly outyielded the rest of the entries. Significant differences were also noted in other yield parameters measured during the wet and dry season trials.

Introduction

The regional yield trial was conducted in 13 stations all over the country. The primary objective was to identify lines/hybrids adapted to the different regions of the country. Results of four season tests were used as a basis by the Philippine Seed Board to release new varieties for regional and/or national recommendation.

Materials and Methods

The dry season trial was composed of four hybrids from IPB, five open-pollinated lines from DA-Dalwangan Seed Farm (DSF), and two lines from AVRDC-POP. For the wet season, two hybrids from IPB, four lines from DSF, and three lines from AVRDC-POP were evaluated.

The entries were transplanted on 2 December 1992 and harvested five times from 27 January to 23 February 1993 for the dry season; and transplanted on 22 June 1993 and harvested three times from 24 August to 7 September 1993 for the wet season.

The crops were raised according to standard national procedure in conducting regional trials. Data on yield and other important horticultural characters were taken from the 10 inner plants of the two inner rows of each subplot.

Results and Discussion

During the dry season, total yield ranged from 24.4 t/ha for AVR-03 to 34.8 t/ha for DSF-82352 (table 12). Total yield of DSF-82352 was comparable to seven test entries including the check, and significantly different from four entries. Marketable yield ranged from 21.8 to 32.3 t/ha. Fruit size significantly varied among the entries with the biggest fruit, 50 and 48 g, from AVR-062 and CL 5915-93 D_4-1-0-C-1, respectively.

Total yield during the wet season also varied significantly with highest yield produced by the check Maigaya (18.4 t/ha). Marketable yields ranged from 1.2 to 15.6 t/ha. Significant differences were observed among the smallest fruit (11-12 g) produced by Maigaya, DSF-82353, and DSF-8234, and the biggest (28 g) produced by AVR-035.

Table 13 shows the significant reactions of test entries to pest, diseases, and physiological disorders during the dry and wet seasons.

Table 12. Total and marketable yields and fruit size of RYT entries during the 1992-93 dry and 1993 wet seasons

Entry	Yield (t/ha)				Fruit size (g)	
	Total		Marketable			
	DS	WS	DS	WS	DS	WS
AVR-035	24.4 d	2.6 cd	21.8 d	2.0 c	41 bc	28 a
AVR-039	31.6 ab	3.1 cd	29.6 ab	2.5 c	41 bc	22 b
AVR-062	28.9 bc	-	25.6 b-d	-	50 a	-
AVR-065	27.4 b-d	-	24.1 b-d	-	45 ab	-
DSF-0585	29.8 a-c	-	27.8 a-c	-	18 g	-
DSF-8505	30.6 a-c	2.3 cd	28.2 a-c	1.8 c	32 ef	20 b
DSF-8234	32.0 ab	2.6 cd	29.6 ab	2.3 c	35 be	11 c
DSF-82352	34.8 a	1.5 d	32.3 a	1.2 c	41 bc	20 b
DSF-82353	31.8 ab	1.4 d	29.4 ab	1.2 c	39 cd	12 c
CL 5915-93 D_4-1-0-C-1	33.0 ab	9.6 b	29.3 ab	8.8 b	48 a	21 b
CL 5915-204 (G) D_4-1	25.0 cd	11.4 b	22.5 cd	9.7 b	29 f	18 b
Maigaya (ck)	30.0 a-c	18.4 a	26.5 a-d	15.6 a	17 g	12 c
EG Alton	-	5.2 c	-	4.6 c	-	21 b
Grand mean	30.0	5.8	27.2	5.0	36.3	18.5
c.v. (%)	11.3	36.7	13.2	43.5	9.7	18.5

DS transplanted 2 December 1992 and harvested five times from 27 January to 23 February 1993.
WS transplanted 22 June 1992 and harvested three times from 24 August to 9 September 1993.
Note: Means followed by the same letter in each column are not statistically different at 5% level (DMRT).

Table 13. Reaction to pest, disease, and physiological disorders during the 1992-93 dry and 1993 wet seasons

Entry	DS rating			WS rating	
	FW	PM	SS	BW	ToMV
AVR-035	1.3 ab	1.0 c	1.8 a	4.8 a	2.3 cd
AVR-039	1.5 ab	1.5 c	1.0 b	4.0 a-c	3.8 a-c
AVR-062	1.8 a	1.8 c	1.0 b	-	-
AVR-065	1.5 ab	3.8 ab	1.3 ab	-	-
DSF-0585	1.0 b	2.8 a-c	1.0 b	-	-
DSF-8505	1.3 ab	2.5 bc	1.0 b	3.8 a-c	3.8 a-c
DSF-8234	1.0 b	4.5 a	1.0 b	4.3 ab	2.0 d
DSF-82352	1.0 b	2.8 a-c	1.0 b	3.8 ab	3.5 a-c
DSF-82353	1.0 b	2.5 bc	1.0 b	4.0 a-c	2.8 b-d
CL 5915-93 D4-1-0-C-1	1.8 a	1.0 c	1.0 b	2.5 d	4.5 a
CL 5915-204 (G) D4-1	1.5 ab	4.3 ab	1.0 b	2.5 d	4.5 a
Maigaya (ck)	1.0 b	2.5 bc	1.0 b	3.5 b-d	3.5 a-c
EG Alton	-	-	-	3.0 cd	3.0 bc
Grand mean	1.3	2.6	1.1	3.6	3.3
c.v. (%)	28.4	40.7	18.6	19.3	26.5

Rating scale of 1 = none to 5 = severe.
FW = Fruit worm.
PM = Powdery mildew.
BW = Bacterial wilt.
ToMV = Tomato mosaic virus.
SS = Sun scald.
Note: Means followed by the same letter in each column are not statistically different at 5% level (DMRT).

Chinese Cabbage Preliminary Yield Trial

Summary

Of the 15 test entries evaluated during the dry season, AVRDC No. 82-157 obtained the highest yield of 20.5 t/ha, followed by No. 82-156 and the check Reyna Elena with 16.7 and 16.2 t/ha, respectively. The yield ranged from 7.7 t/ha for commercial variety Tropical Pride to 20.5 t/ha for No. 82-157.

For the wet season, the highest yielding entry was AVRDC line No. 85-216 with 17.2 t/ha. The performance of most entries was comparable to each other.

Introduction

Seeds of imported varieties of crucifers are commonly used by local vegetable farmers. In most cases, these varieties have varying degrees of heat tolerance and some perform poorly when grown in the lowland tropics. To provide lowland farmers with information on choosing varieties, a study was conducted on the yield performance of the commercial varieties of Chinese cabbage under conditions of the lowland tropics. After two seasons of initial evaluation in non-replicated trials, the promising commercial varieties were entered in the PYT together with the AVRDC lines during the wet season trials of 1992.

Materials and Methods

Fifteen Chinese cabbage lines (eight AVRDC lines and seven commercial varieties) were evaluated during the dry season (transplanted 9 December 1992); and 18 (11 AVRDC lines and seven commercial varieties) during the wet season (transplanting 29 July 1993). Each entry was planted in 1 m x 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 row. Two sidedressings, each with 30.0-7.5-15.0 kg/ha N, P_2O_5, and K_2O were made 10-20 days after transplanting. Mulching with rice straw at about 5 t/ha was done at 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 Trials.

Results and Discussion

Dry season trial

There were highly significant differences among entries in marketable head yield which ranged from 7.7 t/ha for commercial variety Tropical Pride to 20.5 t/ha for No. 82-157 (table 14). The grand mean for the 15 entries was 13.1 t/ha. The second highest yielder was No. 82-156 (16.7 t/ha), closely followed by the check Reyna Elena (16.2 t/ha).

The highest mean head weight was produced by Exp. 86-27 (679 g) which was statistically comparable to Tropical Delight (650 g), No. 82-157 (614 g), and No. 85-202 (611 g).

Entry No. 85-202 produced the highest head solidity of 0.70 g/cc which was not significantly different from the check Reyna Elena (0.63 g/cc) and the rest of the test entries. The harvest rate among entries ranged from 52% to 100% with a mean of 75%.

Table 14. Yield performance of AVRDC Chinese cabbage lines and promising commercial varieties under the PYT, 1992-93[a]

Entry	Marketable yield (t/ha)		Mean head weight (g)		Solidity[b] (g/cc)		Harvest rate (%)		Soft rot (%)	
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS
No. 82-156	16.7 ab	12.4 a-c	552 a-c	453 a-d	0.58	0.47 a-c	91 ab	80	0	5.7
No. 82-157	20.5 a	10.6 bc	614 a	422 b-d	0.56	0.54 ab	100 a	76	3.4	7.0
No. 83-20	15.7 a-c	12.6 a-c	570 ab	527 a-c	0.58	0.53 ab	85 a-c	72	5.7	12.3
No. 85-202	12.8 b-e	11.8 a-c	611 a	504 a-c	0.70	0.51 a-c	64 b-e	0	11.7	
No. 85-216	13.9 b-d	17.2 a	532 a-c	581 a	0.59	0.49 a-c	80 a-e	88	0	3.3
No. 83-2	14.0 b-d	-	516 a-d	-	0.59	-	81 a-d	-	4.3	-
77M(3)-46	11.2 b-d	12.2 a-c	537 a-c	533 ab	0.61	0.55 ab	63 c-e	70	9.8	4.3
Reyna Elena (ck)	16.2 a-c	14.0 ab	563 ab	469 a-d	0.63	0.49 a-c	85 a-c	89	0	1.7
Exp. 86-27	12.4 b-e	11.8 a-c	679 a	553 ab	0.57	0.43 bc	55 c-e	64	0	10.0
Tropical Quick	12.5 b-e	9.5 bc	399 de	335 d	0.48	0.52 ab	93 ab	83	0	5.3
Tropical Delight	11.2 b-e	11.9 a-c	650 a	496 a-c	0.64	0.38 c	52 de	75	3.7	6.7
Tropical Rapid	11.5 b-e	12.9 a-c	444 cd	403 cd	0.54	0.60 ab	77 a-e	95	0	5.0
77M (3)-40		11.7 a-c		451 a-d		0.61 a		78		5.0
77M (3)-35		9.0 bc		503 a-c		0.45 bc		56		3.3
77M (3)-27		10.3 bc		523 a-c		0.60 ab		61		6.3
Corazon		8.0 c		421 b-d		0.35 c		57		7.7
Grand mean	13.1	11.3	533	475	0.59	0.50	75	72	1.8	6.9
c.v. (%)	21.3	28.7	11.5	14.8	17.4	20.5	23.9			

[a]Data mean of double-row 4.8 m^2 raised subplots distributed RCBD and replicated three times.
DS — Transplanted 9 December 1992; harvested 4 February 1993.
WS — Transplanted 29 July 1993; harvested 24 September 1993.
[b]Solidity is an appropriate measure of head firmness expressed in g/cc.
Note: Means in each vertical column followed by the same letter are not statistically different at 5% level (DMRT).

The relatively cool temperature and moderate rainfall during the dry season were favorable conditions for the yield of Chinese cabbage. During the trial, the mean temperature ranged from 21.8°C (min) to 28.2°C (max), while total rainfall was 121.16 mm.

Wet season trial

The marketable yield ranged from 6.5 t/ha for Tropical Pride to 17.2 t/ha for No. 85-216, with significant differences among entries (table 14). The grand mean was 11.3 for the 18 entries. The check Reyna Elena had the second highest yield of 14.0 t/ha.

There were also significant differences in other yield components measured. The highest mean head weight of 590 g was produced by var. Summer Harvest after 45 days, closely followed by No. 85-216 (581 g). The most solid head (0.63 g/cc) was obtained by Summer Harvest after 45 days. Harvest rate ranged from 48% for Tropical Pride to 95% for Tropical Rapid with a grand mean of 72%. Softrot infection ranged from 1.7% (check Reyna Elena) to 13.0% (Tropical Pride).

In general, the performance of Chinese cabbage during the off-season (wet season) was poor in terms of marketable head yield due to high tempeatures and excessive precipitation. The mean temperature ranged from 23.8°C (min) to 27.2°C (max). Total precipitation during the crop cycle was 570.03 mm.

International Hot Pepper Trial Network

Summary

Seventeen and 18 hot pepper entries including the two check cultivars were evaluated in the International Hot Pepper Trial Network (INTHOPE) during the dry and wet seasons, respectively. For both seasons, high significant differences in yield and other horticultural characters were observed among entries.

During the dry season, yields of entries R1-26 (17) and PBC-384 (6.6 and 6.3 t/ha, respectively,) were significantly higher than the rest of the entries. For the wet season PBC-473 with 5.3 t/ha outyielded the local check variety Hotshot (4.9 t/ha), but the difference was not significant.

Introduction

The adaptability of hot pepper to various conditions in the tropics has evolved different landraces in different areas. Among these variations, there is a good chance of identifying high-performing genotypes that possess traits acceptable in other places. To this end, a cooperative trial entitled International Hot Pepper Trial Network (INTHOPE) has been coordinated by AVRDC since 1991. The trial aims to facilitate the exchange and evaluation of hot pepper landraces and elite germplasm across different environments worldwide.

Materials and Methods

Seventeen hot pepper landraces and elite cultivars were evaluated during the 1992-93 dry season and 18 during the 1993 wet season. In both trials, each entry was transplanted in double row 6.0 m^2 subplots (1.5 m x 4.0 m) spaced at 75 cm between rows and 50 cm between hills. The trials were laid out in RCBD with three replications.

The cultural management and data gathered were based on the INTHOPE procedure provided by AVRDC.

Results and Discussion

The yield and other horticultural characters of the different hot pepper cultivars showed highly significant differences among entries in both seasons (tables 15 and 16).

The total yield of the entries ranged from 0.4 to 6.6 t/ha during the dry season and from 0.4 to 5.3 t/ha for the wet season. Entries R1-26 (17) (6.6 t/ha) and PBC-384 (6.3 t/ha) produced highly significant yield differences over the rest of the entries during the dry season. On the other hand, PBC-473 with 5.3 t/ha outyielded the highest yielding check Hotshot (4.9 t/ha), but the difference was not significant.

The high coefficient of variation on yield for both seasons was due to the adverse effects of climatic conditions on plant stand; specifically, moisture stress during the dry season and heavy precipitation and typhoons during the wet season.

Negligible infestations of pests and diseases were noted in both seasons.

Table 15. Field performance of top 12 hot pepper cultivars evaluated under the INTHOPE trial during the 1993 dry season

Entry	Yield (t/ha)	Fruit size (cm) Length	Fruit size (cm) Width	Days to flower after trans-planting	Plant size (cm) Height	Plant size (cm) Width
R1-26 (17)	6.5 a	9.5 d	1.6 a	43.0 a	65.1 a	35.9 a
RBC-384	6.2 a	11.6 a-c	1.4 c	37.0 b	54.2 ab	37.1 a
Cili Langkap	3.2 b	12.4 a	1.5 a-	46.0 a	59.1 a	29.2 a-c
Num	2.8 bc	12.0 a	1.6 ab	42.7 a	49.7 a-d	28.4 a-c
Pant C-1	2.6 b-d	5.9 f-h	0.8 g	45.3 a	53.5 a-c	27.2 a-d
Pangalengan-2	2.6 b-e	10.3 b-d	0.5 hi	46.7 a	53.1 a-d	31.0 a-c
PBC-199	2.2 b-e	5.7 f-i	0.4 i	44.7 a	50.2 a-d	32.6 ab
Hotshot (ck)	2.1 b-e	9.8 d	1.0 de	46.0 a	31.2 e	20.2 cd
Kawit (ck)	1.8 b-e	7.8 e	1.1 d	43.3 a	30.8 e	21.6 b-d
Unknown-41	1.7 b-e	6.4 e-g	0.9 eg	45.0 a	49.9 a-d	23.2 b-d
MI-2	1.6 b-e	7.2 ef	0.8 fg	33.3 cd	36.0 c-e	23.2 b-d
Cheong Yang	1.5 b-e	4.9 g-i	1.3 c	32.7 cd	47.7 a-e	27.0 a-d
Grand mean	2.2	8.2	1.1	40.4	43.5	25.8
c.v. (%)	35.6	7.8	6.4	7.4	15.2	17.6

Transplanted 2 December 1992 and harvested from 1 March to 6 April 1993. Data mean of double-row 6.0 m² subplot distributed in RCBD and replicated three times.
Means followed by a common letter are not significant at 1% level (DMRT).
Data taken at last harvest.

Table 16. Yield and other horticultural characters for 17 entries of hot pepper evaluated under INTHOPE trial during the 1993

Entry	Yield (kg/ha)	Fruit size (cm) Length	Fruit size (cm) Width	Days to flower after trans-planting	Plant size (cm) Height	Plant size (cm) Width
PBC-473	5.3 a	11.7 a	11 cd	34 de	66.6 a	46.5 ab
Hotshot (ck)	4.9 ab	10.3 ab	1.1 cd	33 de	59.0 a-c	42.4 a-d
IR	4.7 ab	11.5 a	1.2 c	24 f	55.0 a-d	43.3 a-c
PSP-11	2.9 a-d	5.8 ef	1.0 c-f	31 de	41.2 de	33.8 a-e
Rotan	2.7 b-d	11.0 ab	0.6 g	37 bc	66.3 a	49.0 a
KA 6-5	2.1 cd	6.3 ef	1.1 cd	29 d-f	51.9 a-d	40.7 a-e
MI-1	2.0 cd	7.0 d-f	0.8 e-g	37 bc	54.5 a-d	40.10 a-e
PBC-370	2.0 cd	4.3 h-j	0.8 e-g	35 cd	62.6 ab	33.7 a-e
Perennial HDV	1.5 cd	3.3 j	0.8 e-g	37 bc	55.6 a-d	33.5 b-e
Luang	1.2 cd	6.8 d-g	1.5 b	45 a	60.3 a-c	34.5 a-e
Mun	1.2 cd	7.6 c-e	1.5 b	42 ab	53.4 a-d	35.9 a-e
Kawit (ck)	1.0 cd	8.3 cd	1.0 c-f	42 ab	38.3 e	27.5 de
Pant C-1	1.0 cd	5.3 f-i	0.8 e-g	35 cd	47.8 b-d	32.6 b-e
PBC-371	1.0 cd	3.7 ij	0.9 d-f	34 de	48.2 b-d	27.5 de
Tiwari 11	0.9 cd	5.0 g-j	0.9 d-f	28 ef	43.9 c-e	27.9 c-e
C-01664	0.8 cd	3.7 ij	0.7 fg	45 a	62.5 ab	40.1 a-e
Szechuan-8	0.8 cd	9.1 bc	1.0 c-f	36 bc	47.7 b-d	33.1 b-e
Yuak	0.4 d	6.8 d-g	2.7 a	44 a	44.8 c-e	25.6 e
Grand mean	2.0	7.08	1.09	36.1	53.33	16.15
c.v. (%)	44.9	10.3	8.2	7.5	11.9	36.0

Transplanted 28 June 1993 and harvested from 14 September to 13 October 1993. Data mean of double row 6.0 m² subplot distributed in RCBD and replicated three times.
Means followed by a common letter are not significant at 1% level (DMRT).
Data taken at flowering stage.

ROC-AVRDC Cooperative Program

Regional Yield Trials

Summary

AVRDC promising varieties/lines were evaluated in regional yield trials (RYT) under different environments in Taiwan. A total of 60 RYTs, which included AVRDC entries of fresh-market tomato, processing tomato, cherry tomato, hot pepper, soybean, vegetable soybean, and mungbean were conducted in 1992–93 in cooperation with the Republic of China (ROC) national programs.

Fresh market tomato hybrids FMTT 270, FMTT 277, and FMTT 285 were better than the check KY 301 and, in some locations, to Taichung ASVEG No. 4 in terms of yield, fruit setting, fruit size, heat tolerance, and disease resistance. Processing tomato PT 4718 had the highest yields in Hsiaying (138 t/ha) and at AVRDC (87.7 t/ha). In addition to high yield, PT 4718 also exhibited good fruit size and better processing quality than the checks, TN No. 3 and UC 82. AVRDC cherry tomato hybrids, CHT 261 and CHT 264, exhibited better heat tolerance and quality, produced stable high yields in autumn and comparable yields to check Season Red in spring; however, they had smaller fruit than Season Red. In hot pepper RYTs, the two best Szechwan selections, 89897 and 90719, appeared to be promising in yields (37 t/ha and 38 t/ha).

Soybean RYTs were carried out at 10 locations in two or three seasons of 1992. The yields of entries varied with location and season. Among the 12 entries evaluated, five lines, i.e., GC 84036, HL 77-79, TARI 12, KS 2164, and KS 2095, appeared promising and more stable than others. Overall, they had yields of 2.0–2.1 t/ha. The results of vegetable soybean RYTs revealed that none of the 11 entries was superior to KS No. 3 in terms of graded pod yields. However, KVS 363 gave the highest average plant yield of 20.3 t/ha and a mean graded pod yield of 7.1 t/ha compared to 21.7 t/ha and 7.5 t/ha for No. 3. The results of mungbean RYTs indicated that varietal difference in yield was significant in all four locations. Irrespective of locations and seasons, the mean yields of nine entries ranged from 1.2 t/ha to 1.5 t/ha compared to 1.4 t/ha of the check Tainan No. 5.

Introduction

RYTs were conducted in cooperation with ROC national institutions to evaluate promising AVRDC breeding lines/varieties and other improved selections of vegetables. The RYTs were mainly supported by the Council of Agriculture and carried out in the national programs under farmers' field conditions. Twelve AVRDC vegetable varieties have been named by the national institutions and released to the farmers based on the results of RYTs. Among these varieties, vegetable soybean KS No. 1, soybean KS No.10 and TN No.1, fresh market tomato Taichung ASVEG No. 4, Hualien ASVEG No. 5, and mungbean TN No. 5 contributed significantly to the

farmers' incomes. In 1992, the total crop values were US$135 million. The production area of vegetable soybean KS No. 1 was 6877 ha which accounted for about 90% of the total vegetable soybean production acreage.

The promising entries from AVRDC and national programs were assembled and evaluated under different environments (locations, season, year, etc.) in cooperation with various District Agricultural Improvement Stations and the Taiwan Agricultural Research Institute during the 1992-93 crop seasons. The main objective of the RYT was to identify promising improved vegetable varieties for release to farmers by the ROC national programs through close collaboration.

Materials and Methods

In 1992–93, RYTs were conducted for the following crops: fresh market tomato, processing tomato, cherry tomato, hot pepper, soybean, vegetable soybean, and mungbean. The details of locations, seasons, and number of entries included in the RYTs are given in table 1. A randomized complete block design with four replications was employed in all the RYTs. Spacing between rows and between plants, and number of plants per hill in different seasons for the seven crops are given in table 2. Cultural management and data collection were based on the standard procedures of RYTs for each crop. Fruit and bean qualities were analyzed by the Analytical Laboratory.

Table 1. Number of locations (NL), number of entries (NE), sowing/transplanting dates (SD/TD) of RYTs, including AVRDC materials, in Taiwan

Crop	Coordinator	Year	Season	NL	NE	SD/TD
Soybean	Tainan DAIS	1992	Sp	12	12	29 Jan. – 24 Mar.
		1992	Su	10	12	16 Jun. – 28 Aug.
		1992	Au	3	12	17 Sept. – 3 Oct.
Vegetable soybean	Kaohsiung DAIS	1992	Au	3	14	18 Sept. – 11 Oct.
		1993	Sp	7	14	15 Feb. – 2 Mar.
Mungbean	Tainan DAIS	1992	Su	3	10	3 Jul. – 21 Jul.
		1993	Sp	3	10	25 Feb. – 9 Mar.
Tomato (fresh market)	Taichung DAIS	1993	Sp	4	7	31 Mar. – 9 Apr.
Tomato (processing)	Tainan DAIS	1992	Au	3	9	8 Oct. – 9 Oct.
Tomato (cherry)	Tainan DAIS	1992	Au	4	8	5 Oct. – 30 Oct.
		1992	Sp	4	8	9 Apr. – 23 Apr.
Hot pepper	Kaohsiung DAIS	1992	Au	4	11	5 Oct. – 28 Oct.

Table 2. Plant spacings in RYTs

Crop	Space between rows (cm)		Space between plants (cm)		Plants per hill
	Spring and summer	Autumn	Spring and summer	Autumn	
Soybean	50	30	10	15	2
Vegetable soybean	50	50	10	10	2
Mungbean	50	–	10	–	2
Fresh market tomato	75	–	50	–	1
Processing tomato	150	150	20	20	1
Cherry tomato	100	–	50		1
Hot pepper	–	75	–	45	1

Results and Discussion

Fresh-market tomato. Six AVRDC fresh market tomato hybrids were included in RYTs at five locations in spring 1993. KY 301 was used as a control. At AVRDC all the entries significantly outyielded the check variety (table 3). FMTT 269 had the highest yield of 33.6 t/ha, and FMTT 277 was the next highest yielding hybrid (32.9 t/ha) which had the second largest fruit size of 122.8 g. In other locations, the best yielders were FMTT 270 (Taitung, Taoyuan), FMTT 277 (Lotung), and FMTT 285 (Puli). The yields of these hybrids were generally higher in other locations than at AVRDC where the temperature was high during the crop season. The AVRDC entries were superior to KY 301 and, in some locations, to Taichung ASVEG No. 4 in terms of yield, fruit setting, fruit size, heat tolerance, and disease resistance; however, the fruit color was inferior to the check varieties and not quite acceptable in the market.

Processing tomato. Seven hybrids of AVRDC processing tomato, together with two check varieties, UC 82 and TN No. 3, were evaluated in RYTs at three locations in autumn 1992. At AVRDC, PT 4718 significantly outyielded both controls with a yield of 87.7 t/ha (35–37% increases) in 135 days from transplanting (table 4). In Hsiaying and Chiku, the highest yields were obtained from PT 4718 (138.1 t/ha) and PT 4714 (88.4 t/ha), respectively. PT 4718 performed very well in all three locations having a good fruit size and good processing quality in addition to high yield, but slightly later maturity than other entries.

Table 3. Yield and horticultural characteristics of fresh-market tomato RYT, AVRDC, spring 1993

Entry	Days to mature	Marketable yield (t/ha)	Cull yield (t/ha)	Fruit size (g)	Soluble solid (Brix)	Acidity (%)	pH value	Color (a/b)
FMTT 269	68.0bc	33.6 a	9.2	122.5 ab	4.5	0.44	4.2	1.26
FMTT 270	67.7bc	30.3 ab	8.6	120.8 ab	4.5	0.43	4.2	1.39
FMTT 277	66.5c	32.9 a	8.4	122.8 ab	4.6	0.43	4.2	1.30
FMTT 285	66.5c	27.0 b	10.2	142.3 a	4.7	0.48	4.2	1.23
FMTT 301	68.5ab	25.1 b	8.2	106.8 b	4.9	0.45	4.3	1.34
FMTT 33	67.6bc	29.8 ab	7.8	117.2 b	4.5	0.40	4.3	1.41
KY 301 (ck)	70.0a	9.8 c	5.1	122.3 ab	5.4	0.58	4.3	1.00

Planting dates: sowing, 11 March 1993; transplanting, 9 April 1993
Means in each column followed by the same letter are not statistically different at 5% level (DMRT).

Table 4. Yield and horticultural characteristics of processing tomato RYT, AVRDC, autumn 1992

Entry	Days to mature	Marketable yield (t/ha)	(%)	Fruit size (g)	Soluble solid (Brix)	Acidity (%)	pH value	Color (a/b)
PT 4691	133	69.8	83	67.5	4.2	0.32	4.46	2.25
PT 4700	133	74.1	85	65.3	4.3	0.32	4.41	2.28
PT 4707	132	72.6	81	67.7	3.9	0.31	4.41	2.18
PT 4708	133	72.4	82	77.9	3.9	0.31	4.55	2.24
PT 4714	133	77.3	85	72.2	3.9	0.32	4.43	2.19
PT 4718	135	87.7	82	78.8	3.2	0.28	4.49	2.14
PT 4454	129	60.3	80	74.2	3.7	0.28	4.51	2.02
PT 4121	131	76.3	84	73.8	3.7	0.35	4.33	2.07
UC 82 (ck)	131	64.1	84	69.2	3.5	0.29	4.40	2.05
TN No. 3 (ck)	133	65.1	82	81.4	4.3	0.35	4.38	2.34
Mean	132	72.0	83	72.8	3.8	0.31	4.44	2.18
c.v. (%)	0.7	10.3		9.1	5.4	8.7	1.3	3.9
LSD (0.05)	1.4	10.8	–	9.6	0.3	0.04	0.08	0.12

Planting dates: sowing 17 September; transplanting 9 October 1992.

Cherry tomato. Six AVRDC cherry tomato hybrids were evaluated at three locations in the autumn of 1992. CHT 261 and CH 264 produced the highest yields over the three locations. They gave significantly higher yields than all other entries at AVRDC (table 5), with smaller fruit of 9–9.4 g compared to 22 g of TC 2 and 41 g of King Kan. In spring 1993, three AVRDC cherry tomato hybrids were compared with Season Red in RYTs at four locations. Season Red, a Known-You variety, gave the highest yields in all locations, including AVRDC (table 6). The yields of CHT 261 and CHT 264 were comparable to Season Red at AVRDC; however, they had a smaller fruit (9 g) than Season Red (14 g). Santa, an excellent quality cherry tomato from Known-You, was also used as a check variety at AVRDC. Although the quality was very good, its yield was very low with very small fruit.

Table 5. Yield and horticultural characteristics of cherry tomato RYT, AVRDC, autumn 1992

Entry	Yield (t/ha)	Days to mature	Fruit size (g)	Soluble solid (Brix)	Acidity (%)	pH value	Color (a/b)
CHT 261	71.4 a	109	9.4 e	5.1	0.44	4.1	1.96
CHT 264	71.6 a	108	9.0 e	5.0	0.44	4.1	1.88
CHT 266	39.4 b	114	12.2 cd	6.4	0.43	4.2	1.95
CHT 267	36.3 bc	115	11.7 cd	6.4	0.42	4.2	1.94
CHT 268	31.7 c	117	10.9 de	6.7	0.45	4.2	1.99
CHT 224	20.9 d	109	13.7 c	6.5	0.40	4.3	1.80
TC 2 (ck)	40.2 b	109	21.9 b	6.5	0.46	4.3	1.96
King Kan (ck)	22.7 d	122	40.7 a	4.8	0.43	4.2	1.83

Planting dates: sowing, 17 September 1992; transplanting, 9 October 1992.
Means in each column followed by the same letter are not statistically different at 5% level (DMRT).

Table 6. Yield and horticultural characteristics of cherry tomato RYT, AVRDC, spring 1993

Entry	Yield (t/ha)	Days to mature	Fruit size (g)	Soluble solid (Brix)	Acidity (%)	pH value	Color (a/b)
CHT 261	17.8 ab	85	9.2 c	7.0	0.55	4.1	1.52
CHT 264	18.0 a	86	8.5 c	6.5	0.50	4.1	1.41
CHT 437	15.4 b	86	18.3 a	6.5	0.61	4.2	1.73
Season Red (ck)	19.4 a	83	14.1 b	6.5	0.70	4.1	1.41
Santa (ck)	3.7 c	90	5.7 d	7.8	0.49	4.3	1.38

Planting dates: sowing, 6 March1993; transplanting, 9 April 1993.
Means in each column followed by the same letter are not statistically different at 5% level (DMRT).

Hot pepper. Pureline selection of Szechwan hot pepper has been going on at AVRDC since 1987. The objectives are to purify the variety, and select better plant type, fruit appearance, high capsaicin content, and overall productivity within the landrace. Nine pureline selections were evaluated in RYTs which were conducted at four locations: TARI, Pingtung, Wantan, and AVRDC. Unfortunately, the AVRDC trial was seriously attacked by viral diseases and insects which caused remarkable yield reduction. At TARI, 90719, 90716, and 90720 outyielded the check Szechwan, but there were no significant differences in yield between these entries and the check variety (table 7). In Pingtung, 89897 gave the highest yield of 54.4 t/ha which was only comparable to the yields of check Szechwan (50.4 t/ha) and Golden Heat (51.0 t/ha). Except for 90719, yields of all selections were significantly lower than the two control varieties in Wantan. Five selections had higher capsaicin contents than the check Szechwan; however, none of them

exceeded that of Golden Heat. The average capsaicin content of these selections was relatively low in this year's trials compared to last year's.

Table 7. Yield and horticultural characteristics of hot pepper RYTs in autumn 1992

Entry	Days to maturity[a]	Plant ht (cm)[b]	Yield (t/ha) TARI	Pingtung	Wantan	Fruit wt (g)[b]	Fruit size (cm)[b] L	D	Capsaicin[b] (mg/g)
89897	141.1	62.6	15.5	54.4	41.3	10.8	12.7	1.28	1.76
90709	143.4	64.4	9.5	29.7	30.9	9.8	14.0	1.12	1.47
90711	136.5	66.9	16.1	44.4	41.3	10.0	11.5	1.24	1.90
90714	147.8	66.0	13.7	41.5	39.6	10.3	14.6	1.16	2.23
90715	146.0	62.5	15.2	33.5	32.9	10.2	13.0	1.19	1.92
90716	146.5	62.5	18.2	45.0	42.5	11.7	14.8	1.22	1.67
90719	142.4	67.7	19.9	48.3	46.1	13.2	13.1	1.42	1.91
90720	142.6	57.8	17.3	41.2	39.3	10.7	12.4	1.33	1.85
VC	144.6	66.6	15.8	38.4	37.8	12.0	12.1	1.33	1.53
Szechwan (ck)	137.0	70.0	16.4	50.4	48.0	13.6	12.8	1.36	1.81
Golden Heat (ck)	139.3	61.8	6.5	51.0	49.7	9.6	12.9	1.16	2.02
Mean	142.5	64.4	14.9	43.4	40.9	11.1	13.1	1.26	1.82
c.v. (%)	2.8		26.6	13.4	7.6	–	–	–	–
LSD (0.05)	5.8		5.7	8.4	4.5	–	–	–	–

[a] Data obtained from AVRDC only.
[b] Data represents the means of three locations (TARI, Pingtung, and Wantan).

Soybean. Ten entries, including two each from AVRDC, TARI, Hualien DAIS, Tainan DAIS, and Kaohsiung DAIS, were employed in Taiwan RYTs at 10 locations in 1992. KS 8 and KS 10 were used as control varieties. Three trials were conducted at AVRDC in spring, summer, and autumn. The maturity duration of the entries were 104-119 days, 81-99 days, and 85-102 days for spring, summer, and autumn, respectively (table 8). TN 4 and TN 6 were the earliest varieties with means of 92 and 91 days over the three crop seasons. The yields of these varieties varied with season. The highest yielders were KS 2164 (2.5 t/ha), TN 4 (1.6 t/ha), and GC 84036 (2.1 t/ha) for spring, summer, and autumn, respectively (table 8). Irrespective of crop season, the highest yield was obtained from KS 2164 (1.9 t/ha) followed by GC 84036 (1.8 t/ha). Protein content was found to be slightly higher in autumn than the other two seasons (table 9). The average protein contents ranged from 42.0 to 43.9% DM. HL 77-33 and HL 77-79 had the highest protein content which were higher than that of KS No. 10 but comparable to KS No. 8s.

Besides the trials at AVRDC, soybean RYTs were also conducted during two seasons at nine locations. The yields of entries varied with location and season. Among the 12 entries evaluated, five lines: GC 84036, HL 77-79, TARI 12, KS 2164, and KS 2095 appeared promising and more stable across locations, although their yields were similar to those of the check KS No. 8. Overall, they had yields of 2.0-2.1 t/ha compared to 2.2 t/ha for KS No. 8.

Vegetable soybean. Vegetable soybean RYTs were carried out at three locations in autumn 1992 and seven locations in spring 1993. The entries included five lines from Kaohsiung DAIS and six lines from AVRDC. KS No. 2, KS No. 3, and Ryokkoh were used as check varieties. The yield data are given in table 10. At AVRDC, the differences in total plant yields between selected lines and the two check varieties, KS No. 2 and KS No. 3, were not statistically significant in either autumn (1992) or spring (1993). However, all six entries — KVS 363, GC 84126-13-1-2, GC 84126-13-1-1, GC 84128-17-21, KVS 351, and KS No. 3 — had high plant yields averaging over

Table 8. Yield and agronomic characteristics of soybean RYTs, AVRDC, 1992

Entry	Yield (t/ha)			Days to mature			Pods/plant			100-seed wt (g)		
	SP	SU	AU	SP	SU	AU	SP	SU	AU	SP	SU	AU
TARI 12	2.0	1.4	1.8	115	91	92	31	42	26	23.4	14.1	17.1
TARI 13	2.0	1.1	1.3	112	99	96	35	42	24	18.3	14.0	17.7
GC 81027	2.0	1.3	1.9	110	91	90	34	36	23	17.2	11.5	15.1
GC84036	2.0	1.5	2.1	104	89	87	23	41	24	20.9	13.9	17.7
HL 77-33	1.7	1.3	2.0	106	89	93	31	35	23	21.0	13.8	18.4
HL 77-79	1.8	1.5	1.8	112	85	102	33	37	25	18.8	14.3	17.7
TN 4	1.8	1.6	1.0	104	81	90	22	25	17	20.0	14.7	17.9
TN 6	1.5	1.1	1.6	104	85	85	22	31	22	20.1	13.9	16.2
KS 2095	1.7	1.4	1.8	106	91	91	24	34	20	24.5	15.2	23.6
KS 2164	2.5	1.2	2.0	119	91	93	26	34	26	26.0	13.4	16.9
KS No. 8 (ck)	1.8	1.2	2.0	109	91	90	22	30	21	23.5	15.5	20.3
KS No. 10 (ck)	2.0	1.3	1.5	109	85	89	22	29	21	18.1	11.5	15.5
Mean	1.9	1.3	1.7	109	89	92	27	35	23	21.0	13.8	17.8
c.v. (%)	11.5	8.55	9.92				17.0	18.9	9.0	9.2	7.8	8.5
LSD (0.05)	0.28	0.14	0.22				5.8	8.3	2.6	2.5	1.4	1.9

Planting dates: SP: 29 January 1992, SU: 16 July 1992, AU: 17 September 1992.

Table 9. Protein and oil content of soybean RYTs, AVRDC, 1992

Entry	Protein (% DM)				Oil (% DM)			
	SP	SU	AU	Mean	SP	SU	AU	Mean
TARI 12	42.2	43.2	43.1	42.8	21.2	21.1	20.3	20.9
TARI 13	42.8	42.9	44.9	43.5	21.9	21.9	20.1	21.3
GC 81027	40.5	41.5	45.7	42.6	21.9	21.9	19.7	21.2
GC 84036	44.3	41.3	43.9	43.2	20.2	21.7	19.7	20.5
HL 77-33	42.2	43.0	46.6	43.9	20.7	21.4	18.2	20.1
HL 77-79	43.7	42.9	45.2	43.9	21.8	21.6	19.7	21.0
TN 4	41.9	41.5	44.6	42.7	23.3	23.2	21.6	22.7
TN 6	42.0	41.3	46.1	43.1	20.5	23.0	19.0	20.8
KS 2095	43.2	43.4	44.8	43.8	21.1	21.6	19.1	20.6
KS 2164	43.8	43.1	43.8	43.6	23.7	21.0	21.4	22.0
KS No. 8 (ck)	42.9	42.5	46.1	43.8	20.6	22.4	18.4	20.5
KS No. 10 (ck)	40.5	42.0	43.6	42.0	23.8	22.7	21.4	22.6
Mean	42.5	42.4	44.9	43.2	21.7	22.0	19.9	21.2
c.v. (%)	1.5	3.1	1.3	–	1.7	6.1	1.7	
LSD (0.05)	0.8	1.9	0.8		0.5	1.9	0.4	

23 t/ha across seasons. Differences in marketable pod yields between selected lines and KS No. 2 or KS No. 3 were not significant in both seasons (table 10). Among the 11 entries, GC 84126-13-1-2, GC 84137-8-2-1, GC 84126-13-1-1, KVS 351, GC 84126-13-4-4, and KVS 363 produced consistently comparable yields of graded pods with the check KS No. 3 (6.4 t/ha) across seasons. Generally, the yields of both plants and marketable pods were higher in spring than in autumn.

The results of RYTs at other locations again indicated that the performances of the 11 entries were not superior to the two check varieties, KS No. 2 and KS No. 3, in plant and marketable pod yields in both seasons (table 10). Among the 11 entries, KVS 363 gave the highest average plant yield of 20.3 t/ha and average marketable pod yield of 7.1 t/ha compared to 21.7 t/ha and

7.5 t/ha for KS No. 3 across seasons and locations. These lines showed comparable quality (as indicated by protein, sugar content, and color) to that of KS No. 2 and KS No. 3 (table 11). They were all earlier maturing than KS No. 2 and KS No. 3, and some of them had larger pods. The marketable pod yield from these RYTs suggests that Kaohsiung, Tainan, and Hualien are high yielding locations. The economic potential of the Hualien area should be explored for vegetable soybean production.

Table 10. Yield of vegetable soybean RYTs, AVRDC, 1992-93[a]

	Total plant yield (t/ha)						Marketable pod yield (t/ha)					
	AVRDC			Others[b]			AVRDC			Others[b]		
Entry	AU (92)	SP (93)	Mean	AU (92)	SP (93)	Mean	AU (92)	SP (93)	Mean	AU (92)	SP (93)	Mean
KVS 133	16.9	19.1	18.0	15.6	19.9	17.8	4.3	7.2	5.8	6.1	5.5	5.8
KVS 256	13.9	20.5	17.2	12.5	13.5	13.0	3.1	7.0	5.1	5.7	4.9	5.3
KVS 363	20.3	28.8	24.4	15.3	25.3	20.3	4.2	8.2	6.2	6.7	7.5	7.1
KVS 351	18.7	28.2	23.5	15.5	23.7	19.6	4.4	8.2	6.3	5.5	6.0	5.8
Ryokkoh 74	17.5	25.1	21.3	14.3	18.9	16.6	5.0	7.2	6.1	6.5	5.8	6.2
GC84126-13-1-1	20.1	27.4	23.8	15.3	22.5	18.9	5.3	7.8	6.6	5.6	5.8	5.7
GC 84126-13-1-2	19.9	28.7	24.3	15.4	22.2	18.8	5.3	8.5	6.9	5.9	6.1	6.0
GC84126-13-4-4	16.9	27.9	22.4	15.4	21.7	18.6	4.8	7.7	6.3	5.8	6.2	6.0
GC84128-9-2-1	15.8	26.1	21.0	14.3	23.2	18.8	2.9	7.8	5.4	4.5	6.2	5.4
GC84128-17-2-1	20.1	27.3	23.7	15.2	25.9	20.6	4.8	6.3	5.6	6.0	7.3	6.7
GC84137-8-2-1	19.4	26.4	22.9	16.1	23.1	19.6	5.6	7.7	6.7	5.1	5.8	5.5
KS No. 2 (ck)	17.9	24.5	21.2	16.5	23.9	20.2	4.2	6.0	5.1	6.9	6.7	6.8
KS No. 3 (ck)	19.5	27.1	23.3	17.5	25.9	21.7	4.9	7.8	6.4	7.5	7.5	7.5
Ryokkoh (ck)	14.8	25.6	20.2	14.1	19.1	16.6	2.8	6.4	4.6	4.9	5.2	5.1
Mean	18.0	25.9	22.0	15.2	22.1	18.7	4.4	7.4	5.9	5.9	6.2	6.1
LSD (0.05)	2.2	5.9						1.4	1.6			

[a] Planting dates: AU: 18 September 1992, SP: 25 February 1993.

[b] Data represent the means of the two locations in autumn (1992) and six locations in spring (1993).

Table 11. Agronomic characteristics and bean quality of vegetable soybean RYTS, AVRDC, 1992-93[a]

Entry	Days to maturity	Pods/ 500 g	Seed shelled out (%)	Dry matter (%)	Protein (% DM)	Oil (% DM)	Sugar (% DM)	Fiber (% DM)	Color[b]
KVS 133	77.5	165.5	58.4	31.7	43.8	18.6	12.0	4.6	2.7
KVS 256	75.5	178.0	62.8	31.7	42.4	20.1	12.0	4.7	2.6
KVS 363	81.5	172.5	56.1	34.5	43.3	19.9	11.4	4.6	3.3
KVS 351	79.5	212.5	60.4	34.4	43.1	20.2	11.3	4.8	2.9
Ryokkoh 74	77.0	153.5	57.2	33.6	44.8	19.0	11.5	4.5	2.8
GC84126-13-1-1	79.0	161.0	61.7	31.5	42.6	20.6	11.5	4.9	2.5
GC 84126-13-1-2	80.5	165.0	59.7	32.8	42.3	20.5	11.0	4.9	2.7
GC84126-13-4-4	79.5	160.5	58.6	33.8	42.8	20.3	11.6	4.8	2.7
GC84128-9-2-1	80.0	170.0	53.7	33.9	44.3	19.7	11.3	4.8	2.9
GC84128-17-2-1	83.0	158.0	55.9	33.3	44.2	19.1	11.0	4.3	3.6
GC84137-8-2-1	78.5	152.5	54.2	33.2	43.0	19.8	11.4	4.6	2.5
KS No. 2 (ck)	83.5	169.0	58.3	35.7	43.4	19.6	11.7	4.7	2.8
KS No. 3 (ck)	83.5	160.5	56.9	35.4	45.4	20.4	10.7	4.8	2.8
Ryokkoh (ck)	78.5	155.5	54.6	33.8	44.8	19.0	11.2	4.5	2.7
Mean	79.8	166.7	57.8	33.5	43.6	19.8	11.4	4.7	2.8

[a] Data represents the means of the two crop seasons.

[b] Color value: lower value means darker green.

Mungbean. Six mungbean RYTs were conducted at three locations in 1992-93. Ten entries including check variety, TN No. 5, were used. The results of RYTs at AVRDC are given in table 12. The 1992 summer crop was affected by rain, therefore, yields of the entries were relatively low. VC 3738B and check variety TN No. 5 gave the highest yield of 1.1 t/ha in summer 1992. In spring 1993, VC 4250A and VC 3738B had the highest yields of 2.0 and 1.9 t/ha, respectively (table 12). Compared to TN No. 5, the differences in yields were significant. The average yields of the nine entries ranged from 1.0 to 1.5 t/ha, compared to 1.2 t/ha of TN No. 5 irrespective of seasons.

Varietal differences in yield were significant in the other three locations (Yenshue, Putze, and Chiku). However, varietal responses to locations and seasons were different. VC 3737A and VC 3738B showed more stable yields than other entries across locations. The mean yields of the nine entries from the four locations in two seasons ranged from 1.1 t/ha to 1.5 compared to 1.4 t/ha of TN No. 5. VC 4386A and VC 3907A had slightly larger seeds than TN No. 5. High percentages for the first harvest were found in all entries.

Table 12. Yield and agronomic characteristics of mungbean RYTs, AVRDC, 1992-93[a]

	Yield (t/ha)		Days to flower		Plant ht (cm)		100-seed wt (g)		Pods/m²	
Entry	SU (92)	SP (93)	SU (92)	SP (93)	SU (92)	SP (93)	SU (92)	SP (93)	SU (92)	SP (93)
VC 3737A	1.1	1.5	39	54	72.8	39.0	4.7	5.5	231	406
VC 3738B	1.1	1.9	39	54	63.7	44.2	5.2	5.5	246	459
VC 3907A	1.0	1.3	39	55	70.2	39.2	5.7	5.9	246	359
VC 4152B	0.9	1.5	37	51	69.9	44.2	5.6	6.0	213	394
VC 4250A	0.9	2.0	39	55	70.9	50.1	5.2	5.9	194	481
VC 4386A	0.9	1.2	36	55	74.8	43.9	5.8	6.2	208	336
VC 4394A	0.8	1.4	37	52	80.4	47.0	5.0	5.8	187	359
VC 4442A	1.0	1.1	36	53	70.3	35.9	4.9	5.5	215	377
VC 4541A	0.8	1.4	31	52	73.7	38.7	4.6	5.7	205	332
TN No. 5 (ck)	1.1	1.3	37	54	65.9	37.4	5.2	5.8	238	344
Mean	1.0	1.5	37	54	71.2	41.9	5.2	5.8	218	384
c.v. (%)	9.4	29.5	0.9	–	4.0	20-.2	5.0	5.7	14.4	34.0
LSD (0.05)	0.1	0.6	0.5	–	4.1	12.3	0.4	ns	45.7	ns

[a]Planting dates: SU: 21 July 1992; SP: 25 February 1993.

Seed Production and Distribution

ROC national programs organized trials of newly released AVRDC varieties/lines to demonstrate their yield potentials under farmers' field conditions. Previously released AVRDC varieties/lines are frequently used as checks in RYTs. AVRDC has multiplied and distributed 671.2 kg of stock seeds for three different crops in 1993 (table 13).

Table 13. Seed production and distribution of AVRDC-released varieties

Crop	Variety	Seed amount (kg)
Tomato	FMTT 33	1.2
Mungbean	Tainan No. 5	520
Soybean	Tainan Sel. No. 1	50
	KS No. 10	100

Varietal Evaluation of Nonprincipal Vegetables

Summary

Varietal observation and evaluation trials of lettuce, onion, and snap bean were conducted in 1992–93. Among the 33 entries of leaf lettuce, the best yielders were Oakleaf and New Red Fire for autumn; and Sierra and Prizemor Oscura VML for spring. For crisphead lettuce trials, Greenfield, Great Lakes, and Summer Gold produced the best head yields of above 40 t/ha in autumn; while Rosa Pablo, Vanguard 75, and Radiant ez. were the most promising varieties which yielded more than 20 t/ha in spring. Butterhead lettuce Felicia ez, Piracicaba 65, and Victoria performed very well in both autumn and spring seasons. The average yields of the promising varieties were 22–28 t/ha. Among the romaine lettuce varieties, the best yielders were Alpi (32 t/ha) and Kalura ez. (42.5 t/ha) for autumn and spring, respectively.

Thirty-three onion varieties were evaluated in a replicated trial for comparison with two local varieties. Significant differences in marketable yields were found among the entries. The top five varieties in terms of marketable yields were: Rio Bravo F_1, Granex 429 F_1, Superex F_1, Evita F_1, and TEG 502 PRR. These varieties produced yields of 66–73 t/ha compared to 47 t/ha for Tainan No. 1 and 42 t/ha for Tainung No. 3.

Preliminary observation of 14 pole snap bean varieties indicated that a locally developed variety, Taichung No. 11-N, was better than the other entries. It gave the highest yield of 13.8 t/ha followed by Kentucky Wonder (12.6 t/ha).

Introduction

Evaluation of AVRDC nonprincipal vegetables such as broccoli, lettuce, onion, and others has been going on since 1987 in the country programs. AVRDC has gained experience in successfully growing and identifying promising varieties of several nonprincipal and potential principal vegetable crops. The purpose of varietal evaluation is to search for improved vegetable varieties through collecting, testing, and selecting those that are especially heat-tolerant and disease-resistant. The selected varieties will be recommended to the national programs.

In 1992-93, several observation trials were conducted at AVRDC for four selected vegetable crops: lettuce, onion, snap bean, and yard-long bean.

Materials and Methods

Lettuce. A total of 103 varieties of lettuce including 33 leaf lettuce, 36 crisphead, 23 butterhead, and 11 romaine types were collected from USDA-ARS and commercial seed companies in 1992. Varietal observation trials were conducted at AVRDC in autumn 1992 and spring 1993. The trials were planted on 4-m-long, two-row beds, with spacing of 50 cm between rows and 20 cm between plants with no replications.

Onion. An onion variety trial was carried out to evaluate 35 varieties collected from NRI/HRI and commercial seed companies in autumn 1992. The onion plants were transplanted in 1 x 2 m two-row plots with 40 cm space between rows and 10 cm between plants and 40 plants per plot. The variety trial was conducted using a randomized complete block design with three replications.

Snap bean. An observation trial was conducted to evaluate 53 bush snap bean varieties in autumn 1992. The bean varieties were seeded directly in a single-row, 6-m-long bed with spacing 75 cm between rows and 10 cm between plants. Another observation trial was carried out to observe 14 pole snap bean varieties in autumn 1992. The pole beans were planted on 4.8-m-long, double-row beds with spacing 75 cm between rows and 40 cm between plants. The trial was replicated twice using RCBD.

Cultural management was based on the standard procedures adopted by the farmers for each crop. Yield data and major horticultural characteristics were collected and recorded. Chemical analyses were done in cooperation with the Analytical Laboratory.

Results and Discussion

Leaf lettuce. The results of the leaf lettuce observation trials are given in tables 14 and 15. The days from transplanting to harvest ranged from 28 to 57 days in autumn and from 14 to 48 days in spring. The fact that the spring crop needed shorter time to harvest than the autumn one was due to earlier bolting of plants. The 33 entries produced yields from 10 to 23 t/ha (average 16.8 t/ha) and from 5.5 to 32.4 t/ha (average 13.6 t/ha) for autumn 1992 and spring 1993, respectively. Varietal responses to seasons were quite different. In autumn, the highest yielders were Oakleaf and New Red Five, while Sierra and Prizemor Oscura VML were the best yielding varieties in spring. Most of the leaf lettuce entries grew quickly and reached harvest 1-2 months after planting. However, they were sensitive to high temperatures which generally caused the early bolting of plants.

Crisphead lettuce. Thirty-six varieties of crisphead lettuce were collected and included in the observation trials which were carried out in two seasons. In autumn 1992, plants were harvested from 46 to 57 days after transplanting. Head weights of the entries ranged from 100 to 450 g. Greenfield, Great Lakes, and Summer Gold produced the best head yields of above 40 t/ha with large and heavy heads (table 16). The crop duration in spring was shorter than in autumn due to higher temperatures. In spring 1993, days to harvest for the 34 entries were from 28 to 48 days (table 17). Large variations were found in both head weight and head yield. Among the 34 entries, head weights ranged from 95 to 409 g while head yields ranged from 1.8 to 25.3 t/ha. The most promising varieties were Rosa Pablo, Vanguard 75, and Radiant ez. These entries yielded above 20 t/ha compared to 19 t/ha for Georgia, which is a crisphead lettuce commonly grown by the farmers in Taiwan. Crisphead lettuce has become a very popular and important leafy vegetable in Taiwan. To extend lettuce to year-round growing, a heat-tolerant and disease-resistant variety is needed. The incidence of tipburn was more serious in autumn than in spring. A number of entries appeared to be very susceptible to tipburn (table 16).

Butterhead lettuce. Twenty-three varieties of butterhead lettuce were collected and tested in autumn 1992 and spring 1993. The 23 entries matured in 41-57 days and 31-45 days for autumn and spring, respectively (tables 18 and 19). Four entries: Anuenue, Felicia ez, Victoria

Table 14. Yield and horticultural characteristics of leaf lettuce variety trial, autumn 1992[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Oakleaf	USDA-ARS	YG	46	91	3	4	230	23.0
New Red Fire	Agway	DR	41	91	4	5	230	23.0
Grand Rapid	Enza Zaden	YG	41	60	3	5	220	22.0
Red Koreana	Choong Ang	GR	41	45	3	5	210	21.0
Local Imp.	Tsou Jway Ho	G	33	54	5	3	200	20.0
Black Seeded Simpson	Burpee	YG	33	54	5	3	200	20.0
Red Salad Bowl	Burpee	GR	41	45	4	5	200	20.0
Grand Rapid	Sakata	YG	41	54	3	4	200	20.0
Red Sails	USDA-ARS	DR	33	60	5	5	190	19.0
Canasta	USDA-ARS	DG	57	103	2	4	320	18.0
Celtuce	Known-You	G	33	54	5	3	180	18.0
Tango	Burpee	DG	41	91	3	5	180	18.0
Slobolt	USDA-ARS	YG	33	54	5	3	180	18.0
Green Koreana	Choong Ang	YG	36	54	4	4	180	18.0
Local Imp. No. 3	Ching Jong	G	33	54	5	3	180	18.0
Local	Ching Jong	G	33	54	5	3	170	17.0
Pai-Lu-Ching	Ching Jong	G	33	54	5	3	170	17.0
Rapidmor Oscura VML	INTA, Argentina	LG	33	54	5	3	165	16.5
Local	Song Tai	G	33	54	5	3	160	16.0
Woldmann's Green	USDA-ARS	G	36	60	4	4	155	15.5
Prizehead	USDA-ARS	LR	41	60	3	5	150	15.0
Local White	Nong Seng	G	33	54	5	3	150	15.0
Brastaga Leaf	Indonesia	YG	33	45	5	3	150	15.0
Jan-Tieh	Shun Far	G	33	45	5	3	150	15.0
Simpson's Curled	Bentley Seed	YG	36	54	4	3	150	15.0
Cavolo Di Napoli	F. Inegnoli	DG	33	45	5	3	145	14.5
Grand Tray	Kaneko	G	36	54	3	3	145	14.5
Rapidmor Clara VML	INTA, Argentina	YG	33	54	5	3	140	14.0
Local Leaf	Shun Far	DG	33	45	5	3	140	14.0
Prizemor Oscura VML	INTA, Argentina	DR	41	60	2	5	130	13.0
Sierra	Zaden	GR	46	103	3	5	200	10.5
Green Wave	Takii	LG	28	41	2	3	100	10.0
Black-Seeded Simpson	Sunseeds	YG	33	54	5	3	160	10.0

[a] Date sown: 15 October 1992; date transplanted : 13 November 1992

[b] Leaf color: DG: dark green; DR: dark red; G: green; GR: green w/red margin; LG: light green; LR: light red; YG: yellow green.

[c] Vigor: 5 — 1: excellent to bad; recorded on 15 December 1992.

[d] Tipburn: 5 — 1: none to serious.

and Piracicaba 65 gave the highest head yields of 23–28 t/ha in autumn; while seven varieties, Carmona ez., Kagraner Summer, Piracicaba 65, Buttercrunch, Felicia ez, White Boston, and Victoria, yielded from 27.5 to 21.5 t/ha in spring. Felicia ez, Piracicaba 65, and Victoria performed very well in both seasons. These promising entries had good head size of 230 to 280 g (tables 18 and 19).

Table 15. Yield and horticultural characteristics of leaf lettuce variety trial, spring 1993[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Sierra	Zaden	GR	38	48	4	5	324	32.4
Prizemor Oscura VML	INTA, Argentina	GR	45	48	3	5	317	28.5
Red Salad Bowl	Burpee	GR	38	48	5	4	180	18.0
Pai-Lu-Ching	Ching Jong	MG	31	28	4	4	186	17.6
Local White	Nong Seng	MG	31	28	5	3	172	16.4
Green Koreana	Choong Ang	LG	31	35	4	5	172	15.9
Black-Seeded Simpson	Burpee	LG	31	35	4	4	159	15.9
Local	Song Tai	MG	31	28	4	4	170	15.8
Black-Seeded Simpson	Sunseeds	LG	31	35	5	4	157	15.7
Local Imp.	Tsou Jway Ho	MG	31	28	4	4	147	14.4
Simpson's Curled	Bentley Seed	LG	31	28	3	4	153	14.1
Rapidmor Clara VML	INTA, Argentina	LG	31	–	2	3	151	14.0
Rapidmor Oscura VML	INTA, Argentina	LG	31	48	4	4	138	13.5
Prizehead	USDA-ARS	GR	38	48	3	4	154	13.5
Red Sails	USDA-ARS	R	28	18	3	5	213	12.8
Local Leaf	Shun Far	G	31	28	4	4	124	12.4
New Red Fire	Agway	GR	45	48	3	5	120	12.0
Woldmann's Green	USDA-ARS	LG	21	35	2	5	135	11.5
Slobolt	USDA-ARS	LG	21	18	3	4	250	11.3
Brastaga Leaf	Indonesia	LG	31	28	3	4	122	11.0
Grand Rapid	Enza Zaden	LG	31	28	3	4	110	10.8
Grand Tray	Kaneko	G	31	28	3	4	105	10.8
Cavolo Di Napoli	F. Ingegnoli	G	14	18	3	4	165	10.8
Grand Rapid	Sakata	LG	21	35	3	4	184	10.1
Canasta	USDA-ARS	R	48	48	4	4	190	9.5
Tango	Burpee	LG	28	31	2	5	224	9.5
Oakleaf	USDA-ARS	LG	48	48	2	4	106	8.5
Celtuce	Known-You	MG	31	35	5	2	128	7.5
Red Koreana	Choong Ang	GR	21	18	3	4	145	7.3
Local Imp. no. 3	Ching Jong	MG	31	35	4	4	110	5.5
Mean			32				167	13.6

[a]Date sown: 18 March 1993; date transplanted: 13 April 1993.
[b]Leaf color: DG: dark green; G: green; GR: green w/ red margins; LG: light green; MG: milky green; R: red.
[c]Vigor: 5 –1: vigorous to weak; recorded on 30 April 1993.
[d]Tipburn: 5 – 1: none to serious; recorded on 18 May 1993.

Romaine lettuce. Romaine lettuce or cos lettuce is perhaps the most ancient type of the lettuces and is still very popular in southern and eastern Mediterranean countries today. Eleven varieties were collected and grown in the autumn and spring observation trials in 1992–93. In autumn, the variety Alpi gave the highest yield of 32 t/ha compared to 15 t/ha for Parris Island which was the lowest yielder (table 20). The next highest yielding varieties were Tall Guzmaine and Floricos with yields of 25 t/ha. These lettuce entries responded differently to various seasons. In spring, variety Kalura ez had the highest yield of 42.5 t/ha, while Alpi, which produced the highest yield in autumn, was the lowest yielder (18.5 t/ha, table 21). The average days to harvest were 50 and 40 days for autumn and spring, respectively. The mean head weights were 218 g and 283 g for autumn and spring, respectively. Generally, these varieties were more susceptible to bolting in spring than in autumn. High temperatures seem to enhance seed stalk elongation, an undesirable event in lettuce production signaling the end of the marketability of the crop.

Table 16. Yield and horticultural characteristics of crisphead lettuce variety trial, autumn 1992[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Greenfield	Arthur Yates	DG	57	68	4	1	450	45.0
Great Lakes	Burpee	DG	57	76	4	3	420	42.0
Summer Gold	Arthur Yates	DG	57	68	4	3	420	42.0
Calmar	USDA-ARS	DG	57	76	4	2	400	40.0
Olympia	Mikado	DG	57	68	3	1	400	40.0
Summer Gold	Arthur Yates	DG	57	83	3	3	400	40.0
Empire	USDA-ARS	DG	57	76	4	4	390	39.0
Vanguard 75	USDA-ARS	G	57	76	4	2	380	38.0
Great Lakes 659	Petoseed	DG	57	76	4	3	360	36.0
Jackpot	Arthur Yates	DG	57	60	3	4	350	35.0
Lagomor VML	INTA, Argentina	G	57	83	4	3	350	35.0
Blanco RS	Royal Sluis	DG	57	91	3	3	340	34.0
Suny Lake	Arthur Yates	DG	57	83	3	3	340	34.0
Brogan ez	Enza Zaden	DG	57	76	3	1	330	33.0
Autumn Gold	USDA-ARS	G	57	83	4	2	320	32.0
Target	Petoseed	DG	57	68	3	2	320	32.0
Sun	Kaneko	G	57	76	4	3	300	30.0
Himalaya	Watanabe	DG	57	76	4	1	300	30.0
Kelvin RS	Royal Sluis	DG	57	76	3	1	290	29.0
Georgia	Known-You	DG	46	68	4	2	290	29.0
Top Mark	Takii	DG	57	83	2	3	280	28.0
Early S-25	Nong Seng	DG	57	83	3	3	280	28.0
Martha	Zorzi Sementi	G	57	68	3	2	270	27.0
Pacific	USDA-ARS	DG	57	68	3	2	270	27.0
Greenway	Arthur Yates	DG	46	68	3	1	260	26.0
Summertime	Petoseed	DG	57	68	3	1	260	26.0
Radiant ez	Enza Zaden	LG	56	85	2	3	250	25.0
South Bay	USDA-ARS	G	46	83	3	3	230	23.0
Salinas	USDA-ARS	DG	46	68	4	2	220	22.0
Montello	USDA-ARS	DG	46	76	3	2	200	29.0
Martha	F. Ingegnoli	DG	46	68	3	4	190	19.0
Ithaca	USDA-ARS	DG	46	76	3	2	180	18.0
Julietta	Mikado	DG	46	68	3	1	170	17.0
My	Kaneko	DG	46	68	3	2	150	15.0
Rosa Pablo (RS867489)	Royal Sluis	DR	57	54	3	3	150	15.0
Mini-Green (90-540M)	USDA-ARS	DG	56	–	1	5	100	10.0
Mean			54				295	29.5

[a]Date sown: 15 October 1992; date transplanted: 13 November 1992.

[b]Leaf color: DG: dark green; DR: dark red; G: green; GR: green w/ red margin; LG: light green; LR: light red; YG: yellow green.

[c]Vigor: 5 – 1: excellent to bad; recorded on 15 December 1992.

[d]Tipburn: 5 – 1: none to serious.

Table 17. Yield and horticultural characteristics of crisphead lettuce variety trial, spring 1993[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Rosa Pablo (RS867489)	Royal Sluis	GR	45	–	4	4	253	25.3
Vanguard 75	USDA-ARS	G	38	35	3	2	214	20.9
Radiant ez	Enza Zaden	G	45	48	4	3	328	20.5
Georgia	Known-You	G	45	48	3	3	271	19.0
Blanco RS	Royal Sluis	G	45	48	4	2	348	18.3
Lagomor VML	INTA, Argentina	G	48	48	4	3	281	18.3
Greenway	Arthur Yates	MG	45	48	4	2	291	16.0
South Bay	USDA-ARS	G	48	48	4	5	252	14.5
Brogan ez	Enza Zaden	LG	48	–	4	4	239	13.8
Suny Lake	Arthur Yates	G	45	48	3	2	235	13.5
Himalaya	Watanabe	G	45	–	3	4	225	13.5
Sun	Kaneko	G	48	–	2	5	178	12.0
Kelvin RS	Royal Sluis	G	45	48	3	3	209	12.0
Summer Gold	Arthur Yates	MG	48	–	3	4	247	11.8
Calmar	USDA-ARS	G	45	48	5	5	409	11.3
Jackpot	Arthur Yates	MG	45	–	4	1	216	10.3
Salinas	USDA-ARS	G	28	48	3	4	195	9.8
Summer Gold	Arthur Yates	LG	48	–	3	5	218	9.3
Great Lakes	Burpee	LG	28	–	3	5	189	9.0
Julietta	Mikado	MG	48	48	3	5	227	8.5
Autumn Gold	USDA-ARS	G	48	48	3	5	183	8.3
Ithaca	USDA-ARS	G	48	–	3	4	229	8.0
Martha	F. Ingegnoli	G	48	–	3	4	238	7.8
Summertime	Petoseed	G	48	–	2	4	176	7.5
Pacific	USDA-ARS	G	48	48	3	4	171	7.3
My	Kaneko	G	48	48	3	4	187	7.0
Great Lakes 659	Petoseed	G	48	48	3	4	165	7.0
Montello	USDA-ARS	G	48	–	3	4	167	6.3
Target	Petoseed	G	48	48	3	4	95	4.5
Empire	USDA-ARS	G	48	48	4	5	213	4.3
Greenfield	Arthur Yates	MG	48	48	3	4	200	4.0
Olympia	Mikado	G	48	–	3	4	166	3.8
Top Mark	Takii	LG	31	31	2	4	118	3.3
Mini-Green (90-540M)	USDA-ARS	DG	48	–	2	4	100	1.8
Mean			45				219	10.8

[a]Date sown: 18 March 1993; date transplanted: 13 April 1993.

[b]Leaf color: DG: dark green; G: green; GR: green w/ red margins; LG: light green; MG: milky green; R: red.

[c] Vigor: 5 – 1; vigorous to weak; recorded on 30 April 1993.

[d] Tipburn: 5 – 1: none to serious; recorded on 18 May 1993.

Table 18. Yield and horticultural characteristics of butterhead lettuce variety trial, autumn 1992[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Anuenue	USDA-ARS	G	57	60	2	2	280	28.0
Felicia ez	Enza Zaden	LG	57	98	22	5	260	26.0
Victoria	USDA-ARS	YG	41	60	3	3	250	25.0
Piracicaba 65	Agroceres	LG	57	91	3	3	230	23.0
Wonder of the 4 Seasons	Daehnfeldt	DR	41	54	3	3	200	20.0
Semira ez	Enza Zaden	G	57	91	3	3	200	20.0
Prado RS	Royal Sluis	LG	41	54	3	3	110	19.0
Dark Green Boston	USDA-ARS	LG	44	55	2	3	190	19.0
Saffier	USDA-ARS	LG	56	–	2	5	190	19.0
Carmona ez	Enza Zaden	R	44	78	2	4	180	18.0
Buttercrunch	Burpee	DG	46	83	3	3	170	17.0
Solista ez 84	Enza Zaden	G	57	91	2	3	170	17.0
Regina 71	Agroceres	LG	44	–	2	4	160	16.0
Buttercrunch	Bentley Seed	DG	46	60	4	3	160	16.0
Patty	F. Ingegnoli	YG	46	60	4	3	160	16.0
Okayama Salad	Takii	DG	41	60	4	2	160	16.0
Amandine	USDA-ARS	LG	44	78	2	4	150	15.0
Kordaat	USDA-ARS	YG	57	83	2	3	145	14.5
Crescendo	F. Ingegnoli	YG	46	60	3	3	130	13.0
Kagraner Summer	Daehnfeldt	G	46	83	2	2	120	12.0
White Boston	Zorzi Sementi	YG	46	60	4	3	110	11.0
Emilia	Zorzi Sementi	G	46	60	3	3	110	11.0
Mirena	Nunhems Zaden	YG	46	68	3	3	100	10.0
Mean			48				178	17.5

[a]Date sown: 15 October 1992; date transplanted: 13 November 1992
[b]Leaf color: DG: dark green; DR: dark red; G: green; GR: green w/ red margin; LG: light green; LR: light red; YG: yellow green.
[c]Vigor: 5 – 1: excellent to bad; recorded on 15 December 1992.
[d]Tipburn: 5 – 1: none to serious.

Onion. AVRDC began the collection and evaluation of the commercial onion varieties in 1987 with the objectives of testing their adaptability and yield potential under subtropical conditions and selecting promising high yielders for the national programs in Taiwan. An onion variety evaluation trial was conducted in autumn 1992. Thirty-three entries, including 20 varieties received from NRI/HRI, U.K., were compared to two local varieties Tainan No. 1 and Tainung No. 3. The results of yield and horticultural characteristics of the promising entries are given in table 22. Marketable yields of the 35 entries ranged from 3.3 to 73.0 t/ha with a mean of 42.6 t/ha. Among the 33 entries, 11 and 14 of them significantly outyielded the local Tainan No. 1 and Tainung No. 3, respectively. The top five varieties in terms of marketable yields were: Rio Bravo F_1, Granex 429 F_1, Superex F_1, Evita F_1, and TEG 502 PRR. These varieties produced yields of 66–73 t/ha compared to 47 t/ha for Tainan No. 1 and 42 t/ha for Tainung No. 3. Maturity, bulb weight, bulb size, and neck diameter were all significantly different among the entries. The maturity in terms of DAT ranged from 125 to 154 days with a mean of 136 days. The bulb weights of 35 entries ranged from 80 to 417 g with an average of 265 g. Large bulb weight was generally associated with the high-yielding varieties, except Tropical Ace F_1 which had the largest bulb weight but low marketable yield. The low yield of Tropical Ace F_1 was mainly attributed to the high number of double bulbs.

Table 19. Yield and horticultural characteristics of butterhead lettuce variety trial, spring 1993[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Carmona ez	Enza Zaden	GR	45	48	4	5	275	27.5
Kagraner Summer	Daehnfeldt	LG	45	–	3	4	257	25.7
Piracicaba 65	Agroceres	G	45	48	4	4	289	25.3
Buttercrunch	Burpee	G	45	48	3	3	250	23.8
Felicia ez	Enza Zaden	LG	45	–	4	4	225	22.5
White Boston	Zorzi Sementi	LG	38	48	4	2	227	22.1
Victoria	USDA-ARS	LG	45	48	3	3	226	21.5
Buttercrunch	Bentley Seed	G	38	–	5	3	279	19.5
Okayama Salad	Takii	G	38	48	3	3	190	18.5
Mantilia	GRSU (LT0073)	G	31	–	3	4	222	17.8
Anuenue	USDA-ARS	G	45	–	2	4	176	17.6
Wonder of the 4 Seasons	Daehnfeldt	GR	38	35	3	5	176	16.8
Mirena	Munhems Zaden	LG	45	48	3	5	206	16.0
Solista ez 84	Enza Zaden	G	45	–	2	3	150	15.0
Regina 71	Agroceres	LG	38	48	3	4	149	14.9
Prado RS	Royal Sluis	LG	38	35	3	3	161	14.5
Semira ez	Enza Zaden	LG	45	48	33	5	204	14.3
Amandine	USDA-ARS	LG	38	48	3	2	118	11.8
Patty	F. Ingegnoli	LG	45	48	3	5	196	11.8
Dark Green Boston	USDA-ARS	G	38	35	3	2	103	9.8
Kordaat	USDA-ARS	LG	45	48	3	2	104	9.4
Saffier	USDA-ARS	LG	45	48	3	2	142	9.3
Crescendo	F. Ingegnoli	G	45	48	3	5	152	8.0
Mean			42				196	17.1

[a]Date sown: 18 March 1993; date transplanted: 13 April 1993.
[b]Leaf color: DG: dark green; G: green; GR: green w/ red margins; LG: light green; MG: milky green; R: red.
[c]Vigor: 5 – 1: vigorous to weak; recorded on 30 April 1993.
[d]Tipburn: 5 – 1: none to serious; recorded on 18 May 1993.

Table 20. Yield and horticultural characteristics of Romaine lettuce variety trial, autumn 1992[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Alpi	Nunhems	LR	69	91	2	3	320	32.0
Tall Guzmaine	Petoseed	G	44	63	2	4	250	25.0
Floricos	USDA-ARS	DG	57	83	3	3	250	25.0
Kalura ez	Enza Zaden	G	46	60	4	3	240	24.0
Prizemor Clara VML	INTA, Argentina	DR	57	68	2	4	240	24.0
Carolangueu	INTA, Argentina	DR	33	54	5	2	215	21.5
Parris Island	Petoseed	DG	46	54	4	3	190	19.0
Maravimor Clara VML	INTA, Argentina	DR	41	60	4	3	190	19.0
Valmaine	USDA-ARS	LG	44	47	2	4	180	18.0
Augustus	Petoseed	DG	46	54	3	3	170	17.0
Parris Island	USDA-ARS	DG	61	60	3	3	150	15.0
Mean			50				218	21.8

[a]Date sown: 15 October 1992; date transplanted: 13 November 1992
[b]Leaf color: DG: dark green; DR: dark red; G: green; GR: green w/red margin: LG: light green: LR: light red; YG: yellow green.
[c]Vigor: 5 – 1: excellent to bad; recorded on 15 December 1992.
[d]Tipburn: 5 – 1: none to serious.

Table 21. Yield and horticultural characteristics of romaine lettuce variety trial, spring 1993[a]

Variety	Source	Leaf color[b]	Days to harvest	Days to bolting	Vigor[c]	Tip-burn[d]	Head wt (g)	Yield (t/ha)
Kalura ez	Enza Zaden	G	45	48	3	4	425	42.5
Augustus	Petoseed	G	38	35	5	4	392	37.3
Floricos	USDA-ARS	G	45	–	5	4	280	28.0
Valmaine	USDA-ARS	G	38	35	5	1	268	26.8
Carolangueu	INTA, Argentina	G	38	35	4	2	278	26.4
Prizemor Clara VML	INTA, Argentina	GR	38	–	3	5	245	24.5
Parris Island	Petoseed	G	38	35	5	2	239	23.9
Maravimor Clara VML	INTA, Argentina	GR	38	35	4	4	238	23.8
Parris Island	USDA-ARS	G	38	35	5	4	277	22.9
Alpi	Nunhems	LG	45		3	4	185	18.5
Mean			40				283	27.5

[a]Date sown: 18 March 1993; date transplanted: 13 April 1993.
[b]Leaf color: DG: dark green; G: green; GR: green w/ red margins; LG: light green; MG: milky green; R: red.
[c]Vigor: 5 – 1: vigorous to weak; recorded on 30 April 1993.
[d]Tipburn: 5 – 1: none to serious; recorded on 18 May 1993.

Table 22. Yield and horticultural characteristics of 24 promising onion varieties, AVRDC, autumn 1992

Entry	Marketable (t/h)	Total Yield (t/ha)	Days to maturity	Bulb wt (g)	Bulb size Ht (cm)	Bulb size Diam (cm)	Neck diam (mm)	Plants bolted (%)	Source
Rio Bravo F_1	73.0	73.0	132	371	7.5	9.5	7.8	0	NRI/HRI
Granex 429 F_1	72.8	78.9	132	398	8.0	9.3	9.4	0	Asgrow
Superex F_1	69.4	70.1	125	345	7.9	9.4	8.7	0	NRI/HRI
Evita F_1	66.6	72.3	135	355	7.5	9.5	8.7	0	Nickerson
TEG 502 PRR	66.4	70.4	125	352	8.7	9.0	9.1	3	Abbott & Cobb
Gladalan Brown	65.2	70.8	132	366	8.6	8.9	8.2	3	NRI/HRI
Granex Y PRR F_1	63.1	67.4	128	336	6.7	10.0	8.4	0	Petoseed
Rio Bingo F_1	62.3	63.8	125	320	8.4	9.2	9.1	0	NRI/HRI
PSX 1029 F_1	62.2	70.3	125	351	9.0	9.3	9.4	0	Petoseed
Dessex F_1	61.2	61.3	125	323	6.7	9.9	7.5	0	NRI/HRI
TG 1015 Y	60.7	63.1	135	324	8.5	9.4	8.1	1	Petoseed
Rio Hondo	58.0	61.3	128	320	8.0	9.3	8.6	0	NRI/HRI
Henry's Special PR	57.4	59.6	125	313	9.0	9.3	8.7	1	Sunseed
Rio Blanco Grande	55.9	56.7	125	290	8.3	8.8	8.4	2	NRI/HRI
Regal	53.0	55.8	135	291	7.8	8.9	8.8	0	NRI/HRI
Pyramid	50.4	53.3	125	253	5.6	9.6	9.9	0	NRI/HRI
XPH 3325 F_1	49.9	49.9	135	342	7.2	9.7	8.9	25	Asgrow
Ringer Grano (PRT)	49.0	51.7	125	273	9.1	8.5	9.3	0	Abbott & Cobb
Tainan No. 1	47.0	48.5	135	263	6.8	8.9	7.6	10	Tainan DAIS
Arad F_1	46.0	53.4	135	273	7.4	9.3	9.5	0	NRI/HRI
Tainung No. 3	42.0	43.8	128	238	6.8	8.6	7.9	6	FTHES
Tropical Ace F_1	41.9	81.3	128	417	8.4	9.0	8.6	0	NRI/HRI
Jaune De Valance	41.0	58.2	128	295	8.1	8.9	9.0	3	NRI/HRI
Yellow Creole	34.1	37.2	141	188	5.7	5.0	9.4	3	NRI/HRI
Mean of 35 entries	42.6	49.3	136	265	7.1	8.0	9.5		
c.v. (%)	18.6	15.1	3.8	20.0	7.6	10.5	11.8		
LSD (0.05)	12.9	12.2	8.5	86.5	0.9	1.4	1.8		

Planting dates: sowing, 19 October 1992; transplanting, 26 December 1992.

Bulb and storage quality of the 24 promising entries are given in table 23. Yellow Creole, Tainan No. 1, Tainung No. 3, XPH 3325F_1, Pyramid, and Arad F_1 had higher dry matter content of 10.6–12.2% than other entries. Relatively low soluble solid (Brix) was found among the entries. The readings of brix were highly correlated with the dry matter. Henry's Special PR and Yellow Creole gave higher pungencies than other varieties. Results of the storage test revealed that most of the entries did not have good keeping quality. However, Tainan No. 1, Tainung No. 3, XPH3325F_1, and Yellow Creole showed better storage quality as indicated by their low percentages of rotted and sprouted bulbs as well as less weight losses during the 4-month period.

Snap bean. The crop of bush snap bean observation trial failed due to the severe infestation of beanflies. The pole snap bean observation trial was also slightly affected by the bean fly infestation. The results of pole snap bean trial are given in table 24. Among the 14 entries, Taichung No. 11-N gave the highest yield of 13.8 t/ha, followed by Kentucky Wonder (12.6 t/ha) and a local variety, Paichia (12.1 t/ha). Kentucky Wonder is a popular pole snap bean with good quality in the USA. These entries matured in 62 to 74 days. Poroto, a waxy bean from Argentina, was a very early pole bean with large pods.

Table 23. Bulb and storage quality of the promising onion varieties, AVRDC, autumn 1992

Entry	Dry matter (%)	Brix (°)	Pungency[a] (µmole/g FW)	Storage for 4 months Rotted (%)	Sprouted (%)	Wt loss(%)
Rio Bravo F_1	8.6	3.6	4.64	96	4	100
Granex 429 F_1	7.8	3.1	5.36	71	7	89
Superex F_1	8.0	3.2	5.46	73	0	76
Evita F_1	9.6	3.7	5.64	89	4	96
TEG 502 PRR	7.5	3.3	6.35	67	7	80
Gladalan Brown	8.8	3.3	5.08	84	0	93
Granex Y PRR F_1	9.1	3.7	5.88	69	9	88
Rio Bingo F_1	8.2	3.3	5.52	51	0	70
PSX 1029 F_1	8.6	3.5	6.86	60	11	86
Dessex F_1	9.8	3.9	4.71	64	9	82
TG 1015 Y	7.4	3.0	4.87	76	13	99
Rio Hondo	8.5	3.7	5.60	71	9	88
Henry's Special PR	7.9	3.2	8.24	87	13	100
Rio Blanco Grande	8.5	3.3	6.58	80	8	97
Regal	8.3	3.3	5.53	80	11	99
Pyramid	10.6	4.2	5.74	91	2	94
XPH 3325 F_1	11.0	4.9	6.06	31	0	63
Ringer Grano (PRT)	7.6	3.1	6.03	84	0	92
Tainan No. 1	12.1	5.1	5.65	33	2	46
Arad F_1	10.6	4.3	6.24	82	6	94
Tainung No. 3	11.6	4.8	5.19	42	0	47
Tropical Ace F_1	8.0	3.2	5.50	89	4	97
Jaune De Valence	9.1	3.7	5.83	93	0	95
Yellow Creole	12.2	5.2	7.76	33	21	64
Mean of 35 entries	9.3	3.8	6.28			
c.v. (%)	7.4	9.9	11.46			
LSD (0.05)	1.1	0.6	1.17			

[a]Pungency: µmole pyruvic acid/g fresh wt.

Table 24. Pole snap beans observation trial, autumn 1992[a]

Entry	Source	Days to flower	Days to mature	Pod wt (g)	Yield (t/ha)
Taichung No. 11-N	Taichung DAIS	41	71	7.4	13.8
Kentucky Wonder	Taichung DAIS	43	69	11.5	12.6
Paichia	Nong Seng Seed	43	74	7.7	12.1
Black Creasback	Taichung DAIS	44	70	7.2	11.8
Poroto (waxy)	INTA, Argentina	36	62	14.1	11.7
Witsa	C. May	42	70	11.6	11.0
Macarrao Favorito AG-480	Agroceres	46	73	10.0	10.8
Taichung No.16-N	Taichung DAIS	42	71	8.6	10.1
Unknown	Thailand	39	67	9.9	9.6
Taichung No.12-N	Taichung DAIS	44	73	8.2	8.8
Emerite	Stockes, USA	37	70	9.8	8.4
Poroto (green)	INTA, Argentina	37	65	19.4	8.0
Kentucky Blue	Burpee, USA	42	72	9.9	7.4
Kentucky Wonder (WS)	Burpee, USA	38	67	9.6	6.2

[a]Data represents the means of two replications. Planting date: 30 September 1992.

Bangladesh-AVRDC Agricultural Research Project

Summary

The financial support contract for Bangladesh Agricultural Research Council (BARC)/ Bangladesh Agriculture Research Institute (BARI) and AVRDC under Agriculture Research Project-II (Supplement) USAID ended on 4 June 1993. AVRDC succeeded in getting an additional grant for a 2-year period from USAID for a proposal to introduce and develop adaptive technologies for year-round vegetable production in Bangladesh. The AVRDC/USAID/ Bangladesh project will continue the germplasm introduction and improvement program. More germplasm from AVRDC and SAVERNET member countries have been received. A large quantity of mungbean germplasm was received from the Asian Regional Center/AVRDC. A total of 381 lines/varieties have been introduced in 1993. These germplam are being tested at BARI. The AVRDC project is assisting BARI in identifying promising lines from the germplasm. Promising lines from AVRDC introductions have been identified in tomato, okra, kangkong, edible podded pea, mungbean, malabar spinach, chili, summer cauliflower, garden pea, vegetable soybean, and Chinese cabbage. They are under preliminary yield trials (PYT) for evaluation. To ensure a year-round tomato crop, protected cultivation with a polythene cover in the months of June, July, and August has been introduced along with the use of raised beds, grafting, tomatotone spray, and heat-tolerant lines. This year a successful crop was produced in a large area under polythene protection. Lines TM0111 and TM0367 developed from AVRDC germplasm were found quite promising for summer and summer rainy season planting. The AVRDC project organized an in-country training on the experimental design and data analysis of vegetable crops and innovative practices for summer vegetable production. The project participated in the internal and central research review for 1993-94 on vegetable crops at BARI and assisted in identifying research priorities. A farmers' field day on summer tomato was organized in collaboration with BARI and extension agencies. Also, a field visit was arranged for 30 USAID staff, the Minister of Agriculture, the Secretary of Agriculture, and members of the Board of Governors (BARI) to see the new varieties and technologies of vegetable crops. Two booklets, one handout, and four consultant reports were released.

Introduction

Vegetable production in Bangladesh is confronted with many problems. The supply of vegetables is limited during the transitional period between summer and winter. Drought in early summer and heavy rain in mid- to late summer makes vegetable production difficult. High incidence of diseases and insects is also responsible for low yield and poor quality. Production also faces difficulty due to the unavailability of good quality seeds of improved varieties, poor storage, and poor transportation facilities.

Efforts are being made to develop new varieties and technologies that can extend vegetable production year-round and ensure production through resistance to diseases, insects, and tolerance to extreme temperature, drought, and other environmental stresses. Many new varieties

and technologies have already been generated by BARI in collaboration with AVRDC. The AVRDC Bangladesh project is working to overcome the problems by introducing the needed germplasm, testing them and identifying the promising lines. Two heat-tolerant tomato lines, TM0111 and TM0367, selected from AVRDC germplasm, are at the advanced stage of release for summer cultivation. For winter five tomato lines have been identified this year for secondary yield trials (SYT). Okra line OK 285, edible podded pea line GP 007, and kangkong line KG 002 have been selected for regional yield trials (RYT). Promising lines in chili/pepper, Chinese cabbage, vegetable soybean, brinjal, summer cauliflower, malabar spinach, and garden pea have been identified for PYT. Efforts are being undertaken for the transfer of identified varieties and technologies to the farmers through training, demonstrations, and field days by involving different extension agencies including the NGOs. The activities and accomplishments for the year up to 31 October are presented here.

Introduction of Germplasm

A collection of more than 381 lines/varieties of different vegetable crops from AVRDC and SAVERNET countries was made during this year (table 1).

All these new lines/varieties have been given to the BARI Horticulture Research Center for testing. Mungbean material has been given to BARI Pulses Division, Regional Agricultural Research Station (RARS), Ishurdi and some material to the Institute for Post-graduate Studies in Agriculture (IPSA).

Table 1. Germplasm collection introduced during 1993

No.	Crop	No. of lines
1.	Tomato	41
2.	Vegetable soybean	8
3.	Mungbean	303
4.	Malabar spinach	7
5.	Kangkong	1
6.	Brinjal	8
7.	Sweet pepper/Capsicum	3
8.	Chili	4
9.	Onion	4
10.	Welsh onion	1
11.	Bitter gourd	1

Crop Evaluation Trials

Tomato preliminary yield trial (PYT)

The performance of 12 tomato lines, 11 selected from AVRDC introductions, were evaluated under PYT at the Central Research Station of BARI, Gazipur, during rabi season 1992-93. Of the lines introduced CL 59125-206-D_4-2-2-0-4 produced the highest yield (97.8 t/ha), followed by FMTT 301 (96.9 t/ha), FMTT 260 (92.6 t/ha), FMTT 304 (92.3 t/ha), and CHT 280 (88.3 t/ha).

Summer tomato

The most significant achievement was the successful large-scale summer tomato crop utilizing technologies such as raised beds, tomatotone spray, AVRDC heat-tolerant lines, and polythene protection.

Three new observational trials on summer tomato were undertaken at BARI.

The grafting technique for early summer tomato crop was standerdized. *Solanum torvum*, a wild brinjal, was found to be the best rootstock among the three wild species tested. The graft compatibility of *S. torvum* with five cultivated varieties (TM0111, TM0367, TM0126, Manik, and Ratan) was studied. It was found that all five varieties were very compatible and scion-stock union was quite successful. There was no significant difference in the percentage of compatibility. It is possible to use any commercial variety of tomato for grafting onto *S. torvum*. For growing early summer tomato, seed of *S. torvum* should be grown by 15 November and the small seedlings should be transplanted to polythene bags in December. Seeds of the commercial variety to be used as scion should be sown in the first week of January. Grafting should be done between the last week of January and the first week of February. The grafted tomato plants should be transplanted in the field on 15-cm raised beds by the last week of February. The fruit from this crop will be available at the end of April or early May.

A trial on the use of different protective materials/treatments (transparent polythene, thick white polythene, black net, white net, and no cover) was undertaken for growing the summer rainy season tomato crop from June to September.

The seeds of three varieties (TM0111, TM0367, and TM0054) were sown on 10 June. Transplanting of the seedlings on 30-cm raised beds was done on 10 July. The flower clusters of the plants were sprayed on 11 August. Fruit setting started just 4 days after spraying. The harvesting was done starting 14 September. Among all the treatments, the crop raised under transparent polythene gave the best yield. The yield of the crop protected under transparent polythene was about three to four times more than the unprotected crops during the heavy rainfall months from June to September. The yield recorded was 20.15, 16.2, and 14.6 t/ha for TM0111, TM0367, and TM0054, respectively, as compared to 5.6, 4.9, and 4.4 t/ha under the unprotected plots.

Another preliminary trial was initiated to study the effect of different concentrations of tomatotone on fruit set. The seeds of three varieties (TM0111, TM0367, and TM0054) were sown on 10 June and transplanted on 20 July. Three sprays of two concentrations, i.e., 2% (50 times dilution) and 1% (100 times dilution) of tomatotone were applied at intervals of 5 days on 20, 25, and 30 August. There was no significant difference in the fruit-set and total yield for either of the concentrations. Hence, by using 1% (100 times dilution), half the hormone cost can be saved.

Chinese cabbage

Thirteen Chinese cabbage lines received from AVRDC were tested during rabi 1992-93 at the Central Research Station of BARI in Joydebpur. Seeds were sown on 23 November 1992 directly in the main field. Line 85-202 produced maximum head weight (658.7 g), followed by 85-216 (590.7 g). They were the best yielders among the entries tested.

Regional yield trial of Chinese cabbage

Line 1-2-70 developed from the germplasm introduced from AVRDC was tested during winter 1992-93 in different regions of the country. The average head weight of line 1-2-70 ranged from 600 g at Ishurdi to 808 g at Jamalpur. The highest yield per hectare was also recorded in Jamalpur (50.6 t). The seed yield was highest in Joydebpur (390 kg/ha) and lowest in Ishurdi (297.5 kg/ha).

Summer Chinese cabbage

Seven Chinese cabbage lines collected from AVRDC were tested in the summer of 1993. The harvesting began 5 June for the crop transplanted on 10 April. Heavy rain throughout the growing season affected the experiment. Under these conditions, three varieties (82-159, 85-156, and 62 [ASVEG]) formed heads. The average head weight observed was 505 g, 478 g, and 445 g, respectively. The line 77M(2/3)-46 formed no head; 85-202 formed partial heads; and line 85-116 formed loose heads.

Vegetable soybean

A germplasm evaluation trial on 20 AVRDC lines was undertaken to identify the promising lines from the crop sown in April. On the basis of single plant yield the five best lines (GC 86025-10, GC 84040-27-1, GC 84040-16-1, GC 86031-4NL, and GC 84040-7-1) were selected.

Another trial on six AVRDC lines was carried out during summer 1993. It is possible to grow two crops of vegetable soybean during the summer. Line GC 84134-P-9-3-15-1 (136 g/plant) gave the best performance, followed by lines GC 84128-9-2-1 (119 g), GC 84126-13-1-2 (109 g), and GC 84128-17-2-0 (105 g).

Chili

A trial was conducted on 17 chili lines during rabi 1992-93 at the Central Research Station of BARI. Seeds of these lines were sown on 25 October and transplanted on 15 December 1992. The harvesting was done from 24 March to 3 May 1993 at 10-day intervals.

Line C-002-90 (PBC 157) from AVRDC produced the maximum dry chili yield of 1.4 t/ha, followed by lines C-017-89, C-018-91 (PBC 398), and C-006-89 (table 2).

Table 2. Data on yield and yield contributing characters of selected chili lines in winter 1992-93

Lines	Mean fruit weight (g)	Mean fruit length (cm)	Mean fruit width (cm)	Yield/ plot (dry) (kg)	Yield (dry) (t/ha)
C-017-89	1.86	4.78	0.81	0.44	1.1
C-002-90	5.13	8.03	0.86	0.56	1.4
C-006-89	1.66	5.60	0.86	0.42	1.0
C-018-91	3.33	6.16	1.01	0.42	1.0
Mean (17 lines)	2.51	6.41	0.84	0.27	0.7
c.v. (%)	39.18	14.68	17.82	52.35	53.3

Mungbean

Line NM 92 introduced from AVRDC performed well at all three locations (BARI, IPSA, and RARS, Ishurdi). The yield of this variety was 2.0 t/ha and 1.8 t/ha at IPSA and BARI, respectively. It has been selected for demonstration trial.

Seed multiplication of the new line was initiated in September 1993 for conducting several experiments in the next season.

Malabar spinach

A trial on seven AVRDC and two local malabar spinach lines showed that lines ID 0002, ID 0006, ID 0014, and ID 0011 were the best. The seed production potentials of these lines under local conditions are now being tested.

Okra

The performance of an advanced line of okra, OK 0285 and the local line was tested at four different locations in a regional yield trial. Line OK 0285 performed well at all four locations (table 3).

Table 3. Performance of advanced okra line at different locations

Location	Days to 50% open flower	Node order of 1st flower	Plant height (cm)	No. of fruit/ plant	Yield /plant (g)	Yield t/ha	First virus appear.	Virus infection (%)
Joydebpur								
OK0285	43	3.5	190	24	450	16.0	-	-[a]
Local	46	4.0	110	14	320	10.7	48	60
Jamalpur								
OK0285	47	5.4	198	22	372	12.3	-	-
Local	48	6.5	199	20	349	11.6	61	20
Ishurdi								
OK0285	48	4.8	185	21	371	12.4	-	-
Local	49	5.2	170	18	306	10.2	-	-
Hathazari								
OK0285	52	4.0	173	24	399	13.3	-	-
Local ck	50	6.1	87	17	280	9.5	65	16

[a]No virus observed.

Kangkong

AVRDC line Broad Leaf gave the best performance for yield, quality, earliness, rapid growth, and most cuttings. The seed production potentiality was also found better than the local variety. This line has been recommended for RYT. New lines yielded about 27% more than the local recommended variety.

Summer cauliflower

Cauliflower is a popular vegetable in Bangladesh grown during the winter season. Recently one heat-tolerant line, CL 026 was introduced from AVRDC and performed well in last year's summer observational trial.

Line 026 is being tested further. The nursery was sown on 9 June and seedlings were transplanted on 25 July 1993 due to heavy rain. The harvesting of the uniform white curds started 20 September. Due to the late transplanting of aged seedlings, the size of the curd ranged from 250 to 350 g.

Cabbage

The cabbage line 1-1-52 was selected from the germplasm collected from AVRDC. A wide range of genetic variability has been observed in this line. An attempt was made to purify the line

through selection during 1992-93. A large population of 1000 plants were grown from last year's seed to select superior and desirable plants at the Citrus and Vegetable Seed Research Center, BARI, Joydebpur.

Results of the performance of the eighth generation of cabbage line 1-1-52 showed that the compactness was 2.33 which is acceptable for a tropical-type, open-pollinated cabbage variety. In the eighth generation 15-20% of the plants flowered during harvesting time which is not a desirable character and needs further improvement. One hundred and ten plants were selected and incised to facilitate flower stalk development. Seeds were collected from each plant for further evaluation.

Garden pea

Pea crops are gaining importance in Bangladesh and a good collection has been started at BARI. Among the 20 garden pea lines tested two maturity groups (early and main season) were identified.

Six lines (GP003, GP023, GP006, GP017, GP018, and GP004) are in the early group; another six lines (GP002, GP008, GP015, GP001, GP 024, and GP020) are in the main season group.

Edible podded pea

A trial on two edible podded pea lines introduced from AVRDC was conducted during winter 1992-93. The line GP 007 gave the highest yield (13.7 t/ha), followed by GP 010 (9 t/ha) Line GP 010 took 53 days to flower, whereas line GP 007 took 67 days.

Research Planning and Review

The AVRDC resident senior horticulturist/agronomist based at BARI actively participated in the annual internal review of the On-Farm Research Division (OFRD), BARI on 18-19 July 1993. The need for location-specific home garden plans was discussed and some new location-specific plans were presented. It was emphasized that new vegetable varieties and technologies developed by BARI should be included in the plans.

In July 1993 the senior horticulturist participated in the internal review of the Horticulture Research Center on vegetable crops, fruits, and spices, and interacted with the scientists. It was emphasized that more work on breeding for resistance to biotic as well as abiotic stresses such as drought, salinity, alkalinity, and salt tolerance should be undertaken. There is a need to develop hybrids particularly in crops like tomato, capsicum, brinjal, and cucurbits/melons and they should have comparable yield and quality with those imported from other countries. In heterosis breeding programs, emphasis should be put on resistant parents to get sources of resistance against major diseases in F_1 lines. Export-oriented research on vegetables and intensification of research on seed production also need attention along with the liberalization of seed import policy in Bangladesh.

The central program and review committee reviewed research programs on horticulture from 16 to 18 August 1993. The vegetable research programs for 1993-94 were discussed at length; a total of 71 experiments on different aspects of vegetable crops were proposed. Under the spice program, 14 experiments including two on chili and three on onion were finalized. Of all these research programs, 29 new experiments have been planned this year.

Training/Symposium

Experimental design and data analysis for vegetable crops training

A three-day in-country training on experimental design and data analysis for vegetable crops was organized at BARI on 9-11 February 1993. Forty participants from BARI, Bangladesh Agricultural Development Corporation (BADC), Directorate of Agricultural Extension (DAE), NGOs, and agricultural colleges of Bangladesh attended the training. Kazi M. Badruddoza, scientist emeritus, inaugurated the training program. S. Shanmugasundaram from AVRDC was the special guest. D. H. Kim, AVRDC mungbean breeder, acted as resource person during the training. Two AVRDC scientists and two national consultants working with AVRDC/Bangladesh delivered lectures and arranged practical classes.

Innovative practices for summer vegetable production training

A four-day training on innovative practices for summer vegetable production was organized at BARI from 26 to 29 April. Forty participants from BARI, BADC, DAE, NGOs, Bangladesh Agricultural University, and colleges of Bangladesh attended the training. BARC Executive Vice Chairman M.S.U. Chowdhury inaugurated the training program. USAID's Office of Food and Agriculture Director Kevin Mullally was the special guest. D. Midmore and G.C. Kuo from AVRDC were resource persons for the training. Three AVRDC and four national scientists delivered lectures. Midmore gave a special practical demonstration on the use of noncirculating hydroponics for vegetable production.

International training

Senior Scientific Officer Md. Ashraf Khan from BARI attended a 3-week special skills training course on advanced methods for virus diagnosis at AVRDC from 22 February to 15 March as part of the SAVERNET program.

International symposium

AVRDC supported four scientists from Bangladesh to attend the International Symposium on Alliums for the Tropics held in Bangkok, Thailand, from 15 to 19 February 1993. Among the scientists who participated were Jamiul Islam of BARI and Mallick of RDRS. Md. Ferdous Mondal and Md. Abdur Rahim from BAU presented a poster.

Others

Summer tomato field day

A field day on summer tomato was organized at BARI on 20 September. Farmers, including 15 women from five districts of Bangladesh, NGO representatives, extension development officers, and field workers participated.

Farmers were given demonstrations on the use of grafting techniques, tomatotone spray, raised beds, and protected cultivation using polythene sheet and nets of different colors. Three lectures were arranged for the farmers: summer tomato cultivation, tomato varieties, and vegetable research and development. Helen Gunther and Latifur Rahman from USAID paticipated. Nazrul Islam, secretary, IMED was the special guest. An exhibition of new BARI technologies was also arranged for the farmers. Farmers named a new summer tomato Red Gold.

Proposal for PL-480 funds

The Horticulture Research Center was assisted in preparing a proposal for getting PL-480 financial support for training and demonstration packages of new technologies for vegetable production. The proposal was approved by BARC and USAID. Funds for conducting several demonstrations and training programs for the extension agents and farmers have been transferred to BARI for implementation.

Interaction with NGOs for transfer of technology

The AVRDC project is helping develop close linkages between NGOs and research institutes for the transfer of technologies. NGO participation was encouraged for the in-country training programs as well as field days. Linkages with NGOs like Mennonite Central Committee (MCC) were strengthened by signing a letter of agreement between the tomato research team of BARI and MCC for summer tomato and other vegetables. Under this program MCC gave demonstration trials to 14 farmers. These farmers were supplied with seedlings of heat-tolerant lines and tomatotone. Farmers were exposed to this new technology for the first time. They also organized two field days in their project areas. AVRDC has also provided MCC with soybean and mungbean germplasm. MCC has identified some promising soybean lines.

Close linkages have been developed with Gono Kallayan Trust (GKT), an NGO. This NGO is working with 3600 landless and marginal families. They have introduced a vegetable crops program for which they want research expertise. Great scope to transfer the new varieties and technologies developed by BARI to the farmers exists through GKT and Bangladesh Rural Advancement Committee (BRAC), another NGO.

BARI field visit for USAID staff

A field visit for the USAID staff was organized on 21 January 1993. Thirty USAID staff members (David Hersefield; Craig Anderson; Ray Morton, agriculture development officer; Kevin Mullally, director, OFA; Helen Gunther, deputy director, OFA; Larry Paulson; Habibur Rahman, program officer; Alex Newton; S. Al-Muti; Rabiul Hoque; Paul Greenough; Alvera Sweet; Harriet Wilson; M.H. Khan, program officer; Tracy Atwoos; Latifur Rahman, program specialist; Peony Chaudhury; Nasim Ahmed; Fatema K. Bithi P.; Gazi Z.; Mir Ershadullah; Zahir Sadeque; T. Khanam; Lulu Bilquis; Nasir U. Ahmed; Jahanara Alam; Shefali Saha; Jahanara Arju; and Julian Malaker) participated in the field visit. The USAID staff members were briefed by the director general of BARI, the director of the Horticulture Research Center, and the AVRDC resident horticulturist/agronomist about the vegetable crop activities.

Ralph Cummings Jr., coordinator, IARC staff, Bureau for Research and Development, USAID, Washington, visited Bangladesh on 15-19 August and reviewed the project activities at BARI and several other locations. He also visited some NGOs and looked into their collaboration with AVRDC/BARC/BARI/USAID project.

Major General Majid-ul-Haq (rtd.), minister for agriculture; Mr. E.N. Eusuf, secretary of agriculture; members of BARC's Board of Governors including the executive the vice chairman; director general, DAE; director general, BARI; director general, BRRI, VC, and BAU; and senior staff of BARI visited vegetable growing areas and saw the summer tomato, summer cauliflower, and virus-free okra crops at BARI. They lauded both BARI and AVRDC for their good vegetable research programs.

Visit to headquarters and ARC

The AVRDC resident horticulturist/agronomist visited the AVRDC regional office and headquarters from 2 to 14 December 1993. At the regional office he met with C.Y. Yang and discussed the Bangladesh project activities. At headquarters he attended the annual review and planning meeting from 8 to 10 December and presented a paper on national partner's perception issues. He also contributed a poster on year-round cultivation of tomato in Bangladesh. He also met with E.Q. Javier, AVRDC director general, S.C.S. Tsou, deputy director general; and S. Shanmugasundaram, director, International Cooperation Program; D. Kim to finalize plans for the training on experimental design and data analysis for vegetable crops to be held at BARI; and G. Kuo and D. Midmore to discuss summer vegetable techniques training.

On 14-20 February he visited ARC in Bangkok, Thailand, to discuss regional activities, attend the International Symposium on Alliums for the Tropics, and present a poster on kharif onion cultivation.

AVRDC back-up specialists

During the year, AVRDC scientists have actively participated in all the activities of the Bangladesh project. C.Y. Yang, S. Shanmugasundaram, D.J. Midmore, G. Kuo, D. Kim, and R. Marsh visited Bangladesh in connection with AVRDC activities.

Strengthening of vegetable laboratory and field facilities

A vegetable research laboratory was set up at BARI using ARP-II (Supplement) funds. This laboratory will help the scientists undertake several new experiments on vegetable crops. Field facilities for doing breeding experiments have also been strengthened.

Consultants

Four national consultants were appointed for vegetable improvement (germplasm), vegetable production, postharvest management, and vegetable protection (insect).

The vegetable improvement (germplasm) consultant reviewed the germplasm wealth of the country, attempted to identify gaps in germplasm and germplasm conservation infrastructure, and suggested a plan for the establishment of a germplasm bank at the national level. The vegetable production consultant surveyed the production status in the country, documented information on indigenous farmers' practices and the technologies generated by various institutes, developed packages of production practices, and examined the technology transfer system. Both the vegetable improvement (germplasm) and vegetable production consultants were appointed for about six and a half months. The postharvest management consultant made an overall evaluation of postharvest handling of different vegetables in terms of harvesting, transportation, and storage systems in Bangladesh. The vegetable protection (insect) consultant has prepared a list of various insect pests of vegetables and a list of insecticides available in the market. Information on the biology, life cycle, nature of damage caused by the major insect pests, and control measures through minimal use of insecticides was gathered. These two other consultants were appointed for four months. Information on vegetable diseases was gathered through a contract paper on vegetable diseases and their control in Bangladesh.

Detailed reports of the consultants were distributed to BARC, BARI, USAID, ARC, and AVRDC headquarters.

Extension materials

Under ARP-II (Supplement) extension handouts and booklets were published in Bangla for the use of farmers and extension workers for 1993.

Tomato varieties (handout in Bangla) — 5000 copies
Simple seed storage (booklet in Bangla) — 3000 copies
Home composting (booklet in Bangla) — 2000 copies
Copies have been distributed to the scientists, farmers, NGOs, and extension workers.

AVRDC publications

Copies of 254 different AVRDC publications have been received. These publications are being distributed to the research and extension staff of NGOs, libraries of different institutes, and organizations in the country.

Project Evaluation

An external evaluation of AVRDC-BARC/BARI vegetable component of ARP-II (Supplement) USAID Project No. 388-0051 was done during May 1993 to assess its achievements. The evaluator found that the project had responded well to the majority of tasks set forth in the terms of reference. In the short span of two years, the project has initiated meaningful activities to address research and development imperatives. The evaluator suggested that this time span was too short to make an impact on the national agricultural research system At least 5 years is needed to evaluate any crop improvement program. Extension of the project for another three years was strongly recommended.

Regional Program

Asian Regional Center

Summary

The Asian Regional Center (ARC) of AVRDC was officially approved for establishment in Thailand by the Royal Government of Thailand during its ministerial cabinet meeting on 21 July 1992. The agreement on the establishment and operation of ARC-AVRDC was formally signed by the president of Kasetsart University as the official representative of Thailand and by the director general of AVRDC. The signing marked the conversion and expansion of the Asian Development Bank-supported AVRDC-Thailand Regional Training and Outreach Program (AVRDC-TOP) into the Asian Regional Center of AVRDC.

As envisioned, ARC aims to bring AVRDC closer to its national partners and to enable the Center to respond more effectively to the differences in the needs and the capabilities of the region. It is expected to carry out research programs and training and information activities appropriate to the needs of the region. Specifically, the regional center has the following responsibilities:

(1) assume primary responsibility for the improvement of the Asian vegetable crops and production systems;
(2) conduct applied and adaptive research on AVRDC and ARC principal vegetable crops, as appropriate to the regional needs;
(3) coordinate the ARC subregional networks and provide them with scientific, administrative, and logistic support;
(4) link regional programs with activities at headquarters and elsewhere, and provide feedback for AVRDC headquarters program planning;
(5) organize training, with emphasis both on research and production, develop specific training information and materials, and translate publications into local languages; and
(6) develop and administer country projects within the region.

The ARC's mandated crops are: mungbean, soybean, yard-long bean, amaranth, snap bean, water convolvulus, okra, and other crops of specific importance to each of the 17 countries covered by ARC.

Coordination of the three networks, AVNET, SAVERNET, and ARC-China also falls under the ARC sphere of responsibility. Furthermore, ARC will be linking all national programs to AVRDC headquarters and to provide feedback for program planning. Since its inception on 10 November 1992, ARC has focused on continuing the regional program while expanding its sphere of research activities, e.g., transfer of the AVRDC mungbean program. Considering its limited resources, ARC spent a big part of 1993 seeking funds. Its activities and accomplishments for the year are discussed here.

Research

A total of 53 experiments were conducted in the field of ARC-AVRDC by ARC researchers and their associate scientists at Kasetsart University. During the regular cool season planting (November 1992 to March 1993), 80% of the experiments conducted in the field were those of the participants in the 11th Regional Training Program. Summaries of the results of the regular experiments and those conducted by the training scholars are presented here.

Tomato

Germplasm collection and seed production of tomato

A total of 203 tomato varieties from various sources have been collected for the past 10 years. Each variety has been tested at least once under Kamphaengsaen experimental field conditions. Data on varietal characteristics such as marketable yields obtained separately from both cool and off-season, heat tolerance, bacterial wilt resistance, tobacco mosaic virus resistance, yellow leaf curl virus resistance, and also fruit characters such as size, shape, color, cracking, firmness, and others were collected in detail. Seeds were multiplied and kept in a temperature and moisture controlled storage room. These seeds and information about them are available to any institution or interested researcher working on tomato improvement programs in Thailand or nearby countries.

Effect of nitrogen on fruit-set, yield, and quality of heat-tolerant tomato

The effect of nitrogen on the fruit-set, yield, quality, and disease reactions of two distinct heat-tolerant tomatoes was evaluated under ARC conditions from October 1992 to February 1993. The nitrogen requirement for high marketable yield for different types of tomato was also recorded. Nitrogen was found to have distinct effects on two different genotypes with respect to many phenological characteristics such as fruit setting behavior, yield, quality, and disease development aspects. A significant increase in fruit set of heat-tolerant TN No.3 was attributed to N application, but no significant increase in fruit set was noted with nitrogen application to the heat-sensitive P 490. Nitrogen application resulted in a lower brix value for both genotypes. Increased application of nitrogen in heavy soil resulted in higher mortality due to the toxic effect, and more fungal wilt and rot complex diseases.

Fresh market tomato varietal trial

Twelve tomato entries from AVRDC and China including six determinate and six indeterminate types were evaluated for their yield and adaptability. Determinate PT 4225 and PT 4121 from AVRDC gave the highest total yield of 9.9 t/ha and 9.2 t/ha, respectively. They had good fruit characters for processing in tropical countries. Indeterminate FMTT 22 gave the third highest total yield of 65.4 t/ha and possessed good horticultural characters except for the green shoulder of the fruit. It showed heat tolerance and disease resistance, making it a good variety for fresh tomato production in tropical countries.

Sukang No.11 had a higher early yield of 4.1 t/ha and a moderate total yield of 5.2 t/ha. It had a large mean fruit weight, good fruit setting, and resistance to bacterial wilt. It was the best variety among the Chinese entries in this trial. All of the entries, except Sukang No.3 and Sukang No.7, had good fruit setting and resistance to bacterial wilt. The major disease problem in this trial was tomato yellow leaf curl virus (TYLCV). None of the tomato varieties were resistant to this virus.

Tomato seed quality as affected by seed age and ripening periods

Tomato cv. Seedathip 2 was harvested at 25, 30, 35, and 40 days after flowering (DAF) and incubated at room temperature for 0, 5, and 10 days. The highest germination and vigor percentages were obtained from seed harvested at 30 DAF with 10-day ripening (95%) and at 40 DAF without ripening (93%). Seed at 25 DAF with 10-day ripening, 30 DAF with 5-day ripening, 35 DAF with 5-day ripening, or 40 DAF with 5-day ripening showed varied germination percentages, ranging from 79.5 to 84.0%.

Pepper

Characterization and seed multiplication of *Capsicum* germplasm

The characteristics of 100 accessions of *Capsicum* were studied at the Tropical Vegetable Research Center, Kasetsart University, Kamphaengsaen Campus from October 1990 to August 1991. Only 81 accessions were classified into either three species: *Capsicum annuum* L., *C. frutescens* L., and *C. baccatum* L. or four groups based on the fruit characters: sweet pepper (12 accessions), big chili (35 accessions), hot pepper (16 accessions), and ornamental (18 accessions). The promising accessions were C 00270 and C 00344 (sweet pepper); C 00001, C 00006 and C 01160 (big chili); C 00263, C 00268 and C 00312 (hot pepper) and C 00633 and C 00490 (ornamental).

Effects of light and sucrose on pollen germination of *Capsicum annuum* cv. Banglane Pan Lak and Prik Chee Pha Bangkhen

The germination of *Capsicum annuum* cv. Banglane Pan Lak pollen collected from dehiscent and nondehiscent anthers in a culture medium containing 25% sucrose, 100 ppm H_3BO_3, 300 ppm $Ca(NO_3)_2.4H_2O$, 200 ppm $MgSO_4.7H_2O$, and 100 ppm KNO_3 was studied. The results indicated that the pollen grains derived from both dehiscent and nondehiscent anthers germinated in dark conditions better than in cool light. The germination percentages of pollen grains from dehiscent and nondehiscent anthers were 2.9 and 7.7 under dark condition and 0.2 and 0.5 under cool light, respectively. Moreover, for *Capsicum annuum* cv. Prik Chee Pha Bangkhen, it was found that germination percentages of pollen increased in proportion to sucrose concentration, attaining maximum levels at 25%.

Application of tissue culture technique for production and micropropagation in pepper

The effects of plant growth regulators (auxin and cytokinin) on callus initiation and callus growth from leaf, petiole, and internode of pepper (*Capsicum frutescens*) cultured on Murashige and Skoog (MS) media containing 0, 0.5, 1.0, and 3.0 mg/l of ∂-naphthalene acetic acid (NAA) or 2, 4 dichlorophenoxy acetic acid (2, 4-D) and in combination with 6- benzylaminopurine (BAP) or 6 furfurylaminopurine (kinetin) at 0, 1.0, 5.0 and 10.0 mg/l were studied. The results showed that cultured explants formed callus on media supplemented with every concentration of NAA or 2, 4-D. The petiole had the highest percentage of callus initiation at 94.4% on media supplemented with 0.5 mg/l of NAA or 1.0 mg/l of 2, 4-D. Explants induced the largest callus on media supplemented with 0.5 mg/l of 2, 4-D. NAA promoted formation of compact callus while 2, 4-D promoted formation of friable callus when used in combination with cytokinin. The highest percentages of callus initiation were 100% and 96.7% from leaf and internode, respectively, cultured on media supplemented with 1.0 mg/l of 2, 4-D combined with 1.0 mg/l of BAP. Callus

initiation was 96.7% and 96.3% on petiole cultured on media supplemented with 0.5 mg/l of 2, 4-D only and in combination with 1.0 mg/l of BAP, respectively. Explants produced the largest callus on media supplemented with 0.5- 3.0 mg/l of 2, 4-D combined with 1.0 mg/l of kinetin.

For multiple shoot induction study, shoot tip, node, and seed of *C. frutescens* and *C. annuum* were cultured on MS media supplemented with BAP or kinetin at 0, 1.0, 5.0, and 10.0 mg/l. Explants but not seed of *C. frutescens* produced multiple shoots on MS media supplemented with BAP 5.0 and 10.0 mg/l. The highest number of shoots was 3.7 obtained from seed of *C. annuum* cultu . on the media supplemented with 10.0 mg/l of BAP. Kinetin had no effect on multiple shoot induction in *C. frutescens* but nodes of *C. annuum* could form multiple shoots when supplied with 5.0 and 10.0 mg/l of kinetin.

Isolation of cucumber mosaic virus from pepper in Thailand

Cucumber mosaic virus (CMV) isolated from field-infected pepper was identified on the basis of host reaction, morphology, and serological reaction. Crude sap extracted from pepper plants induced necrotic local lesions when inoculated into *Vigna sinensis* and *Chenopodium amaranticolor*. It also caused mosaic symptoms on *Nicotiana glutinosa* and *Nicotiana tabacum*. The spherical particles were observed under a transmission electron microscope using partially purified virus preparation. Sap from the infected *N. tabacum* reacted with antiserum of CMV by agar gel double diffusion test.

Sweet pepper varietal trial

Eight pepper varieties were evaluated for their yield and horticultural characters. The yield of the tested varieties ranged from 1.91 kg/plot to 11.88 kg/plot. TVRC no.1 had the highest total yield, the highest fruit weight, and good horticultural characters. However, it was susceptible to pest. Jumbo had the second highest total yield with the most number of fruits per plant at 76.4. TVRC No.14 had the lowest pest and disease damage at 23.2% and 78.6%, respectively.

Hot pepper varietal trial

The performance of 20 hot pepper varieties was evaluated. Results showed that there were significant differences in marketable yield, total yield, and horticultural characters among the varieties. Total yield of 20 hot pepper varieties ranged from 3.5 t/ha to 35.2 t/ha. Xiangyan No.6, Xiangyan No.20, and Xiangyan No.5 showed the highest total yield of 35.2 t/ha, 33.5 t/ha, and 33.5 t/ha, respectively; and highest marketable yield at 34.8 t/ha, 32.9 t/ha, and 33.1 t/ha, respectively. Varieties Leuang, Chao Khon Kaen, and 83-168 produced the lowest total and marketable yields and had undesirable horticultural characters. Total yield had significant positive correlation with average fruit weight, fruit width, and fruit wall thickness. It had significant negative correlation with number of fruits/plant, days to flower, days to first harvest, order of first flower node, and plant height.

Soybean

Development of Nakhon Sawan I soybean resistant to downy mildew

Soybean (*Glycine max* L.) Merr var. Nakhon Sawan I (NS I) was improved by incorporating resistance to downy mildew incited by *Peronospora manshurica*. The backcross method was used to transfer resistant genes from var. AGS 129 to NS I. Six backcross generations, the

recurrent parent (NS 1), and donor parent AGS 129 were evaluated for 12 agronomic characteristics such as days to flowering, plant height at harvest, leaf 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 and expressed uniformity for downy mildew resistance were visually selected from BC_5F_2 generation. The selected isolines were evaluated in a replicated trial where data on four characters, i.e., plant height, number of pods per plant, 100-seed weight, and seed yield were recorded.

The population means of BC_1 and later backcross generations were found not different from the recurrent parent in all traits, except for plant height at harvest and days to harvest which have been stable since BC_2 and BC_6 generations, respectively. All 15 isolines selected from BC_5F_2 were not different from NS 1 in the four traits studied. It was concluded that the backcross method employed to improve resistance to downy mildew on NS 1 was successful in five backcrossings. Seeds of the isolines were increased by Kasetsart University for distribution to farmers and government sectors.

Purple nutsedge control in soybean with imidazolinones and chlorinuron in combination with glyphosate

Glyphosate at the rates of 750 and 1500 g ai/ha in combination with 9 and 12 g ai/ha of chlorinuron, 10 and 12 g ai/ha of imazapyr, 140 and 280 g ai/ha of imazaquin, and 100 and 125 g ai/ha of imazethapyr were applied to 1-mo-old weeds. Soybean variety SJ 4 was used. The herbicide was applied a day after soybean seeds were sown. At 4 wk after application, high rates of glyphosate in combination with both rates of chlorinuron reduced purple nutsedge shoots 60-70%. Imidazolinones and chlorinuron applied alone or in combination with low rates of glyphosate gave only poor to fair weed control.

Post-emergence application of diphenyl ethers for broadleaf weed control in soybean

Diphenyl ethers provided good broadleaf weed control when applied at a time not later than 2 wk after soybean germination. The susceptibility of weeds to herbicides was in the order of *Trianthema portulacastrum* > *Amaranthus hybridus* > *Euphorbia heterophylla*. High rates of herbicides caused more phytotoxicity to soybean than low rates. The phytotoxicity of herbicides to soybean was in the order of lactofen > acifluorfen > formasafen. The tolerance of soybean was in the order of SJ 57 > White Lion > AGS 205 > AGS 305.

Grass control in vegetable soybean with cyclohexenes

Echinochloa colona was more tolerant, while *Digitaria adscendense* was moderately tolerant; but *Dactyloctenium aegyptium* was susceptible to cyclohexenes when applied at 1, 2, and 3 wk after soybean germination. Grasses were more susceptible to herbicides when applied 2-3 wk after germination than when applied immediately 1 wk after germination. Cycloxydim provided more efficacy on weed control than others, while clethodim gave slightly better control than sethoxydim. Application of herbicides at different stages of growth did not affect the yield of soybean. There were differences among herbicides, with cycloxydim application increasing yield of soybean more than clethodim and sethoxydim. However, yields of soybean treated with clethodim or sethoxydim did not differ. Soybean yield increased with the increased application rate of herbicides.

Vegetable soybean varietal trial

Five vegetable soybean cultivars, namely, AGS 292, Shironomai, Tengamine, Oufurisde, and Karitea were evaluated for their yield and agronomic characteristics. The yield component was significantly different among the varieties. AGS 292 gave the highest marketable yield of 5.5 t/ha with the lowest marketable pod per 500 g, while the variety Karitea gave the lowest marketable yield with the highest number of marketable pods per 500 g. All varieties were harvested at an average of 62-66 days after sowing.

Soybean germplasm evaluation

Nine hundred and ninety-six soybean accessions were evaluated in ARC-AVRDC experimental fields according to the traits listed in the AVRDC-GRSU characterization record sheet. The germplasm was divided into 25 sets. Set 1 to set 24 consisted of 40 entries each; while the last set consisted of entry number 961-996. The average number of days from emergence to flowering ranged from 30 to 45 days. The average plant height at R_1 of all entries ranged from 25 to 30 cm, while at R8 it ranged from 35 to 50 cm. Lodging occurred predominantly among the bushy varieties. The average number of pods per plant ranged from 15 to 20 pods.

Effect of N-fertilizer on vegetable soybean yield

This experiment aimed to determine the response of vegetable soybean to seven N fertilizer rates. The weight of fresh pods, number of two-seeded pods/10 plants, average seed weight and harvest index were significantly different among the treatments. There was no significant difference in the yield of vegetable soybean among 60 kg N/ha, 120 kg N/ha, 150 kg N/ha, and 180 kg N/ha treatments. Application of 0 and 30 kg N/ha tended to give the lowest yield.

Relationship between spacing and yield of soybean

An experiment was conducted to identify optimum plant densities of soybean cultivars. Three of them were Chinese cultivars, while the rest were Thai cultivars. A split-plot experiment in randomized complete block design with three replications was used. Two populations were assigned on the main plot, while the cultivars were on the subplot. Soybean yield increased as the plant population increased. The yield obtained from the spacing 10 x 50 cm^2 was higher than that of 20 x 50 cm^2. The Thai soybean varieties SJ 4 and CM 60 at the spacing of 10 x 50 cm^2 gave the highest yield. All the Chinese soybean varieties in this experiment gave lower yields due to nonadaptation to Thailand conditions.

Cluster analysis of soybean varieties

A study aimed at yield improvement of tropical soybeans was conducted, a method of choosing parents for hybridization by quantitatively measuring genetic divergence with the data on several characters measured from 25 soybean varieties from different geographic regions. The soybean genotypes were classified into five groups by this method. A plan for formulating a crossing program based on the information of the statistical distance among different groups was discussed briefly.

Inheritance of embryoid formation ability in soybean

Somatic embryogenesis in soybean was observed to be varietal dependent. In Thailand it was observed that young cotyledons from NS 1 formed more embryoids than the cultivars SK 1 and

Chiangmai 60 (CM 60). If the embryoid formation is heritable, it would be useful for a plant breeder to incorporate the high ability character into the low genotypes. This would broaden the application of tissue culture technique in soybean improvement.

Crosses were made among NS 1 x CM 60 and NS 1 x SK 1 to obtain F_1 and F_2 seeds. At harvest, seeds from the reciprocal crosses, NS 1 x CM 60, CM 60 x NS 1 and NS 1 x SK, SK 1 x NS 1 were maintained separately. Seeds from each plant were sown as plant to row in three planting dates. The dates then served as replications. In each replication, parents were also sown along with the progenies. When young seeds in a pod reached the size of 3-5 mm in diameter they were picked for culturing. The culture media varied according to the purpose. The young cotyledons were placed first on the induction medium to induce embryoids. The embryoids were then dissected aseptically and the dissected pieces placed on the maturation medium for 2-3 wk. The mature embryoids were then transferred to the regeneration medium to produce plantlets.

Results showed that embryoid formation ability of soybean in this experiment is not controlled by a single gene. However, there are possibly major genes working together with a number of minor genes. More data is being collected to further clarify the mode of inheritance.

Introgression of the gene controlling an absence of Kunitz trypsin inhibitor in soybean

Kunitz trypsin inhibitor is a major trypsin inhibitor commonly found in almost all soybean cultivars. It causes poor digestibility when raw soybean is fed to monogastric animals and humans. The indigestion may cause pancreatic hypertrophy and growth inhibition due to the imbalance of methionine and cystein in the pancreas. During the late 1970s at the University of Illinois it was discovered that soybean accessions PI 157440 and PI 196168 were lacking this inhibitor. The soybean cultivar Kunitz which is free of the inhibitor has 30-50% less in overall proteinase inhibition. Developing a soybean cultivar with Kunitz trypsin inhibitor is the first step toward improving soybean seed nutrition in Thailand.

The recommended cultivars NS 1 and CM 60 were crossed with Kunitz and the F_1 seeds were electrophoretically analyzed to compare the enzymatic bands with the parents.

Results showed that the production of this trypsin is conditioned by a single gene with codominant alleles. This is the same as that reported earlier by Orf and Hymowitz. The next step is to employ a series of backcrossing and obtain NS 1 and CM 60 with no Kunitz inhibitor.

Mungbean

In June 1993 the AVRDC mungbean program was officially transferred to ARC in Thailand. Reports of the mungbean program at AVRDC are included in another section of this report. The following are summaries of the mungbean studies conducted at AVRDC-ARC before the transfer of the mungbean program.

Inheritance of resistance to bruchids in mungbean

Two mungbean lines — V 2709 and V 2802 — reported to be resistant to bruchids (*Callosobruchus maculatus*) were tested. To obtain resistance from the multiple gene source rather than the single gene source, seeds of V 2709 and V 2802 from AVRDC headquarters were increased for seed in 1989 and tested for reaction to insect infestation in three replications. The latter two replications were conducted a few months after the first test. After resistance was confirmed, crosses were made among the two lines with KPS 1 and KPS 2. Four direct and four reciprocal crosses were obtained. Each F_1 was backcrossed by both resistant and susceptible parents to get BC_1 and BC_2. Thus, there were six generations in a cross, i.e., P_1, P_2, F_1, F_2, BC_1 and BC_2. Each of the eight crosses were sown in late 1990. Data from individual plants were collected

and the seeds were kept for evaluation of bruchid resistance. Seeds from each plant were placed in a 100-ml plastic box infested with 30 adult bruchids and observed for 2 mo for egg and adult number.

Bruchid infestation on parental lines are shown in table 1. Infestation in KPS 1 and KPS 2 was far more than in V 2709 and V 2802 indicating that the latter two lines carried a number of genes conditioning the resistance.

Table 1. Bruchid infestation (%) of parental mungbean lines tested in the laboratory 1990

Lines	1st test	2nd test	3rd test	Avg.
KPS 1	36.0	97.2	34.0	55.7
KPS 2	25.3	95.2	83.6	68.0
V 2709	0.0	18.4	1.2	6.5
V 2802	0.0	2.8	3.2	2.2

The progenies derived from the above crosses have been tested throughout 1992 for reaction of the insects as well as for agronomic characters. Data are being analyzed according to the generation mean analytical method.

Inheritance of tolerance to micro-essential element deficiency in Takhli soil series in mungbean

Although KPS 1 and KPS 2 are very well accepted by the Thai farmers, they survive poorly in alkaline soils which are deficient in Zn, Mn, or Fe. Identification of tolerant genotypes and mode of inheritance to the character will help identify donor parents with tolerant genes to be incorporated into susceptible lines.

A set of 51 mungbean accessions from AVRDC, Thailand, and Pakistan were sown in alkaline soil (Takhli series). Five tolerant accessions were used: UT 1, CN 36, ATM, NM 6-97, and NM 10-42. Another five accessions, i.e., KPS 1, KPS 2, VC 1628A, VC 4059A, and VC 4143A were extremely susceptible to nutrient deficiency in the soil. These 10 lines were reconfirmed for their reactions once more in early 1992. NM 6-97 and NM 10-12 from Pakistan were identified as more tolerant than any other accession. They were crossed with KPS 1 and KPS 2 to obtain the F_1 seeds. The backcross and F_2 progenies are being produced for further tests.

Initial data revealed that Takhli soil is deficient in Zn. Tolerance to the deficiency is likely to be conditioned by major genes with modifiers. The detailed genetic analysis is under investigation and the plan is to set up a study incorporating the tolerant gene(s) into KPS 1 and KPS 2.

The 19th International Mungbean Nursery Trial

Twenty mungbean lines from AVRDC and major mungbean growing countries were evaluated for their yields and agronomic characters from November 1992 to February 1993 at ARC fields in Kamphaengsaen, Nakhon Pathom, Thailand. The highest yield was obtained from VC 2764B with 1.8 t/ha. Its agronomic characters were also good. It has suitable plant height, medium number of pods per plant, high number of seeds per pod, medium weight of 1000 seeds, and resistance to lodging. The other promising lines were VC 4152B and VC 3541B. They were

not only high yielding but also large-seeded. However, VC 4152B is a dull-seeded line which may have rather limited planting areas in Thailand.

Mungbean varietal trial

A nonreplicated mungbean yield trial was conducted in the field of ARC-AVRDC from November 1992 to 3 February 1993. The trial consisted of 197 F_5 mungbean lines from Pakistan with three recommended cultivars as checks. The lines were evaluated for their yield, agronomic characters, and disease resistance. The yields of 11 lines (3-51, 7-119, 10-12-5, 10-12-8G, 10-43-6, 14-2, 16-2, 23-11, 14-1, 5-80, and NM-54) ranging from 6.9 to 8.7 g/plant were higher than the checks. These lines also had superior agronomic characters and were resistant to foliar diseases.

Evaluation of mungbean lines for resistance to insects

Forty-three mungbean lines and four parents from AVRDC were evaluated for their insect resistance at the seedling stage, high yield, and early/uniform maturity. There were significant differences in terms of insect resistance among the entries, with seven AVRDC mungbean lines and two parents rated as having high resistance to the insect. Eighteen lines had nonuniform resistance at different times. The others were susceptible. Lines (VC 2768A x VC 2802)-1 and VC 38904 x TC 1966)-2 had low resistance but higher yield potential, early and uniform maturity. Line (VC 2778A x TC 1966)-2 expressed nonuniform insect resistance with highest number of pods per plant, number of seeds per pod, and yield per plant.

Evaluation of mungbean lines for resistance to *Callosobruchus chinensis*

Seeds of two mungbean populations, one from a cross between bruchid-resistant mungbean and high-yielding mungbean breeding lines and the other from a cross between the two high-yielding parents with two high-yield parents were evaluated for resistance to a storage pest, *Callosobruchus chinensis*. Results indicated that the two susceptible checks had 80-95% damage, while the two highly resistant parents (check) had only minor damage.

The damage to the BC_3F_4 population was less than that to the two highly resistant parents. These lines were also free from insect infestation. Resistance to this storage pest appeared to be genetic.

Cucumber

Growth and yield performance of six cucumber varieties

Four selected varieties of cucumber, namely, Jed Bai, C-5, C- 20, and C-21 were compared to two commercial varieties — Star Brand and Golden Cup — for their growth characteristics and yield performance under vertical training on the net. The results showed that Jed Bai, C-20, C-21, Star Brand, and Golden Cup produced pistillate flowers on lateral branches at the fourth to the ninth node of the main stem. C-5 produced pistillate flowers directly on the sixth to the 10th node of the main stem and then produced pistillate flowers at lateral branches. C-21 had the highest yield per plant (20 fruit/plant).

Flowering patterns and effect of planting dates on sex expression of two types of cucumber (*Cucumis sativus* L.)

Flowering patterns and effect of planting dates on sex expression were studied in two cucumber types, i.e., long fruit (cv. Jed Bai) and small or short fruit (cv. C-4) at ARC-AVRDC from July 1990 to January 1992. The flowering pattern of Jed Bai consisted of three major phases. The first phase showed only male flowers while the second showed a mixture of male and female flowers. C-4 consisted only of the first two phases as found in variety Jed Bai.

The study on the effect of three planting dates (seasons), winter (January to February), summer (April) and rainy season (July to August), on sex expression of both cultivars found that the plants grown in winter and rainy seasons produced earlier and more female flowers per plant than those grown in summer. The summer and rainy season cucumber produced more male flowers per plant than those grown in winter.

Cucumber evaluation trial

Six cucumber varieties from various countries were evaluated from November 1992 to January 1993 at the ARC-AVRDC experimental field, Kamphaengsaen, Nakhon Pathom. Taeng Ton variety gave the highest marketable yield of 10.9 kg/plot with desirable fruit quality. Bukit Mertajam was also promising in terms of early yield and fruit weight. LV-1043 was predominately a female type which will be very useful for developing gynoecious lines. Correlation between yields and other characters was significant.

Effect of mulching method on growth and yield of cucumber

This study determined the effect of plastic and rice straw mulching on the growth and yield of cucumber. The experiment was carried out at the experimental field of ARC-AVRDC, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, Thailand from 17 November 1992 to 3 February 1993. Results indicate that there was no significant difference in the yield, flower characteristics, ratio fruit set per female flowers, and fruit width of Jed-bai and Pol-lek cucumber varieties. Jed-bai exhibited greater fruit size, length of plant, and mean weight of fruit than that of Pol-lek. Method of mulching had significant effect on the total yield, number of fruits per plant, length of plant, number of branches, and the production of male and female flowers. The black polyethylene plastic mulch was found to significantly increase cucumber yield.

Chinese Cabbage

Chinese cabbage varietal trial

Ten Chinese cabbage entries, nine from AVRDC and one from Thailand were evaluated for their yield and horticultural characters in the ARC field in RCBD with four replications.

Significant differences were observed among the accessions for yield and horticultural characters. ASVEG No. 1 gave the best performance in terms of marketable yield and some other horticultural characters. B 40 performed very poorly, while all other entries from AVRDC showed acceptable yield and horticultural characters.

Effect of planting methods and mulching on the yield of Chinese cabbage

The yield response to planting methods such as in situ planting, transplanting, and mulching with rice straw at 0, 2.5, and 5 t/ha was studied using ASVEG No.1 and Elephant Brand varieties of Chinese cabbage under Kamphaengsaen conditions. Rice straw mulching at the rate of 2.5 t/ha was confirmed effective in increasing the yield of Chinese cabbage. Transplanting method contributed more to production than in situ planting. The hybrid cultivar, ASVEG No.1, performed better than the commercial variety Elephant Brand. Likewise, transplanted ASVEG No.1 was promising in terms of yield, yield components, and other horticultural characters. The effect of other treatment combinations was insignificant.

Nonheading Chinese cabbage varietal trial

Eight varieties of nonheading Chinese cabbage from Taiwan were evaluated for their yield, horticultural characters, and eating quality. Significant differences among all tested entries were found in their total yield, mean plant weight, days to maturity, and several horticultural characteristics such as leaf color, plant height, width, and eating quality. The tallest among the varieties was B 471, while B 65 was of medium height. B 54 was the shortest among the varieties and the earliest to mature.

Insect damage on heat-tolerant crucifers

The insect pests and the damage they inflicted on some heat-tolerant crucifers grown in the ARC-AVRDC field was observed from 7 December 1992 to 14 February 1993. Insect pests were found as one of the key factors that limit the production of cruciferous crops in the lowland humid tropics, in spite of the heavy use of chemical insecticides. The most serious insect pests were diamondback moth, cabbage moth, rice cut worm, and cabbage aphid. *Cotesia plutellae*, the parasitoid of diamondback moth, might play an important role in the control of this pest, if insecticide was not overly used.

Mass rearing techniques and selection of *Trichogrammatoidea bactrae*

Trichogrammatoidea bactrae, one of the important parasitoids of the diamondback moth, was mass reared using the eggs of rice moth (*Corcyra cephalonica*) as host. The virgin female parasitoids were able to produce only male progeny. When a female parasitoid was allowed to stay with one male or more, the numbers of parasitized eggs increased but the percentage of emergence decreased. More female than male progeny were produced. However, when male parents were few, sex ratio of the progeny will be in favor of the male. The selection of parasitoid resistant to fenvalerate was not successful. The F_1 progeny was more susceptible to the insecticide than the parent. The insecticide might have affected the condition of surviving parents and resulted in the weaker progeny.

Common Cabbage

Effect of nitrogen fertilizer on common cabbage yield

The effect of nitrogen rates: 0, 40, 80, 120, 160, 200, and 240 kg/ha was investigated on yield, yield components, and other horticultural characters of Flying Kid, a variety of common cabbage, under Kamphaengsaen, Thailand conditions. Results indicated that N application significantly increased the yield, yield components, and other horticultural characters of common cabbage.

Application of nitrogen up to 160 kg/ha gave the highest significant yield. Results likewise showed that application of N-fertilizer significantly increased head formation and also significantly induced earlier head formation in common cabbage. For optimum and maximum rates of N-fertilizer application on total yield and marketable head yield, the regression equations Y = 8.028 + 1.33 - 0.000265 and Y = 0.376 + 0.0413 - 0.0000672 were considered, respectively. The optimum rate was found to be 160 kg/ha for both yield parameters. The maximum rates for total head yield and marketable head yield was 251 kg/ha and 252 kg/ha.

Cauliflower

Cauliflower varietal evaluation trial

Seven commercial cauliflower varieties were tested for their yields and horticultural characters. The main objective of this evaluation was to learn which varieties have high yield, early maturity, and resistance to major pests and diseases.

In this experiment, data could not be analyzed due to various problems encountered: severe attack of diamondback moth (DBM) for the whole growing period, poor soil condition, and scarcity of water, among others. Despite all these problems, some of the varieties still produced yields of 7.8-9.7 t/ha. The highest yield obtained in last year's experiment was 19.3 t/ha by Flying Kid.

Snap Bean

Snap bean varietal trial

Several varieties of snap bean, both determinate and indeterminate, were evaluated under the climatic conditions of the ARC-AVRDC field at Kamphaengsaen Campus, from 18 November 1992 to 1 February 1993.

The variety TVRC, early to mature and with the longest and the widest pods, gave the highest marketable yield at 6.5 t/ha. The variety no. 153 from AVRDC, Taiwan, gave the highest number of pods per plant (51.3).

Chinese Radish

Chinese radish varietal trial

Six Chinese radish varieties were evaluated for their yield, yield components, root characters, and tolerance to insect pests at the ARC-AVRDC experimental field at Kamphaengsaen Campus, from 1 December 1992 to 13 January 1993. All varieties matured within 44 days. Kaoyuak, A1-F1, and A1 performed better than the check Everest in terms of yield, yield components, and root character. Kaoyuak was the best among all six varieties tested, producing the significantly highest marketable root yield of 33.7 t/ha. There were no significant differences between A1-F1 and A1 in terms of marketable root yield. However, no variety was found tolerant to diamondback moth and flea beetle.

Baby Corn

The effect of spacing and population on baby corn yield

This study was undertaken to examine the appropriate plant density for baby corn production from December 1992 to March 1993 at the ARC-AVRDC experimental field, Kamphaengsaen Campus. The baby corn yield was not significantly affected by the interaction between spacing and number of plants per hill. However, the closer spacing, 80 cm x 20 cm, with more plants per hill gave the highest yield of 1.8 t/ha without husk and highest number of baby corn ears (243,828/ha) while the wider spacing, 80 cm x 80 cm, with single plant per hill gave the lowest yield of 1.2 t/ha without husk.

Asparagus

Effect of chlorine treatment, setting spears in water, and packing methods on postharvest quality of asparagus

The effect of chlorine treatment, setting spears in water, and packing method on the postharvest quality of asparagus UC no.309 for export to European markets was evaluated. Washing spears in water with chlorine from either $Ca(OCl)_2$ or NaOCl at concentrations of 100-400 ppm resulted in decay of only 2.09-5.11%, whereas, those washed in water without chlorine showed decay of up to 32.5%. Setting spears in tap water at levels of 2-10 cm for 1-5 h had no significant effect on fiber content, but setting spears in water at the 2-cm level for 1 h resulted in the least amount of fiber content. Setting spears in water at temperatures of 1+1°C and 28+1°C had no significant effect on fiber content, but higher temperatures resulted in less fiber content. Dry and wet packing of spears in corrugated boxes had no significant effect on fiber content; but wet packing resulted in more decay of spears.

Training

The 12th Regional Training Course started on 15 October 1993 with 22 participants from 10 countries (table 2). For the first time training scholars from Papua New Guinea participated who are sponsored by their own government. As in the past, some of the training scholars are being sponsored by private organizations.

ARC was also responsible for coordinating and arranging special training for some Thais and Vietnamese at AVRDC headquarters. Sponsorship of these trainees was through special projects and the Food and Agriculture Organization (FAO).

A special study tour for officials of the Malakand Fruit and Vegetable Development Project based in Swat, North West Frontier Province of Pakistan was conducted from June to July 1993. ARC staff was also involved in a special 6-wk FAO training on farming systems; one of the training coordinators came from ARC.

Special short courses were also conducted for agricultural students and a group of technicians specializing in vegetable products from various provincial agricultural colleges in Thailand. They came to ARC to conduct their special projects and field practicum. The ARC/Thai staff gave lectures and acted as special project advisors.

Table 2. The 12th Regional Training Course in Vegetable Production and Research participants

Name	Country	Sponsor
Mr. Phoeung Nady	Cambodia	SDC
Mrs. Shi Lin-Qi	China	IDRC
Mrs. Liu Li	China	IDRC
Mrs. Cai Shuping	China	IDRC
Mrs. Chu Jin-Ping	China	IDRC
Mr. Xie Huajun	China	IDRC
Mr. Jiao Zigao	China	IDRC
Mr. Qian Yongzhong	China	IDRC
Mr. Kang Gaogiang	China	IDRC
Mr. Cui Dexiang	China	IDRC
Mr. Rao Zhihong	China	IDRC
Mr. A. Darwin Harahap	Indonesia	ARC-AVRDC
Mr. Khamphanh Thommavong	Laos	SDC
Mr. Viengsaisy Lang	Laos	SDC
Mr. Muhammad Farooq Chaudhary	Pakistan	ARC-AVRDC
Mr. Alfred Nongkas	Papua New Guinea	PNG Government
Mr. John Yamarak	Papua New Guinea	PNG Government
Mr. Joselito L. Antioquia	Philippines	ARC-AVRDC
Mr. Nguyen Ngoc Thanh	Vietnam	SDC
Mr. Ngo Quang Vinh	Vietnam	SDC
Mr. Prasan Vongchalerm	Thailand	ARC-AVRDC
Mr. Somchai Thaisamark	Thailand	ARC-AVRDC

Home Gardens

In addition to regular home garden demonstration trials which are being conducted for the newly released varieties of vegetables by both AVRDC and agricultural agencies in Thailand, five studies regarding home gardens were conducted by the 11th Regional Training Course (RTP) participants from Cambodia. The summary of their results are as follows:

Seed production for home garden (1)

A 60-m^2 area was planted to five home garden crops: green kwang futsoi, amaranth, cucumber, bitter gourd, and yard-long bean for seed production. Green kwang futsoi gave a total yield of 4.1 kg with a return of 58.27 baht; amaranth yielded 16.2 kg with a return of 269.00 baht. Bitter gourd had a total yield of 0.5 kg with a return of 150.20 baht, while yard-long bean gave a total yield of 1.3 kg with a return of 147.5 baht. Cucumber yielded only 0.2 kg with 36.93 baht loss. All plants except cucumber gave a profit. A net return of 588.12 baht was acquired from four crops planted in a 48-m^2 land.

Seed production for home garden (2)

The study on seed production for home garden was conducted with the idea of introducing it to the farmers of Bati, Cambodia. An area of 502 m^2 is sufficient to produce the needed 39 kg seeds of tomato and snap bean that will ensure 6000 home garden pilot projects.

Within a 4-mo period, the net return was 408 baht from 2.4 m^2 of land. The production cost for 39 kg seeds from a 502-m^2 land was 3774 baht. If the 39 kg of seeds had been bought from a commercial seed company, it would have cost 12,600 baht. Thus, the farmer can save 8825 baht when he produces his own seed from his own home garden.

Patterns of home gardens

The main objective of the study was to find out a productive home garden pattern which can give high net return, high product yield, and high nutritive yield. An improved ARC-AVRDC home garden and a Cambodia backyard garden were set up for testing.

The improved ARC-AVRDC home garden gave a product value of 96.2 kg which was 5.0 kg more than the yield obtained from the Cambodian backyard garden.

Both patterns of home gardens could substantially contribute to the family's recommended dietary allowance for protein, iron, calcium, vitamin A, and vitamin C, especially for the people in developing countries. The amount of protein, iron, calcium, vitamin A, and vitamin C produced by the ARC-AVRDC home garden was more than those from the Cambodian backyard garden. A net return of 1432.30 baht from the improved ARC-AVRDC home garden during 100 days was more than the net return of 1142.34 baht from the Cambodian backyard garden.

Effect of various fertilizers on home garden

The effect of using compost with chemicals, compost fertilizer, and no fertilizer input on the yield of selected vegetable crops in a home garden was studied. A 25 m^2-area was assigned for each variable of the fertilizer inputs. The plot with no input gave a total yield of 15.23 kg with a return of 195.13 baht. The compost with chemical fertilizer gave a yield of 46.37 kg with a return of 752.70 baht. The compost fertilizer plot gave a yield of 23.52 kg with a return of 353.58 baht.

In terms of total yield, fertilizer application produced a significant effect except in some crops like cauliflower which had no yield and sweet pea which produced the lowest yield. The compost fertilizer application was so low that the yield of tomato, green kwang futsoi, and kangkong were not higher than the yields of these vegetables in the untreated plots.

Crop protection in home garden through companion cropping

Companion planting in home garden was studied at the ARC-AVRDC experimental field. Green onion, water convolvulus, hot pepper, tomato, shallot, pepper mint, coriander, lemon grass, and marigold were found as good companion plantings in home gardens. They were not attacked by insect pests and gave good yield with high nutrient content. They also reduced insect damage on common cabbage, cucumber, yard-long bean, cauliflower, Chinese kale, and Chinese radish 30 days after germination. The companion planting provided a favorable condition for natural enemies.

Germplasm collection/exchange

A total of 976 packets of vegetable and legume seeds (mungbean = 336, soybean = 56, eggplant = 12, tomato = 209) from AVRDC and other producers were sent to various institutions and cooperating agencies in China, Vietnam, Cambodia, Pakistan, Bangladesh, and other countries all over Asia. With the transfer of the mungbean program to ARC, worldwide mungbean distribution will be conducted by ARC.

The germplasm collected in 1992 from all over Thailand are being multiplied one at a time. Results were sent to GRSU for incorporation in their reports. Half of the collection was sent to GRSU for safekeeping and half was kept at ARC for multiplication and safekeeping. One hundred kilograms of AVRDC mungbean VC 1973A or KPS 1 and VC 2778A or KPS 2 were purchased by the Church World Service (CWS), a nongovernmental organization in Cambodia, for seed production in Phnom Penh. Cambodia is one country where AVRDC germplasm materials are in great demand. Another hundred kilograms of KPS 1 and 2 were purchased by UNDCP (United

Nations Drug Control Program) of Myanmar for planting along the Thai-Myanmar border to replace onion. Germplasm collections from these countries are in order.

Workshops

In February 1993 ARC organized and cosponsored with AVRDC headquarters the International Symposium on Alliums for the Tropics held at the Emerald Hotel in Bangkok. It was attended by more than a hundred scientists from more than 50 countries. During the symposium the status, progress, and direction for *Allium* research were discussed.

A symposium which dicussed the status and the impact of AVRDC mungbean materials was coorganized with the Chinese Academy of Agricultural Sciences in August 1992. This special symposium was held in Chinhuangdao, a suburb close to Beijing. Several in-country workshops were conducted subsequently in different provinces in China.

Publications and Scientific Exchange

ARC continues to serve as a repository and exchange center for AVRDC publications in South, Southeast Asia, and China.

Other Activities

The Kasetsart University Research and Development Institute (KURDI) celebrated its 15th anniversary in October 1993. One of the crops highlighted during this celebration was ARC's vegetable soybean, KPS 292 or AGS 292. This is the major variety being grown by Thai farmers for vegetable soybean production. The impact of vegetable soybean in Thailand both for local market and export is tremendous. KPS 292 seeds are now being produced in large quantities by the Department of Agricultural Extension for distribution to farmers at 100 baht per kilo.

At the KURD celebration, the ARC director was given an award for his outstanding contribution to the development of Thai agricultural research and production, especially in the field of vegetable research.

Africa Regional Program

Introduction

The Africa Regional Program of AVRDC is an extension of the center into Africa, with the mandate to undertake vegetable research, training, and information services for the benefit of the African national programs.

This regional program commenced in July 1992 with the outposting of a training officer cum horticulturist to the regional headquarters at HORTI-Tengeru, Arusha, Tanzania, to prepare for the implementation of the training activities under the auspices of the Collaborative Network for Vegetable Research and Development in the SADC Region (CONVERDS). Training is an activity that was accorded the highest priority by the NARS in the SADC region. The program director (cum plant breeder) followed in October 1992, completing the initial set of senior scientists assigned to the Africa Regional Program.

Two projects are currently being implemented by the regional program, namely: (1) Tomato Improvement Program for the African Highlands, and (2) CONVERDS.

The goal of the highland tomato breeding program is to develop improved cultivars with resistance particularly to two major diseases, viz., tomato yellow leafcurl virus and late blight, which are among the most important diseases of tomatoes in these production zones. In addition, it aims to introduce, evaluate, and promote the adoption of the center's tropical tomatoes for production under the hot and humid conditions of Africa. This regional project fully complements the tomato breeding program for the lowland tropics at the center's Taiwan headquarters.

On the other hand, the major responsibilities of CONVERDS are research and training on behalf of the national programs of the SADC region. The vegetable species of research and development interest are: traditional vegetable species, tomatoes, onions, and the leafy Brassicas. The responsibilities to lead the collaborative research on behalf of the network have been allocated for the aforesaid species to Tanzania, Zimbabwe, Zambia, and Malawi, respectively. Lead responsibility for diploma and short-term training belongs to Tanzania, whereas, professional training is the responsibility of Zimbabwe.

Collaborative Research

In 1993, the Africa Regional Program conducted a number of priority research studies in collaboration with several Tanzanian researchers.

The tomato improvement program for the African highlands is a restricted core project funded by the German Ministry of Economic Cooperation/German Agency for Technical Cooperation (BMZ/GTZ). On the other hand, the traditional vegetables (TVs) are a very important group of vegetables in the SADC region. The mandate to lead the research in this commodity on behalf of CONVERDS belongs to the regional program's host country, Tanzania. As a group, the TVs have not ever received the research attention they richly deserve. Farmers and home gardeners, meanwhile, direly need improved production techniques.

Hybridization program. The tomato breeding program commenced hybridization work. Nine initial crosses were made to improve the local varieties, MoneyMaker and Roma VF, for

resistance to tomato mosaic virus and nematode. While these are not the major pests that the breeding project is supposed to address, they are equally important and widespread in the continent. Resistance is also controlled by single dominant genes, in both cases making them easy to breed for. Therefore, resistance breeding was started. Sources of resistance in the crosses are AVRDC breeding lines. Backcross breeding method will be applied on these crosses.

Selection experiment in Ethiopian mustard. While carrying out management studies on the local population of Ethiopian mustard (*Brassica carinata*), we noted marked variation in several traits. The most striking differences were an apparent "tolerance" to the turnip mosaic virus (TuMV) and in stem color (several shades of purple and green). Twenty-nine selections varying in levels of TuMV tolerance and stem color were made. Each selection was selfed to establish S1 lines which will be tested next for TuMV tolerance and segregation for stem color. New populations with high frequency of TuMV-tolerant plants and/or pure for stem color will be reconstituted from the progenies of the selections, tested further, and the best strains distributed to the farmers.

Performance of AVRDC Tomato Breeding Lines Under Highland Conditions of Tanzania

Summary

Two preliminary trials of AVRDC tomato lines were conducted at HORTI-Tengeru (1450 m above sea level). Among the determinate group, four lines were selected to be advanced to the national multilocational trials that will be carried out in 1994. Some of these selections markedly outyielded Roma VF (local check) and had better fruit and disease resistance characteristics. Among the indeterminate lines, two open-pollinated entries were advanced to the multilocational trial. While a number of fresh market hybrids from AVRDC were vastly superior to the check, MoneyMaker, they were not yet advanced to the multilocational trial because of seed availability problem and will have to await the training of local seed producers in hybrid seed production.

Introduction

Many successful crop varieties worldwide have been developed through three principal methods of breeding: introduction, selection, and hybridization. Often, these are employed simultaneously in breeding programs. Introductions can be used directly as new varieties, parents in the production of hybrids, and as sources of desirable genes that could be bred into locally adapted varieties. These genes may account for high yield characteristics, pest and disease resistance, and other desirable traits.

Through the National Vegetable Seed Production Program of Tanzania, a number of tomato varieties have been introduced and maintained at HORTI-Tengeru. Recently the AVRDC Africa Regional Program has brought in tomato germplasm from AVRDC for use in the Pan-Africa Tomato Improvement Project. Many of these new materials carry genes for resistance to tomato mosaic virus (ToMV) strains 0 and 1 and nematode, and are firm-fruited and resistant to fruit cracking.

The collections from the abovementioned programs, after going through various stages of variety evaluation for adaptability to the local conditions, could be very useful in the Pan-Africa Tomato Improvement Project to improve local varieties for highland growing conditions.

Therefore, preliminary trials were conducted to evaluate the new introductions from AVRDC for adaptability to the highland conditions of Tanzania and to select the most promising entries for further tests.

Materials and Methods

Two sets of materials, determinate and indeterminate lines, were evaluated. The determinate group consisted of 17 entries, with Roma VF, a popular local variety, as the check. The indeterminate group had 16 entries with MoneyMaker, another popular local variety, as the check. These trials were considered preliminary and were designed to look at several introductions for the first time. A randomized complete block design (RCBD) with two replications was deemed adequate since it is a preliminary trial.

The trials were sown on 30 March and seedlings were raised in the seedbed until transplanted to the field on 20 April 1993. Stakes were used to support the indeterminate group. The determinate group was also supported by short stakes to minimize fruit rot and to alleviate the control of diseases and insects.

Ten (10) t/ha farm yard manure was applied before transplanting. Other fertilizer applications followed the recommended rates for tomato multilocational trials in Tanzania.

Furrow irrigation and weeding were done as necessary.

The following data were collected from the trials: days to 50% flowering, fruit setting rate, disease and pest incidence (in collaboration with plant protection staff of HORTI-Tengeru), yield (marketable and unmarketable), days to 50% maturity, and fruit traits (shape, size, color, crack resistance, firmness, smoothness, sweetness, etc.).

Results and Discussion

The trials were fraught with missing plants mainly due to poor nursery techniques. The surviving plants were observed mainly for horticultural characteristics, yield, and other quantifiable fruit characters.

Except for CL 5915-223, all entries have been advanced to the 1994 multilocational trials[1] on account of their superior traits (ToMV [carries the Tm2a gene] resistance for strains and fruit qualities such as firmness, smooth shape, nonpuffy fruits, etc.) compared to Roma VF. Though high yielding, CL 5915-223 had very irregular fruit sizes which were not comparable to other selections in fruit quality. Roma VF is popular in many parts of Africa; however, its fruit is pear-shaped, small, puffy (and, thus, has little puree when cooked) and only moderately firm. It is also susceptible to ToMV which is widespread in the continent.

Among the indeterminate group, two open-pollinated entries were selected for inclusion into the 1994 multilocational trials (table 1). These are CLN 657-285-0-20-0 and its sister line CLN 657-285-0-21-0. Both lines gave higher yields and larger (preferred in Tanzania), firmer fruits than MoneyMaker.

While a number of AVRDC's fresh market indeterminate hybrids did very well, such as FMTT 33 and FMTT 22, they were bypassed in the selection process for multilocation testing because of seed availability problems. However, the FAO Seed Production Unit is interested in producing hybrid seeds and only awaits the training of its personnel by the Africa Regional Program. The trend in the local vegetable seed production scene is to encourage the private sector to be involved and this is currently being done with assistance from the FAO.

[1] The entries for the multilocational tomato trials in Tanzania have just been revised to include even newly tested entries, so long as they are deemed outstanding in preliminary trials.

Table 1. Best performing entries in the highland preliminary trial of AVRDC's indeterminate tomato lines at HORTI-Tengeru, 1993

Indeterminate Group	Marketable yield (t/ha)	Mean fruit weight (g/ft)	Yield index (vs. check)	Other traits[a]
FMTT 267	53.7	151.6	198%	Tm2a, F
CLN 657-285-0-20-0	40.0	108.9	148%	Tm2a, F
CLN 657-285-0-21-0	53.7	112.7	198%	Tm2a, F
FMTT 33	58.7	125.6	217%	Tm2a, F
FMTT 22	53.8	113.8	199%	Tm2a, F
FMTT 3	56.5	104.9	208%	Tm2a, F
MoneyMaker (ck)	27.1	77.4	-	+/+, MF

[a]F = firm; VF = very firm; MF = moderately firm; Tm2a represents the gene for resistance to strains 0 and 1 of the tomato mosaic virus.

Performance of AVRDC Tomato Breeding Lines Under Lowland Conditions of Tanzania

Summary

Two preliminary yield trials of AVRDC's determinate and indeterminate tropical lines were conducted by cooperators in Dakawa (320 m above sea level). None of the best determinate tropical lines significantly outyielded Roma VF, the local check. However, the best lines produced larger fruits than the check, a trait that is preferred by consumers in Tanzania, and have the added advantages of being heat-tolerant, resistant to bacterial wilt and tomato mosaic virus, firm, and with cracking resistance. AVRDC's indeterminate tomato entries were clearly superior over the local varieties, MoneyMaker and Marglobe, with the best entry yielding nearly twice as much as MoneyMaker. In almost all cases, they also produced significantly larger fruit than the local checks. As with the determinate tropical lines, further advantages of the AVRDC indeterminate materials over the checks include the following: resistance to tomato mosaic virus and bacterial wilt, fruit firmness, cracking resistance, and heat tolerance.

Introduction

Tomatoes are among the most widely grown and consumed vegetables worldwide. They are not only nutritious and highly acceptable, but they are also a good cash crop for farmers. While research on the improvement of cultivars has progressed so much in the temperate zones, research in the tropical environments has lagged in many respects.

Cultivation of tomatoes in the tropics is beset by many problems. These production constraints may be generally classified as: biotic stresses, such as, diseases and insect pests; and abiotic stresses such as high temperatures, high humidity, excessive rainfall, low light intensity, and poor soil fertility.

Some work has been done on cultivar testing during the dry season in the medium elevation of Dakawa, Morogoro (320 m above sea level) to evaluate the performance of different cultivars. This work needs to be continued for several seasons to come up with the promising cultivars for use by the farmers. The introduction and evaluation of new germplasm, particularly those bred

for tropical adaptation by tomato breeders at AVRDC in Taiwan, would be a promising line of research.

The AVRDC Africa Regional Program has begun to introduce these new germplasm lines into Africa and a number of the tropical lines have been given to Chollima Scientific Agricultural Research Centre. A preliminary yield trial was conducted to evaluate these new tomato lines for regular and off-season production in the medium elevation of Dakawa, Morogoro.

Materials and Methods

Thirty-seven determinate and 22 indeterminate breeding lines were tested. Roma VF and MoneyMaker served as checks for the determinate and indeterminate groups, respectively. These two check cultivars have already been tested for a few seasons in Dakawa, Morogoro.

The experimental design was a randomized complete block with two replications. Plots consisted of two rows, 4.8-m long and 1.2-m wide each. Spacing between plants in the row was 40 cm and between rows within beds, 50 cm. The two rows of each entry occupied a two-row raised bed, where the actual bed is about 1.0 m wide and the width of each bed, including the furrows, is 1.2 m.

Seedlings were raised in the seedbed for 3 weeks and transplanted to relevant plots. Farm yard manure at the rate of 10 t/ha was applied before transplanting. NPK fertilizer at standard rates for the multilocational trial was split-applied at specific intervals.

Furrow irrigation and weeding were done as necessary.

The following data were collected from the trials: days to 50% flowering; fruit setting rate; disease and pest incidence (in collaboration with the plant protection staff of HORTI-Tengeru); yield (marketable and unmarketable); days to 50% maturity; and fruit traits, such as, shape, size, color, crack resistance, firmness, smoothness, sweetness, etc.

Results and Discussion

None of the best AVRDC determinate lines significantly outyielded the local check variety, Roma VF (table 2). Except CL 143, however, all lines had significantly larger fruits than the check. Large fruits which give a lot of puree upon cooking is highly preferred by consumers in Tanzania. Additional advantages of the AVRDC lines over Roma VF are heat tolerance, resistance to bacterial wilt and tomato mosaic virus, fruit firmness, and cracking resistance. Roma VF also tended to be puffy, which was not evident among the AVRDC lines.

The superiority of AVRDC's indeterminate entries over the local checks, Marglobe and MoneyMaker, was highly evident (table 3). The highest yielding entry, FMT F 304, yielded nearly twice as much as MoneyMaker.

Table 2. Best entries in the lowland preliminary trial of AVRDC's determinate tomato lines at Dakawa, Morogoro, 1993

Variety name/Code	Total yield (kg/plot)	Marketable yield (kg/plot)	Mean fruit weight (g/ft)
CL143-0-10-3-0-1-10	63.9 d [a]	61.3 c	30.4 a-c
CLN 475-265-9-0	62.3 cd	60.6 c	50.4 g-i
Roma VF (local ck)	62.2 b-d	60.6 c	35.6 c-e
CLN 684-58-5-0	60.8 b-d	58.6 bc	63.0 jk
CL 5915-93-1-0-L-2	56.9 b-d	52.1 a-c	55.8 ij

[a] Numbers followed by the same letters are not statistically different at 5% level (DMRT)

Table 3. Best entries in the lowland preliminary trial of AVRDC's indeterminate tomato lines at Dakawa, Morogoro, 1992

Variety name/Code	Total yield (kg/plot)	Marketable yield (kg/plot)	Mean fruit weight (g/ft)
FMTT 304	78 h [a]	74 h	135 hi
FMTT 277	73 gh	68 f-h	146 ij
FMTT 268	72 f-h	68 f-h	156 j
FMTT 267	71 e-h	68 f-h	136 hi
CL5915-206-2-2-0-4	71 e-h	69 gh	118 fg
FMTT 3	70 e-h	67 e-h	113 e-g
FMTT 22	70 e-h	66 e-h	99 c-e
Marglobe (ck 1)	47.8 a-c	44.5 a-c	91 b-d
MoneyMaker (ck 2)	41.4 ab	39.0 ab	80 ab

[a]Numbers followed by the same letters are not statistically different at 5% level (DMRT).

All entries (except FMTT 22) produced significantly larger fruit than the local checks. As with the determinate group, further advantages of the AVRDC materials over the checks include the following: resistance to tomato mosaic virus and bacterial wilt (not in all cases for bacterial wilt, however), fruit firmness, cracking resistance, and heat tolerance (for entries FMTT 22 and CL 5915-206-2-2-0-4).

Identification of Major Tomato Diseases in Tanzania

Summary

Collaborative studies were initiated between the AVRDC Africa Regional Program, HORTI-Tengeru and AVRDC Headquarters to identify the major diseases that attack tomatoes in Tanzania. Four viruses were found affecting tomatoes based on samples collected from various places in Tanzania. These were: tomato mosaic virus (ToMV), potato virus Y (PVY), tomato yellow leaf curl virus (TYLCV), and cucumber mosaic virus (CMV). Potato virus Y was the most frequently detected virus followed by ToMV and TYLCV. Strain typing for ToMV and root-knot nematode is under way. TYLCV was present in 14 of 166 samples tested. Late blight remained as the major fungal disease problem limiting tomato production in many areas. Examination of sporangia from samples collected in different locations showed that *Phytophthora infestans* was the species responsible for the blight. *Phytophthora capsici* was not detected although it has also been implicated in previous studies. Damage due to root-knot nematode attack was also encountered frequently.

Introduction

Tomato is the leading fruit vegetable of Tanzania and is practically available year-round. However, its production during the dry season is difficult because of severe attack by virus diseases. Its price is usually the highest during this season.

During the cool wet season, late blight is the most important disease problem. In some tomato production areas, root-knot nematode has been reported to be a major problem.

Knowledge of the types and strains of diseases that attack tomatoes in Tanzania is severely lacking. Adequate information about them is necessary before sound control strategies can be developed. Moreover, this information is important before the tomato breeders can decide what resistance genes to deploy in the breeding program.

In view of the potential for losses that can be incurred by the major diseases and the lack of sufficient information regarding them in Tanzania, studies were initiated to:

(1) determine the diseases and their distribution;

(2) determine the strains of the most important diseases; and

(3) develop sound control strategies, including resistant cultivars.

These studies are being conducted as part of the collaborative research between the AVRDC Africa Regional Program, HORTI-Tengeru, and AVRDC headquarters.

This report gives the preliminary progress made in identifying some of the major tomato diseases in Tanzania.

Material and Methods

Assay for the common virus diseases. Leaf and shoot samples were collected from tomato plants in the field which showed indicative symptoms of virus infection.

Samples were then taken to the laboratory for preparation. To detect TYLCV, small disks taken by a no. 2 cork borer and squashed on nylon membranes were prepared. To detect other viruses, small amounts of leaf tissue were ground in phosphate buffer, and 2 µl of each sample were then spotted on nitrocellulose membrane.

The membranes were sent to AVRDC headquarters to assay for the viruses that were present in the samples.

Strain-typing for other diseases. In addition to the virus identification work, research activities have been started to determine the major species and/or strains of other diseases and pests that are known to be present in Tanzania. These include: tomato mosaic virus, root-knot nematode, potato virus Y, and late blight.

Results and Discussion

Of 166 samples tested for TYLCV, 14 gave positive signals for the presence of this virus (table 4). On the other hand, of 138 samples tested for other viruses, 64 were positive for PVY, 16 for ToMV, and 9 for CMV. Multiple viral infections were also detected. (Many samples with symptoms typical of TYLCV were found to be negative for this virus.)

Table 4. Occurrence of tomato viruses in Tanzania

Type of virus	Frequency of occurrence
ToMV	1/138
CMV	3/138
PVY	64/138
TYLCV	14/166
CMV + PVY + ToMV	2/138
CMV + PVY	6/138
CMV + ToMV	-
ToMV + PVY	12/138

For ToMV strain-typing, the four tomato differentials that are routinely being used to differentiate various strains of ToMV were multiplied to ensure availability of seeds. These differentials included: GCR-26 (tm/tm), susceptible to all strains of ToMV; CSTMW-18 (Tm-1/Tm-1), resistant to three of the major strains 0, 2, 2^2; and Perou-2 (Tm-2^2/Tm -2^2), resistant to strains 0 and 1. Pure ToMV isolates are now being obtained from cultures established in the greenhouse by purifying them of PVY by passage through *Datura stramonium* which is resistant to PVY. Once the pure isolates of ToMV have been secured, the strain typing will be done by inoculating the differentials.

Samples of nematode-infected tomatoes have been collected from different areas of the country and pure cultures are now established in the greenhouse. These cultures were obtained by using one egg mass derived from each sample. Eight pure isolates have so far been established. Eight weeks after inoculation, species identification and strain typing will commence. Species identification will be done by studying the perineal pattern of the nematode. On the other hand, strain identification will be done by the use of differential hosts. The following differentials have now been established in the greenhouse: tomato cv. Rutgers; watermelon cv. Charleston Gray; pepper cv. Yolo Wonder; and cotton cv. Delta Pine.

Late blight-infected leaves from three highland regions—Arusha, Lushoto-Tanga, Mbeya—and one from the mid-lowland region of Dakawa-Morogoro were cultured using the blotter technique. Examination of the sporangia produced by the isolates showed typical features of *Phytophthora infestans*. Based on morphology, *Phytophthora capsici* was not detected among the samples. Future collections will include sampling during different seasons and from more locations.

Regional Collaborative Tomato Trials

A few of the program collaborators in the region reported the results of their trials of AVRDC tomato breeding lines. The results of these trials are summarized below.

Uganda. An FAO project at Kawanda Research Station evaluated several AVRDC determinate and indeterminate lines for resistance to bacterial wilt and horticultural performance. Table 5 shows the best lines compared to the local check, MT45 from Makerere University. The AVRDC lines had higher bacterial wilt resistance, leading to higher yield per plot (unadjusted for stand).

The bacterial wilt resistance of the indeterminate group was very good according to the cooperator. The local variety, MT 55, showed good resistance as well and had the highest yield. However, it also produced the smallest fruits (table 6).

Table 5. Best performing determinate tomato lines in the bacterial wilt (BW) evaluation trial at Kawanda Research Station, Uganda, 1992

Variety name/Code	Total yield (kg/plot)	Fruit number (no./plot)	BW rating[a]
CLN 65-349-2-0	6.1 c	189 c	R
CL 5915-223-2-1-0	6.0 c	190 c	R
CL 5915-93-1-0-C-1	5.8 c	193 c	R
CLN 475-265-9-0	5.3 bc	177 bc	R
MT 45 (local ck)	1.7 a	52 a	S

[a] R = resistant; S = susceptible.

Table 6. Best performing indeterminate lines in the bacterial wilt (BW) evaluation trial at Kawanda Research Station, Uganda, 1992

Variety name/Code	Total yield (kg/plot)	Mean fruit weight	BW rating[a] (g/ft)
MT 55 (local check)	4.9 e	24	R
CL 6046-51-0-20-5-15-14-1	3.6 d	34	R
CL 6046-51-1-1-20-5-10-13	3.1 cd	25	R
CL 5915-206-2-2-0-4	2.5 bc	63	R

[a] R = resistant; S = susceptible.

Tanzania. A cooperator in the southern highlands of Tanzania (Uyole Agricultural Centre) evaluated a number of determinate and indeterminate breeding lines from AVRDC during the rainy season of 1990-92 at four locations: Uyole, Mbimba, Suluti, and Nkundi. Several lines showed very high yield potential under the southern highland conditions. Among the indeterminate group, the most promising was CL 5915-206-2-1-0, showing consistently good performance in the trials. Mean yield of this line in all trials was 96 t/ha. MoneyMaker, on the other hand, averaged 95 t/ha. However, it does not have resistance to tomato mosaic virus and bacterial wilt which CL 5915-206-2-1-0 possesses. Bacterial wilt is reported to be a serious problem in the southern highlands because of its long tradition of continuous tomato cropping. In the determinate group, the best line was CL 8D-0-7-0 averaging 60 t/ha across the trials. Most of the promising indeterminate lines had medium to large fruit, whereas, the determinate lines had only small to medium fruit.

An on-farm trial at two sites (Majenje and Igurusi) of three AVRDC breeding lines (CL 5915-93-1-0-C-1, CLN 65-349-2-0, and CL8D-0-7-1) and two commercial cultivars (Romitel and Ex. Mbalizi) was also conducted in 1992. The aim was to introduce new varieties to the farmers in the area who have been growing Roma VF for many years. CL 8D yielded the highest in both sites, averaging 20 t/ha. The farmers who visited the station were reportedly impressed by the performance of the new varieties which yielded better and produced bigger fruit than Roma VF.

Effect of Within-Row Spacing and Time of Topping and Deflowering on Leaf, Fruit, and Seed Yield of Yellow Nightshade (*Solanum pseudonigrum*)

Summary

A split-split plot field trial to investigate the influence of within-row spacing (5,10,20, and 40 cm) as main plot; time of topping (early preflowering or late postflowering) as subplot; and deflowering vs. none as sub-subplot on leaf, fruit, and seed yield of periodically harvested yellow nightshade (*Solanum pseudonigrum*) was conducted during the cool season (May-July). The optimum spacing was 20 cm between plants or less sown on 60-cm ridges. Total leaf yield of 5 t/ha was obtained after six biweekly harvests and close spacings were significantly superior. Fruit (1.5 t/ha) and seed yield (132 kg/ha) was best at 10 or 5 cm. Early topping or deflowering Had no advantages on yield nor were there consistent interactions between the tested variables on individual harvest. However, late topping favored an increase in total leaf, fruit, and seed yield while deflowering reduced it, particularly on closely spaced plants. The possible weakness of reproductive sinks is suggested by the lack of yield improvement upon their removal. Deflowering did not significantly increase yield but improved quality of harvested tops.

Introduction

The nightshade is increasingly becoming an important leafy vegetable in Tanzania's northern agroecological zone. The orange-fruited *Solanum pseudonigrum*, erroneously confused in name with *S. nigrum* (with black-purplish fruit when ripe), is perhaps the most popular and is in greatest demand in municipal markets throughout the year. Its fruit is also edible when ripe.

Like other traditional vegetables in Tanzania, there is little information on some of the horticultural practices, e.g., spacing. Some researchers have used 30 cm x 30 cm spacing in their trials, (e.g., Omta and Fortuin 1980; Mwafusi 1992; Murage 1989 and Opole et al. 1991). Others (Tindall 1983, FAO 1988, and Rice et al. 1987) recommended, however, 60-cm rows and 40-50 cm between plants in the row. When deliberately sown by farmers, it is often as an intercrop with other food plants in home gardens and when in monoculture (as is now the tendency to grow it), no proper spacing is used.

The optimum spacing for a leafy vegetable which is repeatedly defoliated by removing tender plant tops would depend on such factors as the degree of induced branching, frequency and amount of defoliation (i.e., defoliation intensity), soil fertility, and variety. The time of topping would possibly have the effect of setting the plant on an early course of redistributing its dry matter to reproductive side branches which are concurrently with leafy shoots. The time of topping and yield performance of *S. pseudonigrum* has not been reported. As flowering and leaf production occur together in this species, the influence of deflowering on productivity is also not known.

To promote the cultivation of this nutritious species, production packages ought to be generated, and this trial is part of that effort.

Materials and Methods

Seeds of *S. pseudonigrum* were sown in the nursery and transplanted 10 weeks after germination on ridges 60 cm apart in 7.2-m^2 plots. The trial was planted during the middle of the cool season on land previously fallow to which a basal dressing of 120 kg/ha NPK (10-10-8) was applied. Seedlings were spaced 5, 10, 20, or 40 cm within rows (main plots); plants were topped 2 weeks after transplanting (i.e., before flowering) and others after 4 weeks (postflowering). These comprised the subplots. Two rows in each of the treatments were periodically deflowered or not (sub-subplots).

The treatments were arranged in a split-split plot design with four replications. Furrow irrigation, hand-hoeing, and aphid control were done when necessary.

Harvesting of the leaves was carried out biweekly until plants became unproductive. Top dressing with 50 kg/ha urea was done once a month. Fruit was harvested as it ripened, and weighed. Seeds were dried and weighed.

Results and Discussion

Total leaf yield was highest at 20-cm spacing or closer (table 7). For each leaf harvest, a close spacing of 10 cm or 5 cm yielded higher than others, except during the fifth harvest.

Early topping (preflowering) significantly reduced total yield for the first harvest only (table 8). Late topping (postflowering) tended to favor yield increase as spacing decreased or when plants were not deflowered. Flower removal did not significantly influence leaf yield.

Table 7. Influence of within-row spacing on leaf yield of periodically (biweekly) harvested yellow nightshade

Spacing (cm)	Leaf yield (t/ha)[a]						
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Harvest 6	Total
5	1.0	0.9bc	0.9b	0.8a	1.2a	0.6a	5.3b
10	1.0c	1.0c	0.8b	0.7ab	1.2a	0.7b	5.4b
20	0.6b	0.8b	0.6a	0.7ab	1.1a	0.8	5.6b
40	0.3a	0.4a	0.6a	0.6a	1.1a	0.6a	3.8a

[a]Numbers in same column followed by the same letter are not statistically different at 5% level (DMRT).

Table 8. Effect of time of topping on leaf yield of periodically harvested yellow nightshade

Spacing (cm)	Leaf yield (t/ha)						
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Harvest 6	Total
Early	0.5a	0.8a	0.7a	0.7a	1.2a	0.6a	4.8a
Late	0.9b	0.8a	0.7a	0.7a	1.1a	0.7a	5.3a

Total fruit yield was highest in 5-cm or 10-cm spacing (table 9) which yielded seed in the same order. Although fruit and seed yield were highest at 10- or 5-cm spacing during the first harvest, there were no significant yield differences during the second harvest.

Table 9. Effect of in-row spacing on fruit and seed yield of yellow nightshade following six periodic leaf harvests

Spacing (cm)	Fruit yield (t/ha)			Seed yield (kg/ha)		
	Harvest 1	Harvest 2	Total	Harvest 1	Harvest 2	Total
5	0.8c	0.7a	1.4c	60.3c	58.4a	118.7bc
10	0.7c	0.8a	1.5c	65.7c	66.2a	132.1c
20	0.4b	0.7a	1.1b	37.3b	63.0a	100.3ab
40	0.2a	0.7a	0.9a	21.1a	62.3a	83.4a

Time of topping did not significantly influence either fruit or seed yield in each harvest or total yields (table 10). Plants which were deflowered were capable of yielding same quantities of fruit and seed during the second harvest, but total yield was significantly less than undeflowered plants.

Early topping tended to increase fruit and seed yield on closely spaced plants while deflowering had a general tendency to reduce fruit and seed yield particularly at higher densities.

Yellow nightshade fruit contains an average of 62 seeds/fruit; 500 g ripe fruit contains 2486 seed and produces 44.3 g clean dry seed.

The yellow nightshade variety used in this study is different from *S. nodiflorum*, *S. scabrum*, and *S. nigrum* on account of its fruit color, seed number, and general morphology. It is a day-neutral, self-pollinated plant which grows well even during the cool season like its close relative,

Table 10. Influence of time of topping and deflowering on fruit and seed yield of yellow nightshade

Treatments	Harvest 1	Harvest 2	Total
Seed yield (kg/ha)			
Early topping	33.4a	45.0a	78.0a
Late topping	32.9a	45.1a	78.4a
Deflowering	23.5a	44.8a	68.3a
Undeflowered	42.9b	45.2a	88.1b
Fruit yield (t/ha)			
Early topping	0.4a	0.5a	0.9a
Late topping	0.4a	0.5a	0.9a
Deflowered	0.3a	0.5a	0.8a
Undeflowered	0.5a	0.5a	1.0b

S. nigrum. Its fruit is preferred by birds and for this reason it occurs as a spontaneous weed in cultivated lands. It has high carotene and vitamin C contents.

Contrary to the wide spacings recommended as optimum for leaf yield, within-row spacing of 20 cm or less gave the highest total yield.

Yield is a function of plant density and compensating growth induced by repeated topping. Early topping, when plants had not fully established ample carbohydrate reserves, lowered first harvest yield but compensated subsequent harvests. Simultaneous removal of potential reproductive photosynthetic and vegetative sinks through periodic topping did not appreciably improve yield, suggesting that fruits allowed to develop on undeflowered plants were not sufficiently strong sinks. This is contrary to the findings of Mwafusi (1992) who reported a yield increase following deflowering. Deflowered plants left to form mature fruits were able to compensate for fruit loss in the first two harvests.

No consistent interactions among spacing, topping, and deflowering during each harvest were noted but late topping favored an increase in total leaf fruit and seed yield, and deflowering reduced it particularly on closely spaced plants.

Effects of Within-Row Spacing on Leaf Yield of Local Ethiopian Mustard (*Brassica carinata*)

Summary

The optimum within-row spacing of Ethiopian mustard (*Brassica carinata*) in raised ridges 60 cm wide and harvested biweekly was investigated. Significantly high leaf yield was obtained at spacings of 45 or 30 cm between plants in which up to 37 t/ha was obtained. Differences in yield among individual harvests were significant only in the second and fourth harvests.

Introduction

Ethiopian mustard (*B. carinata*) is an important leafy vegetable in East Africa, particularly in the highlands. Attaining edible maturity age at 35 days after sowing, its leaf yield is normally higher than that of kale which is a popularly cultivated exotic leafy vegetable in Kenya and Tanzania.

The extent to which sowing density affects leaf yield has not been fully investigated although spacing of 60 x 30 cm for plants subjected to biweekly leaf harvest at 50% defoliation was used by Gerson (1988) in Tanzania.

This study determined the optimum spacing for enhanced leaf yield in Ethiopian mustard.

Materials and Methods

Seeds were sown at four spacings of 60 x 75 cm, 60 x 60 cm, 60 x 45 cm, and 60 x 30 cm. The 7.2-m^2 plots were arranged in RCBD and replicated four times. Leaf harvest was begun at 5 weeks after sowing removing 50% of fully expanded leaves and tender branches every 2 weeks until incipient flowering.

Results and Discussion

The effect of spacing in Ethiopian mustard became evident during the 7th week after sowing when total yield was higher at closer spacings of 60 x 45 cm and 60 x 30 cm primarily due to significantly higher leaf and branch weights and not leaf and branch numbers (table 11). Leaf weights were also significantly higher in the third and fourth harvests for these treatments. Differences in yield among individual harvests were significant only in the second and fourth harvest.

Table 11. Influence of in-row spacing on yield (t/ha) and its components of Ethiopian mustard subjected to periodic defoliation

Harvests/ Traits	In-row spacing (cm)[a]			
	75	60	45	30
Harvest 1				
Leaf no.	150.5a	112.8a	132.3a	154.8a
Leaf wt.	3.3a	2.5a	2.9a	3.7a
Branch no.	94.0a	92.8a	90.5a	79.0a
Branch wt.	1.2a	1.2a	1.5a	1.2a
Total	4.6a	4.0a	4.4a	5.1a
Harvest 2				
Leaf no.	131.3a	108.8a	143.3a	174.8a
Leaf wt.	4.0a	5.0ab	6.0b	6.6b
Branch no.	124.3a	125a	165a	182a
Branch wt.	3.5a	4.7ab	5.7b	5.4b
Total	7.5a	9.7ab	11.1b	12.1b
Harvest 3				
Leaf no.	115.0a	115.5a	125.5a	222.2b
Leaf wt.	3.8a	4.5a	5.6ab	6.7b
Branch no.	102.8a	98.8a	123.0a	123.8a
Branch wt.	4.0a	3.9a	54.4a	5.1a
Total	7.9a	8.5a	10.9a	11.8
Harvest 4				
Leaf no.	66.5a	66.5a	127.8b	71.2a
Leaf wt.	2.1a	2.1a	3.1b	72.2a
Branch no.	98.5ab	82.3a	154.8b	123.5ab
Branch wt.	4.2a	3.2a	5.8a	5.5a
Total	6.3ab	5.1a	8.9b	7.7ab
Total yield	26.3a	27.3a	35.3b	36.7b

[a] Numbers in the same row followed by the same letter are not statistically significant at 5% level (DMRT).

Despite the 100% infestation by turnip mosaic virus (TuMV), total yields were comparable to those of Gerson (1988) at Tengeru and in Zambia. The optimum spacing for Ethiopian mustard appears to be 60 x 45 cm or 60 x 30 cm.

Most market gardeners have adopted high density sowing for once-over harvesting of Ethiopian mustard. Future trials could examine effects of even closer spacings and methods of stand establishment for higher leaf yields.

Influence of Farmyard Manure on Leaf Yield of Local Ethiopian Mustard (*Brassica carinata*)

Summary

In a study to determine the optimum application rate of farmyard manure (FYM) to attain high leaf yield of Ethiopian mustard (*Brassica carinata*), 150 t/ha was found to be optimum. At this rate, a total yield of 42 t/ha was obtained. Periodically defoliated plants yielded 50% of their total yield during the last harvest prior to caulescence irrespective of the FYM regime. Influence of FYM on leaf yield became noticeable early at 5 weeks after sowing when 50 t/ha FYM was applied, whereas, the effect on leaf and branch numbers became significant at 9 weeks after sowing.

Introduction

Ethiopian mustard (*Brassica carinata*) is a traditional leafy vegetable widely grown in Tanzania, especially in the highlands. Generally, commercial farmers use chemical fertilizers in an attempt to increase yield. However, subsistence farmers cannot afford expensive inputs. Use of local resources and efficient farming methods to increase crop production is one of the ways to help the resource-poor farmers.

Most farmers practice mixed farming and the by-product, farmyard manure (FYM), is a cheap and environmentally safe fertilizer that is rich in nutrients. In Tanzania, there is no available report on the leaf yield response of Ethiopian mustard to FYM. The amount that farmers apply vary depending on the number of livestock and the use of FYM in the farmers' crop mix.

This study was carried out to determine the beneficial effects of FYM on the leaf yield of Ethiopian mustard.

Materials and Methods

Seeds of a local cultivar were directly seeded 40 cm apart on 60-cm-wide ridges; plots were 1.8 by 4 m in dimension (7.2 m^2) to which FYM at the following rates were previously applied and hoed in: A — Control (none); B—50 t/ha; C—150 t/ha; D—300 t/ha; E—500 t/ha.

The treatments were arranged in a randomized complete block design and replicated four times. Hand weeding, pest control, and irrigation were carried out as necessary. Periodic harvesting of edible leaves was carried out 5 weeks after seeding and repeated biweekly until flowering. Both harvested leaves and branches were counted and weighed after each harvest.

Results and Discussion

There were significant variations in leaf yield between treatments in each harvest date (table 12). The control treatments became significantly different from others in the second and

subsequent harvests. On the average, the 150 t/ha FYM treatment was the best. This is equivalent to 150 kg/10 m^2 easily applied by home or market gardeners.

Significant differences among treatments with regard to leaf number (table 13) and branch number (table 14) were noticeable in the third harvest (9 weeks after sowing). At higher FYM rates fewer leaves were produced. Total yield increased with FYM rates. The influence of FYM on leaf and branch numbers was delayed until 9 weeks after sowing.

For practical purposes a 150 t/ha rate could be recommended although the tendency to overfertilize is noticeable in certain locations where vegetables are cultivated on old kraals to ensure high yields. This is particularly so where there is zero-grazing or FYM is abundant.

Table 12. Leaf yield (t/ha) of Ethiopian mustard as influenced by FYM rates during each biweekly periodic harvest

FYM rates (t/ha)	Leaf yield (t/ha)					
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
0	1.3a	2.1a	3.8a	1.9a	10.1a	19.1a
50	4.9b	4.0b	5.2ab	2.3a	17.0b	33.5b
150	5.8b	5.0b	7.2bc	2.9a-c	21.0bc	41.9bc
300	4.9b	6.4c	8.3bc	3.6bc	22.5c	46.1c
500	3.2ab	4.9b	10.0c	4.3c	23.8c	46.2c

Table 13. Influence of FYM on leaf number of Ethiopian mustard subjected to biweekly leaf removal

FYM rates (t/ha)	Number of leaves (per nine plants)				
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
0	22.2a	41.0a	41.2b	26.5b	131.0ab
50	21.0a	39.0a	36.5ab	30.2b	129.8ab
150	38.2a	46.8a	33.5a	28.8b	147.2b
300	20.5a	38.2a	36.8ab	20.8a	116.2a
500	17.2a	51.2a	31.8a	27.5b	127.8ab

Table 14. Branch numbers of Ethiopian mustard during the vegetative phase in relation to FYM application rates

FYM rates (t/ha)	Number of branches (per nine plants)				
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
0	39.8a	40.0a	43.8b	22.8a	146.2a
50	36.0a	36.8a	39.5ab	28.8ab	141.0a
150	51.8a	36.8a	38.5ab	30.5a-c	157.5a
300	41.8a	29.2a	41.2b	23.2bc	131.5a
500	37.0a	39.0a	31.2a	29.5c	136.8a

A Description of the Varieties of African Eggplant (*Solanum aethiopicum*) at HORTI-Tengeru

Summary

Eleven African eggplant varieties which have been collected and maintained at HORTI-Tengeru in the past decade were briefly described and named, and their seeds collected for further evaluation. This is the regional program's initial research thrust on this indigenous vegetable which is rapidly becoming popular and the demand for which is increasing in the urban areas.

Introduction

A decade ago, researchers at HORTI-Tengeru assembled African eggplant varieties from local sources. It is only during the last 4 years, however, that the demand for this vegetable has become significant in the urban markets.

During the national vegetable planning workshop coordinated by the Africa Regional Program jointly with HORTI-Tengeru and held in July 1993, the African eggplant was accorded high priority among the traditional vegetables to receive research attention. The others were amaranths and vegetable jute (*Corchorus olitorius*). All three species are widely used in Tanzania and are highly nutritious.

As a first step towards consolidating information on these species, some of the collections at HORTI-Tengeru were charactrized. Since no passport information, e.g., place of collection, etc., is available on these materials, the following brief description in this report would be useful to distinguish existing varieties.

(1) Manyire 1—Fruit: green, round, and slightly grooved; stem: green, semierect; 1-m tall and 1-m-wide canopy.
(2) Manyire 2 A—Fruit: round, light green, lightly grooved, and sunken at the navel-end; stem: green and upright.
(3) Manyire 3—Fruit: elliptical, very lightly grooved, whitish green, large; stem: purplish, central stem 30 cm above the ground and terminates in two distinct branches.
(4) Manyire 4—Fruit: light green, very large; stem: green; plant habit stunted, very low branching, very compact.
(5) Tengeru Striped A—Fruit: elongated, navel-end depressed, green longitudinal stripes; plant habit compact and dwarf; stem: upright and green.
(6) Manyire 6—Fruit: globose, large with stylar end scar, light green and grooved; stem: deep purple, including the veins, leaves and petioles.
(7) Tengeru Striped B—Fruit: green with striation (stripes), globose; stem: green.
(8) Shangingi—Fruit: very large, deep green, deeply grooved, with stylar/navel scar; stem: wholly green; very low branching (procumbent).
(9) Manyire 2 B—Fruit: light green, very grooved, with very small navel scar; stem: very light purple.
(10) Tengeru White—Fruit :very large, white, grooved, with stylar end scar; plant habit small and upright.
(11) Tengeru Grooved—Fruit: round (globose), deeply grooved, light green, with small stylar scar; plant habit semiupright (dwarf); stem: green.

Acceptability of Newly Introduced Leafy Vegetables

Summary

An organoleptic test of two vegetables newly introduced to northern Tanzania — kangkong (*Ipomoea aquatica*) from Thailand and Portuguese cabbage or tronchuda (*Brassica oleraceae* var. *tronchuda*) — against favorite local leafy vegetables was conducted using a 10-member taste panel.

Kangkong was rated good to very good by 80% of the taste panel. On the other hand, tronchuda was rated similar to the other brassicas but was slightly better than amaranths. Differences in the mean scores were not significant however. The agronomic and commercial prospects of these two leafy vegetable species appear promising.

Introduction

Leafy vegetables are commonly used in Tanzania as relish along with the starchy corn staple *ugali* (stiff porridge). They are well appreciated because some are available year-round, and they add flavor and taste to the otherwise bland staple. Moreover, they are easily procured, add bulk to the meal, and are rich in minerals and vitamins.

There are many plant species which provide edible foliage. Apart from such plant features as ease in propagating by seed or cuttings, yield potential, and adaptability, most farmers (and consumers) generally look for vegetables that, when prepared for a meal, have acceptable sensory qualities especially taste, flavor, smell, etc. Farmers are avid seekers of new vegetable varieties, and the research stations are often the formal entry point of these new varieties.

The two species which have been introduced by the Africa Regional Program for the first time in the northern agroecological zone (if not Tanzania as a whole) are water convolvulus or kangkong (*Ipomoea aquatica* or *Ipomoea reptans*), brought from Thailand (courtesy of Mr. Simon Groot of East West Seed Company) and tronchuda or Portuguese cabbage (*Brassica oleracea* var. *tronchuda*) from Zambia.

These species were direct-seeded in the field in April 1993, grew well and set seed by July (kangkong) and August (tronchuda). Initial unofficial taste tests indicated that they could be alternative leafy green vegetables, particularly at times when amaranths do not grow well. It became necessary, thus, to subject these species to an official taste panel before the seed materials were distributed to the farmers through extension agents.

The organoleptic test was conducted to rate the palatability of the newly introduced vegetables against some local favorite vegetable species.

Materials and Methods

The first test (preliminary and unreplicated) was done on 21 September 1993. Leaves were harvested, washed, cut, fried, and compared with amaranth (*A. hypochondriacus*). They were cooked in similar fashion except that lemon juice was added to kangkong to reduce its drawing tendency when cooked. The taste panel included institute staff (senior and junior; local and expatriate). They were instructed to rate the cooked vegetables from A (very good taste) to D (very poor taste), when eaten with *ugali*. This exercise was carried out during lunch hour (1300 h).

In the second trial, kangkong was prepared without adding lemon juice. Furthermore, additional popular vegetables, such as, head cabbage and Ethiopian mustard (*Brassica carinata*) were included in the test. The entries were replicated twice.

Results and Discussion

In the first trial, tronchuda was rated similar to amaranth, whereas, kangkong was rated good or poor tasting by half of the taste panel on account of its acid taste (table 15).

In the second trial, however, kangkong was rated good to very good by 80% of the respondents and was actually the best overall (table 16). Tronchuda, on the other hand, was rated similar to the other brassicas but was better than amaranth.

These two newly introduced vegetable species appear very promising and could benefit from wide distribution of planting materials to vegetable gardeners in the future. It has been demonstrated in our field plantings that the seeds of these vegetables could be produced locally.

There is a need to test other cultivars as well which have been shown as promising in neighboring countries, such as Zambia. In the case of kangkong, the lowland aquatic type might be the choice in flood-prone areas and in dambo environments.

Table 15. Taste ratings of three vegetables by a nine-member taste panel (Trial I); HORTI-Tengeru, 1993

	Species taste rating				
	A	B	C	D	Mean
Tronchuda	4	2	2	1	4.0
Kangkong		4	4	1	3.3
Amaranth	4	3	1	1	4.2

Note: Taste keys and weights (in parentheses) are as follows: A(5)= very good; B(4)= good; C(3) = poor; D(2) = very poor.

Table 16. Taste ratings of kangkong and tronchuda as compared to other common vegetables at HORTI-Tengeru (means of two independent observations) by a 10-member taste panel

Species	Taste rating				
	A	B	C	D	Mean
Kangkong	3.0	5.5	1.0	1.0	4.1 a
Cabbage	3.5	2.5	2.5	1.5	3.8 a
Tronchuda	2.0	4.0	3.5	1.0	3.8 a
B. carinata	1.5	5.0	2.5	1.0	3.7 a
Amaranth	2.0	3.0	4.5	1.0	3.6 a

Note: Taste keys and weights (in parentheses) are as follows: A(5)= very good; B(4)= good; C(3) = poor; D(2) = very poor.

Training

The training activity proposed for 1993 has now been rescheduled to commence in March 1994 under the auspices of CONVERDS. All NARS in the SADC region have been informed accordingly.

Meanwhile, preparations have been made for the immediate implementation of training once funding becomes available. However, no firm move towards significant development for training has been made without the benefit of formally affirmed support.

The senior staff members of the Africa Regional Program collaborated with a number of Tanzanian national researchers in prioritizing research topics. In the process, a limited form of manpower development in the host country, Tanzania, has been carried out by the program. In this activity, a total of eight Tanzanian researchers (six from HORTI-Tengeru and two from outside institutions) collaborated with the program staff members.

Priority Setting and Strengthening Linkages with the National Programs

The Africa Regional Program assisted Tanzania in holding its first-ever national vegetable research priority-setting workshop. During the meeting, the national vegetable research program was formed to oversee the vegetable research activities in the country. Priority commodities and research areas in each were set during the workshop. A follow-up meeting further refined the research priorities and successfully allocated them to various research institutions in the country based on comparative strengths and weaknesses. The proceedings of the aforesaid national meetings are now being compiled by the Africa Regional Program for publication into a booklet that will serve as every researcher's guidelines on priorities of the national vegetable program.

Similar priority-setting workshops are now being explored with other countries in the region, particularly the other lead NARS of CONVERDS, namely, Zambia, Malawi, and Zimbabwe. The program is also coorganizing with Zimbabwe (the lead NARS for tomato research in the SADC region) a regional tomato research planning workshop with the view to succinctly define the regional research priorities for the commodity and to determine a set of priority research areas that could be implemented in a networking mode.

In the East African Region, the Africa Regional Program has recently completed discussions with Kenya Agricultural Research Institute (KARI) on collaborative vegetable research and development. A Memorandum of Understanding (MOU) has been prepared and submitted to KARI to formalize the collaborative relationship.

Program Staffing

Two staff members (program director cum plant breeder and training officer cum horticulturist) formed the senior technical staff of the Africa Regional Program in 1993. The senior plant pathologist who will work under the tomato project is yet to be hired.

Among the support staff, a secretary, driver, and watchman have been hired. Following the program's negotiations with Tanzania's Ministry of Agriculture, Livestock and Development Cooperatives (MALDC), two national researchers from HORTI-Tengeru — one plant virologist and one seed technologist — have been seconded to work with the regional program.

Facility Development

A 14-acre site at the Madiira Farm of HORTI-Tengeru is now being developed for research and training activities. Once completed, this facility will have irrigation and drainage canal networks, water reservoir, and guard houses, and will be fully secured by a fence. The construction of a field house and screenhouse at the site is currently being explored.

At HORTI-Tengeru, renovations have been completed for the offices of three senior staff members, two research assistants and a secretary. Renovation of the library for research and training purposes, and construction of a screenhouse for plant protection research is under consideration.

Appendices

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Publications

Symposium Proceedings

AVRDC. 1992. Vegetable production and marketing; Proceedings of a national review and planning workshop. AVRDC Publication no. 92-379, 286 p.

Kuo. C. George (ed.). 1993. Adaptation of food crops to temperature and water stress: proceedings of an international symposium, Taiwan, 13-18 August 1992. AVRDC Publication no. 93-410, 531 p.

Progress Report

AVRDC 1992 Progress Report, 523 p.

Vegetable Research and Development in Southeast Asia: the AVNET Final Report, 50 p.

Strengthening National Agricultural Research Systems through Training, 50 p.

AVRDC (corporate report), 50 p.

Catalog

AVRDC. 1992. AVRDC Germplasm Catalog: Sweet Potato. AVRDC Publication no. 92-382, 237 p.

Training Report

AVRDC. 1993. Training Report 1991. AVRDC Publication no. 93-399, 191 p.

AVRDC. 1993. Training Report 1992. AVRDC Publication no. 93-413, 234 p.

AVRDC. 1993. Breeding of Solanaceous and Cole Crops. AVRDC. Publication no. 92-384, 308 p.

Mnzava, N.A. (ed.). 1993. Trainee Research Reports: Outcomes of a special research skills course for the Southern Africa and South Asian vegetable networks. AVRDC. Publication no. 93-397, 133 p.

Bibliography

AVRDC. 1992. Annotated Bibliography of Soybean Rust (*Phakopsora pachyrhizi Sydow*). AVRDC Library Bibliography Series 4-1, Tropical Vegetable Information Service. AVRDC Publication no. 92-372, 160 p.

Field Guide

Black, L.L., Green, S.K., Hartman, G. L., and Poulos, J.M. 1993. Maladies du Poivron: un Guide Pratique. AVRDC Publication no. 93-400.

Black, L.L., Green, S.K., Hartman, G. L., and Poulos, J.M. 1993. Enfermedades del Chile: una Guia de Campo. AVRDC Publication no. 93-401.

Black, L.L., Green, S.K., Hartman, G. L., and Poulos, J.M. 1993. Pepper Diseases: a Field Guide (Chinese). AVRDC Publication no. 93-407.

Newsletter

Impact, Vol. 5 no. 1 and 2, December 1992, 12 p.; Vol. 6 no. 1, January-June 1993, 12 p.; Vol. 6 no. 2, July-December 1993, 12 p.

Centerpoint, Vol. 10 no. 2, December 1992, 12 p.; Vol. 11 no. 1, May 1993, 12 p.

AVRDC Newsletter (52 issues)

Special Publication

Fletcher, Alan Mark. 1993. The AVRDC Story: Twenty Years of Service to Tropical Agriculture. AVRDC Publication no. 93-406, 158 p.

Villareal, R.L., Shanmugasundaram, S., and Chadha, M.L. 1993. A Primer on Vegetable Gardening. AVRDC Publication no. 93-409, 213 p.

Working Paper

Jansen, H.G.P., Charnnarongkul, S., and Kim, D. 1993. Economic analysis of mungbean production in Thailand. Working Paper No. 6, 96 p.

Journal and Conference Papers

Adam, G., Yeh, S.-D., Reddy, D.V.R., and Green, S.K. 1993. Serological comparison of tospovirus isolates from Taiwan and India with impatiens necrotic spot virus and different tomato spotted wilt isolates. Adv. Virol. 130:237-250.

Barg, E., Lesemann, D.E., Green, S.K., and Vetten, H.J. 1993. Identification, partial characterization and distribution of viruses infecting allium crops in South and Southeast Asian countries. In: Proceedings of an International Symposium on Alliums for the Tropics, 14-19 February 1993, Bangkok, Thailand. Acta Horticulturae vol. 358 (in press).

Benziger, V. 1992. Small fields, big money: Two successful programs in helping small farmers make the transition to high value-added crops. In: Lynam, J. (ed.) Proceedings of a conference of Rockefeller Social Science Research Fellows, November 1992 (in press).

Benziger, V. 1994. The rural road system during the reform period: Challenges, accomplishments, and continuing problems. China Economic Review (in press).

Cababasay, M.P., Engle, L.M., and Gironella, A.I.N. 1993. The Philippine Journal of Crop Science 18 (Supplement No. 1):4.

Carter, T.E., Jr., and Shanmugasundaram, S. 1993. Vegetable soybean (*Glycine*). In: Williams, J.T. (ed.) Pulses and Vegetables. Chapman and Hall, London. p. 219-239.

Cha, S.W., and Shanmugasundaram, S. 1993. Evaluation of developmental growth stages of Korean soybeans (*Glycine max* [L.] Merr.) in the sub-tropics. II. Dry matter accumulation patterns on different Korean soybean varieties. The Research Reports of the RDA, Suwon, Korea.

Chadha, M.L. 1993. AVRDC Experimental Data Collection Sheets and Their Use. Paper presented in the training on Experimental Design and Data Analysis for Vegetable Crops held at BARI, 9-11 February 1993.

Chadha, M.L. and Sidhu, A.S. 1993. Kharif Onion Cultivation — A New Technology. Poster presented in the International Symposium on Alliums for the Tropics, 15-19 February 1993 in Bangkok.

Chadha, M.L. 1993. Techniques for Production of Summer Tomato. Paper presented in the training program on Innovative Practices for Summer Vegetable Production held at BARI, 26-29 April 1993.

Chatchawankanphanich, O., Chiang, B.-T., Green, S.K., Singh, S.J., and Maxwell, D.P. 1993. Nucleotide sequence of a geminivirus associated with tomato leaf curl from India. Plant Disease 77:1168.

Chen, N.C., Hsiao, C.H., and Ho., W.J. 1993. Vegetable improvement and production in Taiwan. In: International Symposium on Horticulture in Northeast Asia: Past, Present and Future, Suwon, Korea, 27-29 May 1993.

Chen, N.C., Huang, Y.K., and Engle, L.M. 1993. Germplasm collection and utilization at AVRDC. In: Workshop on Crop Germplasm Research and Utilization Between Mainland China and Taiwan (in Chinese), Beijing, Peoples Republic of China, 8-10 September 1993.

De la Viña, A.C., and Engle, L.M. 1992. The cytology and morphology of shrub and tree types *Leucaena leucocephala* (Lam.) de Wit and its hybrids. The Philippine Agriculturist 75 (1&2):113-136.

Engle, L.M. 1993. Genetic diversity. Lecture delivered in the course Plant Genetic Resources Conservation and Management, University of the Philippines Los Baños (UPLB), Los Baños, Philippines, 21 and 23 June 1993.

Engle, L.M. 1993. The conservation and utilization of vegetable genetic resources at the Asian Vegetable Research and Development Center. Paper delivered at the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences, Beijing, China. 7 September 1993.

Engle, L.M. 1993. The management of vegetable germplasm collections. In: The symposium on the Plant Germplasm Conservation ... Perspectives for 2000s, Taichung, Taiwan (ROC).

Engle, L.M. 1993. The preservation of pepper and eggplant germplasm. Capsicum and Eggplant Newsletter 12:13-24.

Engle, L.M., Cababasay, M.P., Gironella, A.I.N., and Kim, D. 1993. The Philippine Journal of Crop Science 18 (Supplement No.1):44.

Engle, L.M., Cruz, V.M.V., Shieh, J.C., and Laude, R.P. 1993. Diversity in seed protein in the white-flowered Capsicums. The 7th International Congress of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO) and International Symposium of World Sustainable Agricultural Association (WSAA), 16-20 November 1993, Academia Sinica, Taipei, Taiwan (ROC). Abstracts p. 58.

Fukai, S., and Midmore, D.J. 1993. Adaptive research for intercropping: Steps towards the transfer of intercrop research findings to farmers' fields. Field Crops Res. 34:459-467.

Hanson, P.M., Pastor-Corrales, M., and Kornegay, J.L. 1993. Heritability and sources of ascochyta blight resistance in common bean. Plant Disease 77:711-714.

Hartman, G.L. and Wang, T.C. 1993. Resistance in *Lycopersicon* species to black leaf mold caused by *Pseudocercospora fuligena*. Euphytica 71: 125-130.

Hobbs, H.A., Black, L.L., Valverde, R.A., Bond, W.P., Gatti, J.M., Jr., Schaefer, D.O., and Johnson, R.R. 1993. Transmission of tomato spotted wilt virus from pepper and three weed hosts by *Frankliniella fusca*. Plant Disease 77:797-799.

Howeler, R.H., Ezumah, H.C., and Midmore, D.J. 1993. Tillage systems for root and tuber crops. Soil and Tillage Research 27:211-240.

Jansen, H.G.P. 1993. A review of horticultural export performance of Asian developing countries: Aspects of quality, competitiveness and sustainability. Paper presented at the Fourth International Conference on Marketing and Development, San Jose, Costa Rica, 7-10 January 1993.

Jansen, H.G.P. 1993. Economic analysis of field experiments: Yield of hot pepper as influenced by management practices. FFTC Newsletter, Food and Fertilizer Technology Center, Taipei, Taiwan (ROC).

Jansen, H.G.P. 1993. Ex-ante profitability of animal traction investments in semi-arid sub-Saharan Africa: Evidence from Niger and Nigeria. Agricultural Systems 43:323-349.

Jansen, H.G.P., Charnnarongkul, S., and Kim, D. 1993. Mungbean in Thailand: A farm-level study. Invited paper presented at the National Mungbean Meeting, 25-27 May 1993, Nong Khai, Thailand.

Jansen, H.G.P. 1993. The economics of mungbean cultivation in Thailand. Contributed paper for the First Asian Conference of Agricultural Economists, Seoul, Korea, 10-13 August 1993.

Johnson, R.R., Black, L.L., Hobbs, H.A., and Valverde, R.A. 1993. Association of *Frankliniella fusca* with movement of tomato spotted wilt virus in tomatoes in Louisiana. Phytopathology 83:0000-0000. Abstract (in press).

Lai, S.H., Chen, N.C., Shanmugasundaram, S., and Tsou, S.C.S. 1994. Evaluation of onion cultivars at AVRDC. In: Proceedings of an International Symposium on Alliums for the Tropics, 14-19 February 1993, Bangkok, Thailand. Acta Horticulturae vol. 358 (in press).

Lo, H.F., Li, L., Tsou, S.C.S., and Liao, C.H. 1993. Effects of curing and storage on the quality of sweet potatoes. Hua-kang Agr. Bull. 6:55-65.

Midmore, D.J. 1993. Agronomic modification of resource use and intercrop productivity. Field Crops Res. 34:357-380.

Midmore, D.J., Dumsday, R.G., Jansen, H.G.P., Azmi, A.A., Poudel, D.D., Valasayya, S., Radzali, M., and Fuad, N. 1993. Technical and economic aspects of soil conservation practices among vegetable growers in the Cameron Highlands, Malaysia. Paper presented at the 3rd Wye International Conference on Sustainable Agriculture, Wye College, University of London, U.K., 31 August-4 September 1993.

Midmore, D.J., Roan, Y.C., and Wu, M.H. 1992. Management of moisture and heat stress for tomato and chili production in the tropics. In: Kuo, C.G. (ed.). 1993. Adaptation food crops to temperature and water stress: Proceedings of an international symposium, Taiwan, 13-18 August 1992. AVRDC Publication no. 93-410, p. 452-460.

Midmore, D.J., Yang, S., Kleinhenz, V., Green, S.K., and Tsay, J. 1992. Intercropping chili peppers with maize. In: Proc. Chili Pepper Production in the Tropics. 13-14 October 1992, Kuala Lumpur, MARDI (in press).

Pathak, C.S. 1993. Allium improvement program at AVRDC. Onion Newsletter for the Tropics 5:7-10.

Pathak, C.S. 1994. Allium improvement for the tropics: Problems and the AVRDC strategy. In: Proceedings of an International Symposium on Alliums for the Tropics, 14-19 February 1993, Bangkok, Thailand. Acta Horticulturae vol. 358 (in press).

Perera, K.D.A., and Poulos, J.M. 1993. Studies on stigma position of seventeen pepper accessions. Capsicum and Eggplant Newsletter. 12:44-46.

Perera, K.D.A., and Poulos, J.M. 1993. Studies on percent outcrossing in "closed flower" line "UFBG 8209-1". Capsicum and Eggplant Newsletter 12:47-49.

Poulos, J.M. 1993. *Capsicum* L. In: Siemonsma, J.S. and Kasem Piluek (ed.). Plant Resources of South-East Asia No. 8. Vegetables. PUDOC/PROSEA, Wageningen, the Netherlands. p.136-140.

Poulos, J.M. 1993. Pepper breeding strategies at AVRDC. [poster presentation] The 7th International Congress of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO) and International Symposium of World Sustainable Agricultural Association (WSAA), 16-20 November 1993, Academia Sinica, Taipei, Taiwan (ROC).

Poulos, J.M. 1993. Pepper breeding. In: AVRDC. Breeding of Solanaceous and Cole Crops: A compilation of lecture materials of a training course held in BARI, Joydebpur, Gazipur, Bangladesh, 29 September-3 October 1991. AVRDC, Shanhua, Tainan, Taiwan (ROC). Publicaiton no. 92-384. p. 85-121.

Reifschneider, F.J.B., Boiteux, L.S., Della Vecchia, P.T., Poulos, J.M., and Kuroda, N. 1992. Inheritance of adult-plant resistance to *Phytophthora capsici* in pepper. Euphytica 62:45-49.

Sarker, A., Chadha, M.L., and Amzad Hossain, A.K.M. 1993. Kangkong - A promising summer leafy vegetable of Bangladesh. Paper for 90 annual meeting of the American Society for Horticulture Science held on 24-29 July 1993.

Shanmugasundaram, S., and Yan, M.R. 1993. Soybean research at AVRDC. Paper presented at the Planning Workshop for the Establishment of the Asian Component of a Global Network on Tropical and Subtropical Soybean, 2-7 March 1992, Chiang Mai, Thailand, FAO RAPA.

Shanmugasundaram, S., and Yan, M.R. 1993. Vegetable soybean - A promising sustainable crop. The 7th International Congress of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO) and International Symposium of World Sustainable Agricultural Association (WSAA), 16-20 November 1993, Academia Sinica, Taipei, Taiwan (ROC).

Smith, B.J., and Black, L.L. 1993. In vitro activity of fungicides against *Colletotrichum fragariae* from strawberry. Acta Hort. 348:509-512.

Smith, B.J., and Black, L.L. 1993. In vitro fungicide studies show the occurrence of Benomyl-resistant *Colletotrichum* spp. from strawberry. Adv. in Strawberry Research 12:42-48.

Sripacharavut, P., and Engle, L.M. 1993. Somatic karyotype of seven species of *Capsicum*. The Philippine Journal of Crop Science 18 (Supplement No. 1):45.

Sukprakarn, S., Engle, L.M., Mongkolporn, O., Tumsan, J., Sripacharavut, P., Wachvitan, P., Sangkaew, V., and Srisathit, R. 1993. Collecting and conservation of local vegetables in Thailand. In: The 31st Kasetsart University Annual Conference Proceedings, 3-6 February 1993, Kasetsart University, Thailand.

Summerfield, R.J., Lawn, R.J., Qui, A., Ellis, R.H., Roberts, E.H., Chay, P.M., Brouwer, J.B., Rose, J.L., Shanmugasundaram, S, Yeates, S.J., and Sandover, S. 1993. Towards the reliable prediction of time to flowering in six annual crops. II. Soybean (*Glycine max*). Expl. Agric. Vol. 29:253-289.

Talekar, N.S. 1992. Insect factors in breeding and cultivation of sweet potato. In: Hill, W.A., Bonsai, C.K., and Loretan, P.A. (ed.) Sweet potato technology for 21st century, Tuskegee University, Tuskegee, USA. p. 143-152.

Talekar, N.S., and Hu, W.J. 1993. Morphological characters in *Vigna glabrescens* resistant to agromyzids (Diptera:Agromyzidae). J. Econ. Entomol. 86:1287-1290.

Talekar, N.S., and Huang, C.C. 1993. Efficacy of pyrazophos in controlling agromyzid flies in Taiwan. Internl. J. Pest Management. 39:188-192.

Talekar, N.S., and Shelton, A.M. 1993. Biology, ecology, and management of the diamondback moth. Annual Review Entomol. 38:275-301.

Talekar, N.S., and Tengkano, W. 1993. Mechanism of resistance to bean fly (Diptera: Agromyzidae) in soybean. J. Econ. Entomol. 86:981-985.

Tsai, S.-J., Hong, T.L., and Tsou, S.C.S. Predicting tofu productivities of soybean varieties by tofu gel centrifugation. Proc. of the 6th International Congress on Engineering and Food. 23-27 May 1993. Makuhari Mesee, Chiba, Japan (in press).

Valverde, R.A., and Black, L.L. 1993. Properties of an isometric virus isolated from *Capsicum frutescens*. Phytopathology 83:0000-0000. Abst. (in press).

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, 1993 and 1992, and the related statements of changes in core fund, working capital fund, restricted core fund, special projects fund, and self-sustaining operation projects fund for the years then ended. Our examinations were made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

As mentioned in Note 2 to the financial statements:

1. The Center maintains its accounts on a cash basis, except for the inclusion of provisions and reserves for employee benefits.

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, 1993 and 1992, and the changes in its funds for the years then ended, on the basis of accounting described in the second paragraph, which basis has been applied on a consistent manner.

In connection with our examinations, we noted no indication that the Center was not in compliance with any of the terms, conditions, or provisions of 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 15, 1994

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF ASSETS, LIABILITIES AND FUNDS
(Prepared on a Modified Cash Basis and
Expressed in U.S. Dollars - Note 2)

	December 31	
A S S E T S	1993	1992
CASH	$4,400,223	$3,590,983
ADVANCES AND REFUNDABLE DEPOSITS (Note 3)	442,946	51,533
PREPAYMENTS	17,183	141,743
TOTAL ASSETS	$4,860,352	$3,784,259
LIABILITIES AND FUND BALANCES		
RECEIPTS FOR CUSTODY (Note 4)	$ 168,281	$ 167,020
RESERVES FOR EMPLOYEE BENEFITS (Note 5)	1,167,582	1,170,819
FUNDS		
Core fund	1,000,110	841,864
Working capital fund	800,000	500,000
Restricted core fund	478,935	400,145
Special projects fund	1,133,402	617,825
Self-sustaining operation fund	112,042	86,586
Total Funds	3,524,489	2,446,420
TOTAL LIABILITIES AND FUNDS	$4,860,352	$3,784,259

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN CORE FUND
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	Year Ended December 31	
	1993	1992
ADDITIONS		
Contributions:		
Republic of China	$5,386,901	$5,085,061
United States of America	1,000,000	1,000,000
World Bank	550,000	425,000
Federal Republic of Germany (from restricted Core Fund)	439,827	301,452
France	320,331	154,275
Philippines	248,592	50,000
Japan	233,000	233,000
Thailand	209,888	221,457
Republic of Korea	183,527	277,194
Australia	126,575	101,318
Total contributions	8,698,641	7,848,757
Grants:		
Japan International Cooperation Agency	60,431	-
Taiwan Kagome Co.	-	1,972
MAHYCO American, Inc.	-	1,000
Total grants	60,431	2,972
Translation adjustment (Note 2)	(90,512)	(56,776)
Other (Note 6)	630,667	652,566
Total Additions	9,299,227	8,447,519
DEDUCTIONS		
Capital expenditures (Notes 2 and 6)	581,556	775,170
Operating expenditures (Note 6)	8,191,550	8,012,599
Transfer to working capital fund	300,000	100,000
Total Deductions	9,073,106	8,887,769
INCREASE (DECREASE) IN FUND	226,121	(440,250)
BALANCE, BEGINNING OF YEAR		
As previously reported	841,864	1,283,676
Translation adjustment (Note 2)	(67,875)	(1,562)
As restated	773,989	1,282,114
BALANCE, END OF YEAR	$1,000,110	$ 841,864

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN WORKING CAPITAL FUND
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	Year Ended December 31	
	1993	1992
ADDITIONS		
Transfer from Core Fund (Note 7)	$300,000	$100,000
DEDUCTIONS	-	-
INCREASE IN FUND	300,000	100,000
BALANCE, BEGINNING OF YEAR	500,000	400,000
BALANCE, END OF YEAR	$800,000	$500,000

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN RESTRICTED CORE FUND
(Prepared on a Modified Cash Basis and Expressed in U.S. Dollars - Note 2)

	Year Ended December 31	
	1993	1992
ADDITIONS		
From German Agency for Technical Corporation (Note 8)	$546,008	$308,490
DEDUCTIONS		
Transfer to Cor: Fund	(439,827)	(301,452)
INCREASE IN FUND	106,181	7,038
BALANCE, BEGINNING OF YEAR		
As previously reported	400,145	417,501
Translation adjustment (Note 2)	(27,391)	(24,394)
As restated	372,754	393,107
BALANCE, END OF YEAR	$478,935	$400,145

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN SPECIAL FUND
(Prepared on a Modified Cash Basis and Expressed in
U.S. Dollars - Note 2)

		Year Ended December 31, 1992				Year Ended December 31, 1993			
Sponsors	Balance, Beginning of Year	Translation Adjustment	Additions	Deductions	Balance, End of Year (Note 9)	Translation Adjustment	Additions	Deductions	Balance, End of Year (Note 9)
Council of Agriculture (COA)/ROC	$375,455	$ 5,183	$ 769,635	$ 952,715	$ 197,558	($ 9,426)	$1,414,172	$ 810,277	$ 792,027
Asian Development Bank (ADB)	65,129	-	500,900	570,094	(4,065)	-	524,939	457,022	63,852
Japan Government	-	-	240,000	178,026	61,974	-	310,000	199,342	172,632
U.S. AID	(65,458)	-	276,805	276,946	(65,599)	-	227,794	268,012	(105,817)
International Development Research Center (IDRC)	(10,880)	-	200,858	189,978	-	-	130,962	125,500	5,462
Others	510,500	2,538	459,522	544,603	427,957	(2,017)	468,982	689,676	205,246
Total	$874,746	$ 7,721	$2,447,720	$2,712,362	$ 617,825	($ 11,443)	$3,076,849	$2,549,829	$1,133,402

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN SELF-SUSTAINING OPERATION FUND
(Prepared on a Modified Cash Basis and Expressed in
U.S. Dollars - Note 2)

	Year Ended December 31	
	1993	1992
ADDITIONS (Note 10)	$ 53,372	$ 56,537
DEDUCTIONS (Note 10)	(27,916)	(102,480)
INCREASE (DECREASE) IN FUND	25,456	(45,943)
BALANCE, BEGINNING OF YEAR	86,586	132,529
BALANCE, END OF YEAR	$112,042	$ 86,586

The accompanying notes are an integral part of the financial statements.

(With T N Soong & Co report dated March 15, 1994)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS
(Amounts Expressed in U.S. Dollars Unless Otherwise Stated)

1. ORGANIZATION AND OPERATIONS

The Center was established in the Republic of China as an autonomous, philanthropic, and non-profit research and development organization for promoting production, marketing and utilization of vegetables in Asia. Its members consist of the original signatories to the Center is Charter and other 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. BASIS OF ACCOUNTING

The Center maintains its accounts on a cash basis, except for the inclusion of provisions and reserves for employee benefits, namely, unused compensated annual leave and repatriation expenses.

The Center records its transactions in the currencies in which these are denominated The accompanying statements reflect the actual U.S. dollar amounts of transactions in U.S. dollars, and the U.S. dollar equivalents of transactions in other currencies 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.

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.

Contributions to the retirement savings plan are charged as deduction from the Core Fund when paid.

3. ADVANCES AND REFUNDABLE DEPOSITS

	December 31	
	1993	1992
Advances to Asia Regional Program	$201,465	$ 1,827
Advances to Africa Regional Program	182,800	-
Others	58,681	49,706
	$442,946	$ 51,533

4. RECEIPTS FOR CUSTODY

These include reserve for medical care of trainees, Vitamin A Gardening Project, and income from field operation, less related cost and expenses.

5. RESERVES FOR EMPLOYEE BENEFITS

	December 31	
	1993	1992
Unused compensated annual leave	$ 815,722	$ 806,342
Repatriation expenses	351,860	364,477
	$1,167,582	$1,170,819

Local employees and international staff are entitled to annual leaves of 44 days and 48 days, respectively. The Center shall compensate an employee for accumulated unused annual leaves upon resignation or termination.

The Center is responsible for the transportation and relocation costs of the international staff and his immediate family upon termination of such staff employment.

6. CORE FUND

The core fund is used exclusively in support of the Center's overall operations. Contributions and grants are often subject to certain terms and conditions specified in the relevant agreements.

The details of certain changes in this fund are as follows:

Other additions	1993	1992
Income from various services rendered	$307,175	$295,653
Interest earned from funds other than US contribution	197,073	193,451
Food and dormitory services (net of employees' salaries and benefits of $216,361 in 1993 and $229,756 in 1992)	13,263	61,801
Income on training overhead and fund balance	23,573	23,094
Refunds of various expenditures incurred in previous years	56,524	15,046
Miscellaneous income	33,059	63,521
	$630,667	$652,566

Capital Expenditures

Buildings and improvements	$110,883	$384,111
Equipment and furniture	153,410	256,663
Vehicles	285,563	97,375
Books and journals	31,700	37,021
	$581,556	$775,170

Operating Expenditures

Salaries	$3,563,310	$3,349,151
Regular wages	1,116,400	1,209,364
Employee benefits	1,534,242	1,603,364
Supplies	603,845	664,620
Travel	362,927	331,577
Utilities	253,822	237,885
20th anniversary celebration	169,723	-
Training scholarships	90,711	141,303
Postage, telephone and cable	85,131	83,984
Moving expenses	74,701	44,563
Collaborative research	67,131	80,738
International conference	66,757	76,071
Other	202,850	189,979
	$8,191,550	$8,012,599

Employee benefits include payments for the follows:

	1993	1992
Contributions to retirement and group insurance plans for international staff	$ 182,776	$ 164,088
Contributions to retirement savings plan of local employee	443,778	426,136

The Center has made arrangements for its international staff members to be hired by the Association of International Agricultural Research Centers (AIARC) so that they may participate in suitable retirement and group insurance plans. The Center pays the entire cost of participation in these plans.

The Center has a retirement savings plan covering all local employees. The Center deposits 1/12 to 2/12 of the employee's monthly salaries, depending on service period, to a savings account. Payments from the plan are governed by the provisions of the plan. The changes in the fund are summarized as follows:

	1993	1992
Balance, beginning of Year	$2,223,161	$1,738,973
Translation adjustments	(106,064)	18,965
Contributions	433,778	426,136
Interest income	176,101	158,766
Payments	(142,493)	(119,679)
Balance, end of Year	$2,584,483	$2,223,161

7. WORKING CAPITAL FUND

The Center has established this fund, following a common practice among international agriculture research centers. Yearly appropriations are made to this fund from the Core Fund.

8. RESTRICTED CORE FUND

This Fund is contributed by the German Agency for Technical Cooperation, and is restricted as to its use. Expenditures of this fund are reflected as part of contributions and deductions to Core Fund.

9. SPECIAL PROJECTS FUND

The special Projects is nomally based on agreed-upon budgets. Accordingly, some projects may have negative year-end balances, which shall be reimbursed in the following year.

Expenditures from this Fund 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.

10. SELF-SUSTAINING OPERATION FUND

This represents the fund for the Center's dormitory. Additions and deductions represent rentals received and expenditures incurred, respectively.

11. CONTINGENC

In 1989, the U.S. AID supported AVRDC Vitamin A Gardening Project in Nigeria was sued by some Nigerien merchants for recovery of merchandise ordered by a U.S. Embassy employee using the Project's stationery. Most of the merchandise has been recovered by the merchants, but the lawsuit is still pending. The possible outcome of this litigation is not determinable but the Center's management believes this cold not have a significant clause effect on the Center.

Meteorological Information for 1993

Monthly mean meteorological data collected at AVRDC weather station, 1993

		January	February	March	April	May	June	July	August	September	October	November	December
Humidity	Max.	94	96	94	94	94	94	94	95	95	94	95	95
(%)	Min.	66	61	72	73	72	75	70	73	64	49	54	49
Air temp.	Max.	21.5	24.1	24.3	26.9	29.6	30.4	32.0	32.1	32.1	30.3	27.4	23.6
(C)	Min.	13.3	15.1	17.7	20.8	23.8	25.3	26.1	26.5	25.3	20.7	18.5	13.7
Soil temp. °C	Max.	21.2	23.5	25.2	27.6	29.5	29.4	31.1	29.5	30.0	27.8	25.6	22.2
10 cm	Min.	18.0	19.2	21.2	24.0	26.8	27.2	28.5	27.8	27.8	25.6	23.5	19.8
Soil temp. °C	Max	19.7	20.7	22.6	25.1	27.7	28.1	29.5	28.9	29.0	27.1	24.9	21.6
30 cm	Min	19.2	20.0	21.8	24.4	27.0	27.5	29.0	28.5	28.6	26.6	24.5	21.2
Wind	Daily	106	77	74	70	62	66	67	72	62	72	59	82
(km)													
Solar radiation	Daily	3663	4495	4485	4812	5415	5367	5798	5746	5148	4531	3326	3271
(Watt-h/m²)													
Precipitation	Total	5.0	4.5	25.0	84.0	253.0	497.0	203.5	313.5	37.0	0	30.5	5.0
(mm)													
Evaporation	Daily	3.7	4.4	4.5	4.8	5.7	6.2	6.3	5.9	5.8	5.4	3.2	3.3
(mm)													