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Abbreviations and Acronyms

AARD - Agency for Agricultural Research and Development (Indonesia)
ABA - abscisic acid
ACB - Asiatic cornborer
ACC - 1-aminocyclopropane-1-carboxylic acid
ACCT - Agency for Cultural and Technical Cooperation (France)
a.i. - active ingredient
AID - Agency for International Development (USA)
AMV - alfalfa mosaic virus
ARTT - advanced soybean rust tolerance trial
ASET - AVRDC Soybean Evaluation Trials
atm - atmosphere
AVRDC - Asian Vegetable Research and Development Center
AYT - advanced yield trials
AzMV - Adzuki bean mosaic virus

BARI - Bangladesh Agricultural Research Institute
BC - backcross
BCMV - bean common mosaic virus
BER - blossom end rot
BICMV - blackeye cowpea mosaic virus
BLS - bacterial leaf spot
BORIF - Bogor Research Institute for Food Crops (Indonesia)
BW - bacterial wilt
BYMV - bean yellow mosaic virus

CAAS - Chinese Academy of Agricultural Sciences
CARDI - Caribbean Agricultural Research and Development Institute
CATIE - Tropical Agricultural Research and Training Center
CCC - Chloroethyltrimethyl- ammonia acid
CENARGEN - Centro Nacional de Recursos Genéticos (Brazil)
CIAT - Centro Internacional de Agricultura Tropical (CGIAR)
CIP - International Potato Center
CIRAD - Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CLS - Cercospora leaf spot
CMS - cytoplasmic male sterility
CMV - cucumber mosaic virus
CPA - Para-chloro-phenoxyacetic acid
CSIRO - Commonweath Scientific and Industrial Research Organization (Australia)
CV - coefficient of variation
CVMV - chili veinal mottle virus
CTA - Technical Center for Agricultural and Rural Cooperation (EC)
DAA - days after anthesis
DAE - days after emergence
DAIS - District Agricultural Improvement Station (Taiwan)
DAS - days after sowing
DAT - days after transplanting
diam - diameter
DBA - days before anthesis
DBM - diamondback moth
df - degrees of freedom

EC - European Community
EMBRAPA - Empresa Brasileira de Pesquisa Agropecuaria (Brazil)
ELISA - enzyme-linked immunosorbent assay

FAO - Food and Agriculture Organization of the United Nations
FMV - feathery mottle virus

g - gram
GA - gibberellic acid
GAET - advanced germplasm evaluation trial
GOT - germplasm observational trial
GRSU - Genetic Resources and Seed Unit (AVRDC)
GYT - general yield trial

ha - hectare
HES - Horticultural Experimental Station (Rep. of Korea)
HI - heat injury
HKI - Helen Keller International
HS - heat-sensitive
HT - heat-tolerant

IAA - indoleacetic acid
IARC - international agricultural research center
IARI - Indian Agricultural Research Institute
IGR - insect growth regulator
IBPGR - International Board for Plant Genetic Resources
ICW - imported cabbageworm
IDRC - International Development Research Centre (Canada)
IITA - International Institute for Tropical Agriculture
IMN - International Mungbean Nursery (AVRDC)
INRA - Institut Nacional de la Recherche Agronomique (France)

IPDR - Institut Pratique de Developpement Rural (Niger)
IPM - integrated pest management
IRRI - International Rice Research Institute
ISNAR - International Service for National Agricultural Research
IYT - intermediate yield trial

JICA - Japan International Cooperation Agency

kg - kilogram

LEHRI - Lembang Horticulture Research Institute (Indonesia)
LER - land equivalent ratio

m - meter
MARDI - Malaysian Agricultural Research and Development Institute
min - minute/minutes
MF - male fertile
ml - milliliter
MLO - mycoplasma-like organism
mm - millimeter
MYMV - mungbean yellow mosaic virus

NBPGR - National Board of Plant Genetic Resources (India)
NSKE - neem seed kernel extract

OIS - Office of Information Services (AVRDC)
OP - open-pollinated
OYT - observational yield trial

PC - principal component (analysis)
PI - plant introductions
PeMV - pepper mottle virus
pm - powdery mildew
PMV - peanut mottle virus
POP - Philippine Outreach Program (AVRDC)
ppm - parts per million
PStV - peanut stripe virus
PVC - polyvinyl chloride
PVF - polyvinyl formate
PVMV - pepper veinal mottle virus
PVY - potato virus Y
PYT - preliminary yield trial

REDSO/WCA- Regional Economic Development Support Office for West and Central Aftrica
RCBD - randomized complete block design
RDA - Rural Development Administration (Rep. of Korea)
RYT - regional yield trial

sd - standard deviation
SLW - specific leaf weight
SMV - soybean mosaic virus
SPLV - sweet potato latent virus
SPVB - sweet potato virus B
SPV II - sweet potato virus II
SPVB - sweetpotato vine borer
SPYDV - sweet potato yellow dwarf virus
SYCA - sequential yield component analysis

t - metric ton
TA - technology adaptation
TBRV - tobaco ring spot virus
TEV - tobacco etch virus
TFW - tomato fruitworm
TLCV - tomato leaf curl virus
TMV - tobacco mosaic virus
ToMV - tomato mosaic virus
TOP - Thailand Outreach Program (AVRDC)
TRSV - tomato ring spot virus
TSWV - tomato spotted wilt virus
TVIS - Tropical Vegetable Information Service (AVRDC)

USAID - United States Agency for International Development
USDA - United States Department of Agriculture
mg - microgram

WAE - weeks after emergence
WAT - weeks after transplanting
WHO - World Health Organization
WUE - water use efficiency

Crop Improvement Program

Chinese Cabbage Breeding

Combining Ability Trial

Summary

Inbred lines previously developed from the Hakuran backcross program crossed with heat-tolerant inbreds and the resulting combinations were tested in a summer trial. Eight hybrids were selected for their early maturity, perfect heading rate, high harvest rate and promising preference traits for further evaluation.

Introduction

Since a decision had been made to scale down the Chinese cabbage improvement program to a maintenance level, conventional crossbreeding to search for high-yielding F_1 hybrids was discontinued this year. Among the inbred lines developed from the Hakuran backcross program, however, some appeared to possess characteristics such as round head shape, hairlessness and smooth dark leaves which are preferred by Taiwanese farmers. These were, therefore, crossed to selected heat-tolerant inbreds to test their value as parents of F_1 hybrids for the local market.

Materials and Methods

Forty-one F_1 hybrids were made by crossing inbred lines developed from the Hakuran backcross program with a part or all of the nine old heat-tolerant inbreds during the 1986-87 cool season. They were sown together with the check cultivar, Hybrid 62, on 31 July and transplanted on 19 August 1987. A randomized complete block design with two replications was employed. Each plot consisted of a 4-m long, double-row raised bed. Plants were spaced 40 cm apart in two rows which were 50 cm apart from each other. The distance between the centers of two adjacent beds was 150 cm. Data on yield and other horticultural traits were collected. Evaluation of preference traits was made at proper growth and development stages.

Results and Discussion

Contrary to the high expectation based on the performance of the inbred lines, none of the entries was very impressive. Although 11 entries were significantly higher in yield than the check, Hybrid 62, all were significantly later in maturity by 6 to 21 days. The majority of the entries were also low in heading efficiency rate.

Table 1 shows the yield and other traits of the most preferred entries. They were not significantly different from Hybrid 62 in maturity, yield, soft rot incidence, heading efficiency rate, and harvest rate. All of the selected combinations showed perfect heading rate (= 100%) and generally appeared to have smoother leaf texture than Hybrid 62. The selected entries had very little or no leaf hair.

Based on the grand mean of the head size (553 g) which is much smaller than that usually obtained from summer trials, the environment of the trial is not considered very favorable for plant growth.

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Table 1. Yield and other horticultural traits[z] of the best performing Chinese cabbage F_1 hybrids in the 1987 combining ability trial.

Entry	Maturity (DAF)	Yield (t/ha)	Heading rate (%)	Head weight (g)	Heading efficiency rate	Head shape index	Harvest rate (%)	Soft rot (%)
87111	36 ef	17.8 h-m	100 a	567 i-o	1.13 b-h	1.20 j	97 abc	3 ab
87151	33 f	18.4 g-m	100 a	614 h-l	1.00 b-j	1.50 efg	95 a-e	5 ab
87152	36 ef	20.9 d-l	100 a	644 g-k	0.89 h-k	1.50 efg	99 ab	0 b
87162	36 ef	20.4 d-l	100 a	662 g-j	0.94 c-j	1.30 hij	97 a-e	3 ab
87181	33 f	15.3 lmn	100 a	474 m-o	1.05 b-j	1.30 hij	98 ab	2 ab
87182	35 ef	14.8 mn	100 a	459 no	1.42 a	1.35 g-j	98 ab	2 ab
87184	35 ef	18.6 g-m	100 a	598 h-m	1.24 ab	1.30 hij	91 a-e	7 ab
87186	33 f	16.8 j-n	100 a	505 l-o	1.02 b-j	1.45 e-h	100 a	0 ab
Hybrid 62[y]	33 f	16.3 k-n	100 a	553 j-o	0.99 b-j	1.35 g-j	93 a-e	7 ab

[z]Mean separation within columns by DMRT at 5% probability level. [y]Check cultivar.

Therefore, it should be worthwhile to reevaluate the selected entries in the trials with seasonal replications in 1988.

Advanced Yield Trials

Summary

Nine F_1 hybrid combinations selected from the 1986 combining ability trials were further evaluated in six advanced yield trials over the summer season. Two combinations, 86181 and 87187, were comparable in maturity and stability, and slightly better in yield to the standard check, Hybrid 62.

Introduction

Nine F_1 hybrid combinations selected from the 1986 combining ability trials were evaluated in six plantings over different growing environments to select entries which have stable yield and outperform the check, Hybrid 62.

Materials and Methods

Nine best F_1 hybrids were selected from the 1986 combining ability trials and included in the advanced trials scheduled as follows:

	Sowing date	Transplanting date
AYT[z] I	22 May	12 June
AYT II	8 June	30 June
AYT III	22 June	13 July
AYT IV	7 July	5 August
AYT V	22 July	12 August
AYT VI	6 August	28 August

[z]AYT = advanced yield trials.

Three cultivars, Hybrid 62, WW and SL4, were also included in each trial as checks. A randomized complete block design (RCBD) with four replicates was employed for the field layout. Each plot consisted of two 4-m long double-row raised beds. Spacing between hills was 40 cm and the two rows on each bed were 50 cm apart. Bed width was 1.5 m from one center to the next. Data on yield

and other horticultural traits were first analyzed for each trial and combined stability analyses were done for yield and maturity characters.

Results and Discussion

The majority of the entries had perfect or near perfect heading rates except for the heat-susceptible check, WW, indicating that they are heat-tolerant. As shown in Figure 1, the yields of 86173 and 86153 were much higher than the standard check, Hybrid 62. However, both were quite late-maturing, especially 86173 (Table 2). Considering the yield, maturity and stability parameters together, 86181 and 86187 were the best performers, although they were not the highest yielders. These two combinations, therefore, will be further evaluated in regional and international trials in the future.

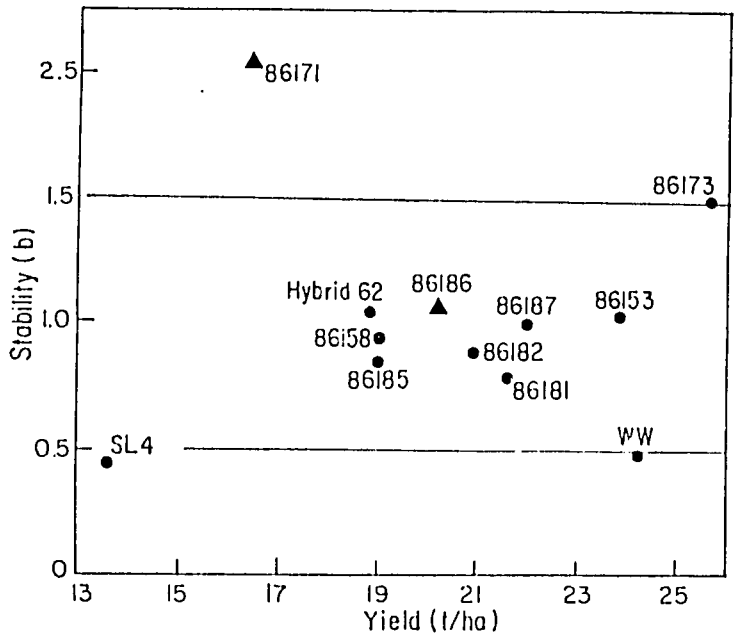

Fig. 1.
The relation of yield and stability of the entries entered into advanced yield trials. Estimates of s^2d were significant only for entries indicated by ▲.

Table 2. Means and stability parameters[z] for selected characters in the advanced yield trials.

	Harvest rate[y] (arcsine $\sqrt{\%}$)			Heat weight (g)[y]			Days to maturity[y] (DAT)		
	Mean	b	s^2d	Mean	b	s^2d	Mean	b	s^2d
86153	80	0.34	19	752	0.87	6,105	40	.82	8*
86158	80	-0.41	41	598	0.98	1,382	36	.99	2
86171	53	4.64*	118*	821	1.41	11,056*	47	.61	11*
86173	77	1.84	10	825	1.10	4,279	41	.98	4
86181	80	2.03	68	678	0.67	1,555	37	1.02	1
86182	83	0.66	3	660	0.85	2,292	35	.82	3
86185	87	-0.19*	7	575	0.95	2,390	32	.74	3
86186	87	0.27	24	611	1.29	10,109*	33	.76	3
86187	80	1.07	30	689	1.18	4,755	36	1.33	1
Hybrid 62	83	0.75	14	586	1.08	4,645	33	1.31	0
SL 4	84	0.49	13	419	0.56	834	32	1.07	0
WWCC	68	0.49	43	856	1.05	2,069	45	1.56	4

[z]b = regression coefficient; s^2d = deviation from regression. [y]Test for significance of regression coefficient (b) is against Ho:b = 1.

Cytosterility Backcross Program

Summary

To develop a simpler and more stable alternative to the self-incompatibility system in F_1 hybrid seed production, two different sources of cytoplasmic male sterility (CMS), radish and leaf mustard (*Brassica juncea*) had been backcrossed to tropical Chinese cabbage. Radish-originated CMS lines in the BC_5-BC_6 generations were evaluated for their combining ability during the summer season. They performed much poorer than the corresponding male fertile lines as both parents and F_1 hybrids. Backcrosses in BC_4-BC_5 of *B. juncea* origin showed less undesirable traits than in the previous generation. Twenty-four elite plants were selected from this group of CMS backcross materials to be used in further backcrosses.

Introduction

Cytoplasmic male sterility (CMS) would be a simpler and more easily applicable alternative to the self-incompatibility system which has been widely utilized and successfully employed for F_1 hybrid seed production of Chinese cabbage. A program was initiated to transfer the CMS in radish and mustard into tropical Chinese cabbage. In 1987, further backcrosses were made for both CMS with intensive selection to remove the undesirable traits associated with male sterility. Radish-derived CMS was evaluated for its practical value in developing hybrid cultivars by comparing the F_1 combinations produced from CMS female lines with those from male fertile (MF) sister lines.

Materials and Methods

In the radish-CMS backcross program, a total of 1,811 seeds harvested from 14 backcross families which had been selected in a previous generation were sown on 24 October 1986. A total of 776 seedlings of 11 families were transplanted in the field on 27 November 1987, after excluding those with undesirable traits. They were evaluated for vegetative traits to make 124 selections on 19 January 1987. These selected plants were transplanted into clay pots with a diameter of 30 cm to induce flowering. At the flowering stage further selection was made for improved reproductive traits. Thirty-seven plants out of seven backcross families were finally selected and used (1) to produce F_1 hybrids by crossing with pollen of nonrelated heat-tolerant inbred lines; (2) to further backcross with recurrent parents by bee pollination in screen cages; and (3) to advance generation of one single plant whose nectary gland was much larger than other CMS lines by crossing it with mixed pollen source to obtain offsprings for the genetic stability of improved nectary.

A total of 3,394 seeds in 21 mustard-originated CMS backcross families were also sown on 24 October 1986. After discarding undesirable seedlings, 1,943 plants were transplanted on 27 November 1986 to further select for vegetative and reproductive traits following a similar process to that which was applied to the radish-CMS families. Forty-two plants out of 11 families survived this selection process and were entered into screen cages for further backcrossing by bee pollination with recurrent pollen parents. Ten plants were finally selected to advance to the next backcross (BC) generation.

During the above processes, recurrent parents were always grown together for comparison as well as for further backcrossing.

For the combining ability test of CMS lines, entries shown below were sown on 30 June and transplanted on 5 August.

Recurrent parent	No. of F_1's produced from CMS	No. of F_1's produced from MF[a]	CMS parent	Recurrent parent	Hybrid 62 (Check)
CT1-27	4	5	1	1	1
CT1-32	10	5	1	1	1
7252-1	8	4	–	1	1

[a]MF = male fertile.

Field layout was RCBD with three replications in each recurrent parent group. A plot consisted of 20 plants. Plants were spaced 40 cm apart on two rows 50 cm apart from each other on raised beds. The distance between two adjacent beds was 150 cm from center to center. Data were collected at maturity or at the termination of the experiment on 24 September 1987.

Results and Discussion

At the vegetative growth stage, much improvement had been noticed in CMS-associated undesirable traits, such as poor vigor and chlorosis, compared to the previous generations. In the selected families, chlorosis was not obvious and plants were very similar to and as vigorous as the recurrent parents in both CMS sources.

However, nectary development was still minimal or absent in the majority of the plants of radish-derived CMS. It was more true in the inner nectaries, which are known to be active in honey production, except for one individual plant, 86W13-17. After six backcrosses, pod shape and seed set were still apparently abnormal. Chlorotic symptoms in varying degrees also appeared during the reproductive stage in the majority of the plants.

Table 3 shows the F values and their significance for single degree of freedom comparisons between male sterile vs. corresponding male fertile sister entry groups. All F values between these groups were highly significant. The male sterile F_1's and parents had shorter leaf length later in maturity and lower mean growth (Tables 2 and 3). In fact, no F_1's produced from male sterile female parents formed marketable heads by the termination of the field trial, 50 days from transplanting (Table 4). Such a difference, although not as great, was also observed between male sterile parents and their corresponding male fertile recurrent parents. The poor performance must be basically due to the undesirable traits associated with cytoplasmic male sterility or the serious incompatibility between *Brassica* nucleus and *Raphanus* cytoplasm. In the plantings in the autumn season which were grown for selection and generation advancement, the differences were not so obvious especially in the last two generations. Regardless of the underlying cause, it was deemed not worthwhile to carry out the program with the radish-derived CMS any further.

Table 5 summarizes the degree of chlorosis, nectary development, nectar secretion, flower size and pod set of the final selections from *B. juncea*-originated backcross families. Chlorosis in the vegetative stage was already minimal, but it was, in general, a little more prominent in the reproductive stage. Two active inner nectary glands were observed in most of the flowers, even if the size was smaller than that of the recurrent parents. The small nectary gland size may be partly due to the small flower size as seen in the petal size. The pod set rate was still generally much lower than the normal rate observed in the recurrent parents, while size and shape were rated almost normal in certain selections.

Table 3. Comparison of male sterile (MS) and corresponding male fertile (MF) entries in three different backcross families of radish-derived male sterility.[z]

Variable	Comparison	Backcross family by recurrent parent		
		CT1-27	CT1-32	7252-1
Leaf length	For all entries	29.4***	29.3***	55.5***
	Parents vs. F_1's	50.4***	1.2NS	16.5***
	Hybrid 62[y] vs. other F_1's	7.5*	16.4***	39.6***
	MS vs. MF in F_1's	188.7***	329.6***	474.7***
	MS vs. MF in parents	44.7**	34.4***	-x
Mean growth	For all entries	36.7***	127.8***	73.5***
	Parents (Ps) vs. F_1's	58.8***	16.1***	5.9*
	Hybrid 62[y] vs. other F_1's	20.8**	178.9***	59.8***
	MS vs. MF in F_1's	268.5***	1470.9***	782.2***
	MS vs. MF in Ps	12.5**	53.8***	-x

[z]F values significant at 5% (*), 1% (**) and 0.1% (***) probability levels. [y]An F_1 check unrelated to the backcross families. [x]MS parent is missing, therefore no comparison with MF parent.

Although the selected families appeared almost similar to their recurrent parents in the vegetative stage at the present generation of BC_4 - BC_5, more backcrosses are required to improve the defects, such as flower and nectary size and pod set, observed during the reproductive stage.

Table 4. Comparison of male sterile (MS) and male fertile (MF) parents and their F_1's in different entry groups.

Recurrent variety	Entry group	No. of entries	Leaf length (cm)	Maturity (DAT)	Mean growth (g)	Harvest rate (%)
CT1-27	All entries	12	23.5	>41	740	50
	Hybrid 62 (ck)	1	27.0	34	1,174	100
	F_1's	9	24.1	–	781	56
	MS F_1's	4	19.0	>50	282	0
	MF F_1's	5	28.2	35	1,179	100
	Parents (Ps)	2	19.0	–	335	50
	MSP	1	14.2	>50	130	0
	MFP	1	23.7	34	539	100
CT1-32	All entries	18	21.4	>45	563	39
	Hybrid 62 (ck)	1	25.6	34	1,172	100
	F_1's	15	20.9	–	539	33
	MS F_1's	10	17.4	>50	179	0
	MF F_1's	5	28.0	35	1,257	100
	Parents	2	23.4	–	441	50
	MSP	1	18.9	>50	204	0
	MFP	1	27.8	>50	678	100
7252-1	All entries	14	22.5	>45	767	57
	Hybrid 62 (ck)	1	27.3	34	1,229	100
	F_1's	12	21.9	–	716	50
	MS F_1's	8	18.2	>50	341	25
	MF F_1's	4	29.3	36	1,466	100
	Parent (MF)	1	25.8	48	917	100

Table 5. Expression[z] of traits associated with male sterility in different backcross groups of *B. juncea*-originated CMS.

	Backcross group by recurrent parent		
	CT1-32	CT1-56	B-18
No. of selections	10	5	9
Chlorosis (degree)[y]			
Vegetative stage	+(– ~ +)	+	+
Reproductive stage	+ +(+ ~ + + +)	+ +(+ ~ + +)	+ +(+ ~ + + +)
Petal size (% of recipients)	64 (50 ~ 70)	74 (60 ~ 80)	62 (60 ~ 70)
Nectary score (%)[x]	51 (32 ~ 75)	65 (50 ~ 90)	52 (35 ~ 75)
Nectar secretion	yes	yes	yes
Pod set rate[w]	P (P ~ F)	P (P ~ F)	F (P ~ G)
Pod size[w]	G (F ~ E)	G (F ~ G)	G (P ~ E)
Pod shape[w]	F (F ~ G)	F (F ~ G)	G (P ~ E)

[z]Mean figure or most frequent score outside parentheses and ranges within parentheses. [y]– = no chlorosis, + + + + + = very serious chlorosis. [x]Scores taken from five random flowers in consideration of the number and size of the nectary glands in reference to 100 in the recipients. [w]P = poor, F = fair, G = good, E = excellent.

Salt Spray and CO_2 Treatment to Induce Temporary Breakdown of Self-Incompatibility

Summary

In the search for economical methods to multiply self-incompatible inbred lines of Chinese cabbage and related crops, the effects of CO_2 gas treatment and salt (NaCl) spray, combined with bee pollination, were studied. The CO_2 treatment did not significantly increase pod and seed set. A daily spray of salt (1% to 2%), however, successfully broke self-incompatibility and produced as high seed yields as bud pollination. Observation of pollen germination on the stigma and pollen tube count in the style corresponded with the seed yield data.

Introduction

For Chinese cabbage parental lines to produce a high percentage of hybrid seeds through open pollination by insect pollinators, it is essential that they possess strong and stable self-incompatibility. Since these self-incompatible parents produce little or no seeds if pollinated during the open-flower stage, seed multiplication has conventionally relied on laborious and expensive bud pollination. Among the various alternative methods studied, only CO_2 treatment is known to have a potential for commercial scale application in certain selected crop varieties of *Cruciferae*. Electric shock and stigma mutilation using steel brush may be used on a small, non-commercial scale. Based on the positive results obtained from the preliminary study of the previous year, the CO_2 treatment was tried on a semicommercial scale. Spray of salt (NaCl) solution, combined with bee pollination, was also tried on Chinese cabbage and some related crops.

Materials and Methods

One or more lines were selected from five tropical Chinese cabbage inbreds, B-18, E-7, E-9, WW and FL-9, depending on their availability at the time of treatments. For semicommercial trials, they were induced to flower and placed in screenhouses after removing all the previously opened flowers. After fasting two nights and one day, honeybees, in cages, were placed in each screenhouse for the pollination during the day. CO_2 treatment was conducted from 1800 h to 0800 h the next morning inside the sealing hood made of plastic film. An electric fan was used to secure an even CO_2 concentration in the hood. The CO_2 concentration was regulated by the flow speed meter and release time was based on the hood dimension, and then confirmed with a detection kit (Model 126 SH of Komyo Physicochemical Co.). Commercial grade salt was diluted in distilled water and sprayed at around 1000 h over the inflorescence. Each trial had a daily treatment and lasted from one to two weeks. Fifteen to 20 plants were used for each replicate of each treatment. At the termination of the treatment, all the buds were removed by pinching and the plants were moved out of the screenhouse after four to five days. At maturity, pod and seed set of five branches each of six randomly chosen plants in each plot were counted. Ten random flowers which opened on the previous day were sampled from each plot during the treatment period, and pollen germination and pollen tube growth in the style were recorded.

For experiments with artificial pollination, the flowers which bloomed on the day of treatment were regarded as open flowers, while ready-to-open and too tiny buds were not used for bud pollination. The remaining flowers and buds were removed after pollination. Experimental plants were kept away from each other in the insect pollinator-free screenhouses. At maturity, pod and seed set data were collected from healthy branches of the healthy plants.

Results and Discussion

Contrary to the expectation from the artificial pollination data of last year, the CO_2 treatment did not increase seed set of the inbred, B-18, compared to the check under bee-pollinated conditions (Table 6). The pod set rate was only higher in the 2% CO_2 treatment.

Table 6. Effect of CO_2 treatment[z] on pod and seed set of a self-incompatible Chinese cabbage inbred, B-18, bee-pollinated in isolation cage.

CO_2 conc.	Bee pollination	No. of[z] flowers sampled (A)	No. of pods w/seed (B)	No. of pods w/o seed (C)	No. of seeds set (D)	Pod set[y] rate (B/A, %)	Seed no. per flower (D/A)	Seed no. per pod set (D/B)
0% (ck)	No	674	120	95	215	17.8 b	0.53	2.84
0% (ck)	Yes	694	269	44	754	38.6 ab	1.10	2.84
2 %	Yes	613	392	21	967	64.0 a	1.58	2.41
4 %	Yes	622	254	30	679	41.6 ab	1.09	2.45

[z]Single replicate for each treatment. [y]Mean separation within columns by Duncan's multiple range test at 5% probability level.

Similar results were also obtained in the other three inbreds as shown in Table 7. Such little or no effect of CO_2 treatment may have been partly caused by the interference of senile compatibility which could bring about increased pod and seed set in nontreated check plots, especially those with bee pollination. But the absence of effect against the check without bee pollination over four different genotypes cannot be readily explained. On the other hand, the 2% salt spray resulted in a significant increase in the number of seeds per flower in all three lines. Such increase was attained more by the increase in number of seeds/pod rather than the increased pod set rate.

Pod and seed set data with hand pollination indicates that 1% or 2% salt spray results in as many seeds per pollinated flowers as by bud pollination (Table 8). The combined scores of pollen germination on the stigma and pollen tube growth into the style (Table 9) generally corresponded well with the seed set data presented above. However, the significant increase in score resulting from bee pollination without CO_2 and salt treatment strongly implies that senile compatibility could result in an increased seed set if bee-pollinated.

From the small-scale simple treatments with salt sprays, it was possible to obtain positive results in broccoli, cauliflower and cabbage inbred lines. However, the effect was not obvious in radish. In the case of *B. oleracea* crops, damage on pods was frequently observed because of the petals which remained wet due to the moisture captured by the sprayed salt. This is related to the unique petal structure of those crops. To solve this problem, spraying with water sometime after the salt spray may be tried to wash out the salt after breaking the self-incompatibility.

Table 7. Effect of salt spray and CO_2 treatment on pod and seed set of self-incompatible Chinese cabbage inbreds, FL-9, E-7 and WW, bee-pollinated in isolation cage.

Inbred	Treatment	Bee pollination	No. of flowers sampled (A)	No. of pods set w/seed (B)	No. of pods set w/o seed (C)	No. of seeds set (D)	Pod set[z] rate (B/A, %)	Seed no.[z] per flower (D/A)	Seed no.[z] per pod (D/B)
FL-9	Check	No	527	3	6	3	1.4 b	0.10 b	0.50 b
	Check	Yes	498	234	52	311	46.6 a	0.60 b	1.25 b
	2% CO_2	Yes	556	214	67	391	37.5 a	0.70 b	1.72 b
	4% CO_2	Yes	483	149	51	226	30.1 a	0.47 b	1.47 b
	2% salt	Yes	484	327	43	3,935	68.6 a	6.24 a	9.03 a
WW	Check	No	525	8	356	2	0.4 c	0.01 b	0.13 c
	Check	Yes	429	79	137	109	17.3 b	0.26 b	1.35 c
	2% CO_2	Yes	374	108	122	554	29.0 b	1.55 b	1.92 b
	4% CO_2	Yes	341	119	113	116	34.4 ab	0.34 b	1.07 c
	2% salt	Yes	355	205	79	1,930	57.6 a	5.39 a	9.34 a
E-7	Check	No	611	11	10	23	1.3 a	0.04 b	2.05 b
	Check	Yes	598	187	65	461	31.1 a	0.80 b	2.26 b
	2% CO_2	Yes	585	173	77	419	25.9 a	0.68 b	2.24 b
	4% CO2	Yes	518	140	40	298	24.9 a	0.60 b	1.80 b
	2% salt	Yes	553	301	28	2,665	54.4 a	4.79 a	8.81 a

[z]Mean separation within columns within inbreds by Duncan's multiple range test at 5% probability level.

Table 8. Pod and seed set of a Chinese cabbage inbred, WW, as affected by pollination type and salt treatments.

Poll.[z] type	Treatment	Flower no. pollinated (A)	Pod no. set (B)	Seed no. set (C)	Pod set[y] rate (B/A, %)	Seeds[y] per pod (C/A)	Seeds per[y] pollination (C/A)
FS	None	105	45	198	44.2 c	3.6 b	1.9 d
FS	Water on stigma	118	54	203	46.1 c	3.3 b	1.8 d
FS	2% salt on stigma	112	77	1,193	70.3 ab	13.7 a	10.8 a
FS	1% salt on stigma	94	72	1,042	78.3 a	13.4 a	10.7 a
FS	Water on pollen	125	66	445	53.7 bc	6.2 bc	3.7 cd
FS	2% salt on pollen	124	4	1	0.9 d	0.1 c	0.0 d
FC	None	113	72	611	65.0 abc	9.3 a	6.6 bc
BS	None	137	110	1,551	72.4 ab	12.4 a	10.1 ab

[z]FS = self-pollination at open-flower stage; FC = cross-pollination at open-flower stage; BS = self-pollination at bud stage. [y]Mean separation within columns within inbreds by Duncan's multiple range test at 5% probability level.

Table 9. Effect[z] of CO_2 and salt treatment on the combined score[y] of on-stigma germination of pollens and in-style tube count of Chinese cabbage inbreds, bee-pollinated in isolation cages.

Treatment	Bee pollination	Inbred			
		B-18	E-9	FL-9	WW
None	No	3 c	4 c	0 c	4 c
None	Yes	16 b	37 b	30 b	36 b
2% CO_2	Yes	18 b	31 b	42 b	21 bc
4% CO_2	Yes	33 a	26 b	37 b	21 bc
2% salt	Yes	–	70 a	89 a	85 a

[z]Mean separation within columns by DMRT at 5% probability level. [y]Scores summed from 10 observations giving 0, 2, 4, 8 and 10 to no germination, germination without penetration, few pollen tubes in the style, 10 to 20 tubes in the style and numerous tubes in the style, respectively.

International Cooperation

In 1987, a total of 1,085 packets of Chinese cabbage seeds were distributed to 93 cooperators in 39 countries. They were to be entered into trials under different growing environments together with local checks and an AVRDC heat-sensitive check. This year, seed production of AVRDC F_1 hybrids was attempted in a few countries such as the Philippines, Nepal and Indonesia. Reports from the cooperators are summarized as follows:

China

Repeated performance tests during the summer seasons since 1982 have proven that Hybrids 58 and 62 are outstanding; therefore, they were released with the names Summer Pearl and Summer Abundance, respectively, in 1987 by the Vegetable Research Institute, Jiangsu Academy of Agriculture. The Institute provided farmers with the recommended cultural practices for the released cultivars through an article in the Jiangsu Nongye Kexue (Jiangsu Agricultural Science) Journal. Seed production of the hybrids has also been studied by the Institute for the last few years.

Indonesia

Dr. Thongchai Tonguthaisri, Resident Scientist of the Indonesia-AVRDC Bilateral Program, conducted several trials in cooperation with Dr. Anggoro Hadi Permadi of the Lembang Horticultural Research Institute in both the highlands and lowlands during 1986-87. Based on the results obtained from these trials, Dr. Anggoro was able to narrow down the number of entries to be entered into

further trials (Table 10) which are now being conducted in five different selected locations of lowland and highland Java. Dr. Anggoro is also attempting to establish the techniques for hybrid seed production with the parental seeds of Hybrid 62 provided by AVRDC.

Dr. Brian Hilton, University of Merdeka, filed a report on a replicated trial conducted on five AVRDC Chinese cabbage varieties and a check cultivar from Japan in the Duegus area of East Java during the rainy season (Table 11). All AVRDC entries formed heads in 50 to 60 days from transplanting, whereas the check did not until the trial was terminated 82 days after transplanting. Because of the large coefficient of variation (32% for yield), varietal difference was not statistically recognized in any investigated trait except for days to maturity. However, Hybrids 59 and 62 were preferred due to the earlier maturity and higher level of heat tolerance. AVRDC entries were well accepted because they were sweeter and tastier than the locally available Chinese cabbage.

Dr. Simon Field of NTT Integrated Area Development Project conducted two trials to search for varieties that can outperform Sanguihe and Talaud, AVRDC open-pollinated varieties previously released in Indonesia. One was conducted in the lowlands mainly with open-pollinated entries, and the other in the highlands with F_1 hybrids. Although varietal difference was not statistically recognized in yield and most of the important traits, AVRDC entries matured earlier and yielded higher than the locally grown imported check. In the highland, Sanguihe and Talaud did not perform as well as the other entries. Sanguihe had the smallest head weight and Talaud the lowest harvest rate among the entries tested together. Securing a reasonable population size is essential in the course of regeneration of any open-pollinated variety to avoid genetic drift. The reported deterioration of the previously released varieties may not have been properly handled in this respect. Dr. Field's future plan to study the seed production techniques should be accorded high priority.

Table 10. AVRDC Chinese cabbage F_1 hybrids that performed well in trials conducted by LEHRI.

Hybrid nos.	
Hybrid 58[z]	82-157
Hybrid 62	83-2
82-46	

[z]Seed production now being tried.

Table 11. Performance of AVRDC Chinese cabbage entries in a trial at Daerah Dungus-kabupatan Madium, East Java.[z]

Entry	Maturity (DAT)	Head wt. (g)	Heading rate (%)	Harvest rate (%)	Yield (t/ha)
77M(3)-26	60 a	698	72	56	13.1
77M(2/3)-43	56 ab	725	83	67	16.3
Hybrid 58	57 ab	659	89	72	15.9
Hybrid 59	51 b	771	91	74	18.9
Hybrid 62	52 b	594	93	80	16.1

[z]Sown on 17 December 1986 and transplanted on 6 January 1987 in three replications.

Japan

AVRDC's heat-tolerant Chinese cabbage was tested at Fukuoka Prefecture Horticultural Research Center. Two hybrids, 82-46 and 83-20, and one open-pollinated variety, 77M(3)-27, were sown on 4 August 1987. They produced larger heads than the local check, Omi, and proved promising for late July and early August sowing when conventional varieties are difficult to grow. AVRDC entries, in general, had rounder heads, less leaf hair, darker leaf color and softer leaf texture than the locally popular commercial cultivars.

Liberia

Mr. Andrew Saye, Sr. of Lowland-N.C.R.D.P. filed a report on a trial with AVRDC Chinese cabbage at Nimba County, Liberia. Seven entries out of 10 included in the trial successfully formed

marketable heads of 470 to 810 g by 51 to 55 days after transplanting on 12 January 1987. Entry 77M(2/3)-46 was the highest yielder. Soft rot and/or downy mildew were serious in the entries Hybrid 59, 77M(3)-27 and 77M(3)-35 from which data could not be taken.

Malaysia

Mrs. Fadelah Abdul Aziz of the Malaysia Agricultural Research and Development Institute (MARDI) reported on a trial with AVRDC Chinese cabbage at the Jalan Kebun Station, Malaysia. Surprisingly, all the entries, including the heat-sensitive check B-40, showed very high or perfect heading rates. As shown in Table 12, two hybrids and two open-pollinated varieties had higher yields, if not significantly different from the check, Saladeer, and Hybrid 62.

Nepal

In a trial conducted in Kathmandu by Dr. S. S. Rekhi of the HMG/FAO Vegetable Production Project, Hybrids 58, 59 and 62 showed excellent performance (Table 13). Hybrid 62 also performed very well in all the other trials conducted elsewhere in the country. Hybrid 62 received the highest rating due to its early maturity, compact head, bolting tolerance and for getting the highest yield per unit time and area among all the entries in the trial.

Regarding the potential of Hybrid 62, the Research Coordinating Committee of HMG/Nepal has decided to conduct multi-locational trials in the 1987-88 season and include it in the list of prerelease varieties. The committee has also decided to run a seed production trial to meet the future seed requirement in the country. AVRDC has provided seed materials for both performance test and seed production of the F_1 hybrid.

Table 12. Yield and other traits[z] of some selected Chinese cabbage entries in a trial[y] at MARDI at Jalan Kebun, Klang, Malaysia.

Entry[x]	Yield (t/ha)	Maturity (DAT)	Harvest rate (%)	Head weight (%)
82-156	36.5 a	46 a	100 a	1.09 a
82-157	36.3 a	45 ab	100 a	1.09 a
77M(3)-27*	33.3 ab	41 c	84 ab	1.00 abc
77M(2/3)-46*	33.3 ab	43 abc	91 ab	1.04 ab
Hybrid 62	26 7 bc	41 c	86 ab	0.83 cd
Saladeer (ck)	28.6 abc	40 c	76 b	0.86 bcd

[z]Mean separation within columns by DMRT at 5% probability level [y]Sown on 6 June 1987 and transplanted on 3 July 1987 [x]Entries marked with asterisks are open-pollinated varieties, while others are F_1 hybrids.

Table 13. Yield and other traits of some selected Chinese cabbage entries in a trial[z] at Kathmandu, Nepal.

Entry	Yield (t/ha)	Maturity (DAS)	Bolting rate (%)	Head weight (g)	Soft rot (%)
Michilli	41	96	0	1,560	0
Hybrid 58	22	65	5	851	0
Hybrid 59	21	65	5	816	0
Hybrid 62	26	61	0	981	0

[z]Four-week old seedlings were transplanted on 23 October 1987 No mean separation was provided in the summary table.

Nigeria

Mr. Y.S. Chen of the International Institute for Tropical Agriculture (IITA) tested three AVRDC Chinese cabbage hybrids, together with a check variety, without irrigation utilizing only the residual soil moisture during the dry season by transplanting immediately after the rice crop at Ibadan, Nigeria.

Chinese cabbage did not suffer from drought and reached maturity in 45 to 54 days from transplanting (Table 14). Hybrid 58 showed heat tolerance with no internal rot and had the highest yield among the entries.

Philippines

The Philippine Outreach Program (POP) conducted a feasibility study on hybrid seed production of Hybrid 62 in cooperation with the Eastwest Seed Company in the Baguio highland area during the 1986-87 dry season. The trial was reported to be successful. Mr. J. van Balen also found that 14 days of cold treatment was long enough to induce flowering in the female parent, E-7. In the 1987-88 dry season, the company will expand its trial to a limited commercial scale of 2,000 m^2 under an agreement among the Bureau of Plant Industry, POP/AVRDC and the company.

Dr. M. Yasuo, Team Leader of the APC-JICA Project, filed a report on two trials conducted on AVRDC Chinese cabbage at the Bohol Agricultural Promotion Center in Tagbilaran City, Philippines. All entries showed high levels of heat tolerance in both plantings (Table 15). Insect damage was the most serious problem, followed by soft rot and tipburn. In the second planting, yield was significantly different between entries. However, this was mainly due to differences in insect damage. These trials proved that it is possible to obtain economic yields using AVRDC varieties if good insect control is provided.

Messrs. E.I. Castro and V.V. Alpuerto of the Mariano Marcos State University at Batac, Ilocos Norte conducted a Chinese cabbage trial which included five entries from AVRDC from February to April 1987. Hybrid 62 was the highest yielder followed by Soro 127 and Hybrid 58 (Table 16). All entries were damaged by diamondback moth to a certain degree. However, most entries still produced an economic yield.

South Africa

At the University of Stellenbosch, Dr. P.C.J. Maree conducted trials in two different seasons. His spring planting was not successful because of high bolting rates caused by the cool night temperature. In the autumn trial (Table 17), however, AVRDC entries grew well and formed heads by the 41st to 67th day from transplanting without obvious problems. The mean head weight ranged from 590 to 790 g, depending on the entries.

Turkey

Two summer trials were conducted by Dr. A. Yazgan, Department of Horticulture, Cumhuriyet University in Tokat. The trial site was located 858 m above sea level. The first trial was sown on 1 August and the second on 20 August 1986. Depending upon the entries, disease (not specified by the cooperator) and bolting were recognized as the major problems in the first and second plantings, respectively. However, most entries normally grew to form marketable heads. Some of the newly developed F_1 hybrids matured as early as or earlier than Hybrid 62 and yielded higher. Hybrid 83-20 showed a perfect harvest rate, early maturity and high yield in both plantings. Among open-pollinated varieties, 77M(2/3)-46 performed best.

Table 14. Yield and other traits[z] of Chinese cabbage in a trial[y] at IITA, Ibadan, Nigeria.

Entry	Marketable weight (t/ha)	Head weight (kg)	Heading rate (%)	Maturity (DAT)	Internal rot (%)
Hybrid 58	26.4 ab	1.53	95 a	48	0 b
Hybrid 59	28.0 a	1.17	100 a	50	0 b
Hybrid 62	23.9 ab	1.07	94 a	48	75 a
Top Yield (ck)	14.6 b	1.29	50 b	54	75 a

[z]Mean separation within columns by DMRT at 5% probability level. [y]Trial conducted from November 1986 to February 1987.

Table 15. Performance of selected Chinese cabbage entries[z] in a trial at Bohol Agricultural Promotion Center, Tagbilaran City, Philippines.

Entry	Yield (t/ha)	Harvest rate (%)	Head weight (kg)
77M(3)-33	14.7	75	0.59
77M(3)-35	16.9	84	0.61
77M(3)-40	16.5	87	0.57
77M(2/3)-41	17.9	81	0.66
77M(2/3)-43	14.7	67	0.68
CV (%)	26	20	16

[z]Sown on 12 November 1985 and terminated on 5 February 1986.

Table 16. Yield performance[z] of Chinese cabbage entries in a trial[y] at Mariano Marcos State University, Ilocos Norte, Philippines.

Entry[x]	Yield (t/ha)	Head weight (kg)	Solidity
77M(3)-26*	13.4 b	0.60 b	0.88
77M(3)-27*	10.1 c	0.50 c	0.75
77M(3)-35*	13.6 b	0.60 b	0.83
Hybrid 58*	17.7 a	0.79 a	0.88
Hybrid 62*	18.7 a	0.84 a	0.93
Shagum 091	11.0 c	0.51 c	0.62
Soro 127	18.6	0.83 a	0.93
CV (%)	15.8	16.3	15.0

[z]Mean separation within columns by DMRT at 5% probability level. [y]Conducted from 25 February to 13 April 1987. [x]Entries with asterisks are AVRDC cultivars.

Table 17. Mean head weight[z] of some selected AVRDC Chinese cabbage entries in an autumn trial[y] at the University of Stellenbosch, South Africa.

Entry	Head weight (g)
Hybrid 62	680
82-156	667
83-2	590
77M(2/3)-46	761

[z]Mean from nonreplicated trial [y]Sown on 2 February and transplanted on 4 March 1987.

Chinese Cabbage Entomology

Biological Control of Diamondback Moth on Farmers' Fields in Luchu

Summary

Attempts were made to control diamondback moth (DBM) (*Plutella xylostella*) on a commercial crucifer planting of 115-ha fields owned by 130 farmers in Luchu township in Kaohsiung county. A total of 110,050 cocoons of two larval parasites, *Diadegma cucerophaga* and *Apanteles plutellae*, were released at intervals throughout the season. Total parasitism ranged from 10.2% to 24.0%. This level of parasitism, coupled with use of *Bacillus thuringiensis*, gave adequate control of DBM. Despite advice to the contrary, most farmers used chemical insecticides which caused parasite mortality and reduced parasitism. An effective extension program is a necessity for the success of any biological control program with DBM.

Introduction

In Luchu township of Kaohsiung county, farmers grow cruciferous vegetables mainly in the cool dry season each year from October to May mainly for export. The major vegetables are cauliflower, broccoli and common cabbage. Diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae), is the major pest of crucifers in this area. The insect larvae feed on the foliage from seedling stage up to harvest. As a result of insect feeding, the yield and, at times, quality of the produce is adversely affected.

Farmers in Luchu use a large quantity of insecticides to combat this pest. The insecticide use is intensive and, at times, several insecticides are mixed together and sprayed at an interval of less than one week. This intensive insecticide use has lead to the development of insecticide resistance in diamondback moth, which has forced farmers to apply even greater quantities of insecticides more frequently. Such use has intensified the insecticide resistance and increased the cost of production. The residues left on the produce have increased the potential for health hazards both to the consumers and the farmers. The large quantity of insecticides that eventually end up in the soil poses the possibility of soil contamination and subsequent absorption of pesticide residues by food crops.

To overcome the above-mentioned hazards associated with intensive insecticide use, AVRDC attempted biological control to combat diamondback moth in Luchu by releasing two larval parasites.

Materials and Methods

Parasite mass rearing. *Diadegma cucerophaga* Horstm (Hymenoptera: Ichneumonidae) was imported from Indonesia in 1984 and reared continuously in the laboratory on diamondback moth larvae. *Apanteles plutellae* Kurdj (Hymenoptera:Braconidae) was collected from the farmers' fields in Luchu township in 1984, and similarly reared on diamondback moth larvae continuously in the laboratory. Diamondback moth larvae were reared on cabbage seedlings and exposed to parasite adults for oviposition for 24 hours. The parasitized larvae were reared further on cabbage seedlings.

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At pupation, the parasitized larvae died and the parasite larvae feeding inside formed its own cocoon. These cocoons were collected and placed at 10°C until needed for release in the field.

Parasite release in the field. The area of this experiment covered 115 ha owned by 130 farmers. A total of 35 release stations were established throughout the area. A typical release station consisted of a quadrangular wooden box with slanted top and a door on one side that can be opened and closed. Except for the top and the bottom, all sides were perforated with three or four 1.5 cm diameter holes. The box was mounted on a 1 m high wooden pole. Parasite pupae were placed inside the box and the holes on its sides permitted the adult parasites to fly away easily. Starting on 20 August 1986 when some farmers started raising the crucifer seedlings in the field, parasite pupae were placed in the release station at intervals. The parasite release continued until 5 March 1987 when most of the farmers began harvesting their second crucifer crop.

Parasitism evaluation. At intervals throughout the season, 20 fields were selected at random and 20 plants were sampled in each field. The number of DBM larvae and pupae and parasite cocoons on each plant were recorded. DBM larvae were cut open and the number of parasite larvae found inside them was recorded. The percentage of parasitism was calculated by dividing the number of parasitized larvae + parasite cocoons by the total number of DBM larvae + pupae (parasitized + unparasitized) and multiplying the ratio by 100.

Control of other pests. For the control of other pests, especially *Spodoptera litura*, water trough traps baited with sex pheromone were established at regular intervals in the field. A total of 477 traps were set. The pheromone was replaced once a month. All farmers were requested not to use any chemical insecticides and they were encouraged to spray *Bacillus thuringiensis* to control any lepidopterous pest that causes significant damage.

Information exchange. At the beginning of the experiment, a meeting with all farmers was held to explain the purpose and procedure of this experiment. At this meeting, various insect pests that might attack their crops during the season were also shown and measures to control them were identified. The parasites were shown to them and the process of parasitism explained. Once every two weeks, evening meetings were held with the farmers where they were encouraged to bring up pest problems they might have noticed during the preceding fortnight. At the same time, the farmers were informed of new developments in biological control of diamondback moth and the results of AVRDC's observations.

Results and Discussion

The schedule of parasite release and the number of parasites released in the field are summarized in Table 1. From 20 August 1986 to 5 March 1987, parasites were released 23 times. A total of 51,700 cocoons of *D. eucerophaga* and 58,300 of *A. plutellae* were released. Based on laboratory studies, 80% of *D. eucerophaga* and 95% of *A. plutellae* cocoons emerged into adults.

The data on the diamondback moth infestation and parasitism are summarized in Table 2. The number of DBM larvae + pupae per plant which was 4.6 by 23 October was reduced to 1.34 on 6 November 1986. During this period parasitism went up from 10.2% to 22.1% (Table 2). The parasitism rate stayed high for the next two weeks but declined thereafter to 15.6% by 19 February 1987. There was a tendency for the diamondback moth larval population to decline with an increasing level of parasitism. The level of parasitism observed, however, was not adequate to control diamondback moth completely. In the intervening period, especially late December and early January, most farmers harvested their first crucifer crop and some planted the second.

Limitations. Despite repeated requests not to use chemical insecticides, practically all farmers still resorted to spraying insecticide mixtures. This obviously resulted in the mortality of parasites which are highly susceptible to a variety of chemicals presently being used. Although the parasitism rate in the laboratory and under screen in the field was high, the frequent use of chemical insecticides killed the parasites which adversely affected the parasitism rate. An effective extension program of

discouraging farmers from indiscriminate use of chemical insecticides is essential for the success of any diamondback moth biological control program. At times secondary pests such as *Spodoptera* spp. become a problem. To combat these pests, use of sex pheromone, coupled with one or two sprays of newly developed insect growth regulators which are not toxic to parasites, is necessary.

Table 1. Schedule of parasite release in Luchu.

Date	No. parasites (× 1000)		
	Diadegma	*Apanteles*	Total
20 August 1986	1.7	3.4	5.1
28 August	1.9	3.8	5.7
4 September	3.3	3.3	6.6
11 September	2.1	2.1	4.2
24 September	4.8	7.2	12.0
2 October	4.6	4.6	9.2
9 October	2.6	0	2.6
20 October	3.8	0.6	4.3
23 October	0.4	0	0.4
11 November	2.2	1.0	3.2
20 November	0.8	2.0	2.8
28 November	2.0	0.6	2.7
9 December	0.6	2.0	2.6
23 December	2.6	2.9	5.5
31 December	2.6	2.0	4.0
14 January 1987	3.1	3.1	6.2
21 January	1.4	2.5	3.9
27 January	2.4	3.1	5.5
5 February	1.8	2.8	4.6
13 February	2.9	2.8	5.7
19 February	1.5	1.8	3.3
26 February	3.3	3.7	7.0
5 March	0	3.0	3.0
Total	51.8	58.3	110.0

Table 2. Parasitism of diamondback moth in Luchu.[z]

Date	No. of larvae + pupae/plant	Parasitism (%)
23 October 1986	4.05	10.2
6 November 1986	1.35	22.1
20 November 1986	3.30	24.0
19 February 1987	5.12	15.6

[z]Insect survey data are based on 20 plant samples from each of the 20 randomly selected fields.

Biological Control of Diamondback Moth on Farmers' Fields in Yangminshan

Summary

Attempts were made to control diamondback moth (DBM) by releasing two larval parasites, *Diadegma eucerophaga* and *Apanteles plutellae*, on 10 ha of farmers' fields near Taipei. A total of 97,200 parasites were released during the season. Parasitism ranged from 20% to 80% and the DBM population was reduced from over 10 larvae/plant to 0.3/plant. Secondary pests were kept under control by sex pheromone and occasional sprays of *Bacillus thuringiensis*. *Spodoptera litura* still caused some damage.

Introduction

Crucifers are important vegetable crops cultivated in the Taipei suburb of Yangminshan, especially during the rainy-hot summer when they fetch a high price in the Taipei market. As elsewhere in Taiwan, the diamondback moth, *Plutella xylostella* L. (Lepidoptera:Yponomeutidae), is the most important insect pest. In cooperation with the Taoyuan District Agricultural Improvement Station (DAIS), a project was launched to control this pest by releasing two larval parasites, *Diadegma cuceroplaga* Horstm (Hymenoptera:Ichneumonidae) and *Apanteles plutellae* Kurdj (Hymenoptera:Braconidae).

Materials and Methods

When farmers started transplanting in early April, 18 parasite-release stations were erected throughout the 10-ha area. Each station consisted of a quadrangular wooden box with slanted top and a door on one side which can be opened and closed. Except for the top and the bottom, all sides were perforated with three to four 1.5 cm diameter holes for easy escape of the parasite adults. The box was mounted on a 1-m high wooden pole. Starting mid-April, at intervals of 10 to 15 days, pupae of both parasites were released in each station. A total of 35,600 *Diadegma* and 97,200 *Apanteles* pupae were released throughout the season.

Starting in the beginning of May till mid-July, observations on the parasitism were made by the Taoyuan DAIS at weekly intervals. Diamondback moth larvae from 15 randomly selected plants were collected and raised in the laboratory until pupation. At pupation the numbers of pupae of parasite and diamondback moth were recorded and the rate of parasitism computed.

Farmers were requested to use, when necessary, only *Bacillus thuringiensis* to control other caterpillar species. Several traps baited with sex pheromone to trap *Spodoptera litura*, an occasional pest of crucifers, were placed throughout the field.

Results and Discussion

The results of the diamondback moth infestation of cabbage and rate of parasitism are shown in Figure 1. Diamondback moth larval population which was quite high initially (122 to 154 larvae/15 plants) decreased gradually. The parasitism rate which was very low soon after parasite release increased to 52.4% four weeks later. From this time onwards, the pest population remained relatively low dropping to 5 larvae/15 plants and parasitism stabilized between 35% and 40%. At this stage plants had already formed heads and most of the pests were on the outer leaves which did not affect the yield. A week before the start of harvest, the larval population increased to 90 insects/15 plants but it was reduced to 5 larvae/15 plants the following week when parasitism reached 80%. A cyclical pattern between the pest population and parasitism rate was evident, though it was not very distinct.

Most of the parasitism was caused by *Apanteles*. *Diadegma* parasitism was observed only on three occasions in June. It ranged between 4.5% and 7.6%. In a similar experiment in Luchu area,

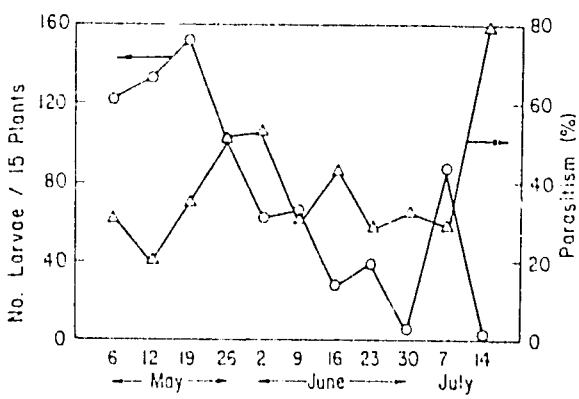

Fig. 1.
Infestation of crucifers by diamondback moth and rate of diamondback moth larval parasitism in Yangminshan area.

no significant parasitism by *Diadegma* was observed. The reasons for such low parasitism by this parasite are not fully understood.

All instars of diamondback moth larvae were parasitized by *Apanteles*. The average parasitism was 28.6% for the combined sample of the first and second instar, 41.7% for the third and 28.3% for the fourth instar diamondback moth larvae.

None of the farmers used chemical insecticides and only *Bacillus thuringiensis* was used to control caterpillar pests, such as *Trichoplusia ni*, *Pieris rapae* and *Spodoptera* spp. A large number of *S. litura* adults were trapped in the sex pheromone traps. However, this pest still caused some damage especially at the base of the cabbage head. This damage was visible only when the cabbages were harvested.

Studies on Various Aspects of Diamondback Moth Parasitism by *Diadegma eucerophaga* and *Apanteles plutellae*

Summary

Biological studies were conducted on two larval parasites of diamondback moth (DBM), *Diadegma eucerophaga* and *Apanteles plutellae*, to understand the nature of their parasitism and facilitate their use for controlling diamondback moth. *Diadegma* prefers lower temperatures (15° to 25°C) than *Apanteles* (20° to 35°C). The second and third instar larvae were preferred over the first and fourth instar for oviposition by *Diadegma* with no parasitism at all of the fourth instar DBM larvae. *Apanteles* parasitized all instars of its hosts. The second instar larvae were slightly preferred over the other instars. Both parasites were able to parasitize equally the larvae of insecticide-resistant and susceptible strains of DBM. Among the insecticides, all formulations of *Bacillus thuringiensis* and insect growth regulator, CME-134, and a selective aphicide, pirimiphos, were not toxic to either parasites. A synthetic pyrethroid, deltamethrin, was highly toxic.

Introduction

Diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae), is the most destructive insect pest of economically important cruciferous vegetables in the tropical and subtropical regions of the world. In Asia, the pest problem is aggravated by excessive and indiscriminate use of insecticides which has led to the development of resistance in most strains of this pest to practically all commercial insecticides presently being utilized for its control. As a result, despite the availability of chemicals, this pest cannot be controlled readily.

In 1984-85, therefore, AVRDC introduced a larval parasite, *Diadegma eucerophaga* Horstm (Hymenoptera: Ichneumonidae), from Indonesia. This parasite and *Apanteles plutellae* Kurdj (Hymenoptera: Braconidae), which is native to Taiwan, were mass-reared in the laboratory, and after initial successful tests on AVRDC fields are now being released on farmers' fields to combat diamondback moth. In addition to mass-rearing and release on farmers' fields, certain tests in the laboratory were also conducted in 1987 to characterize the nature of parasitism. In particular the effect of temperature, diamondback moth larval instars and diurnal variation on parasitism, and the toxicity of various types of insecticides to the parasites were studied.

Materials and Methods

Effects of temperature on parasitism. In this experiment, the parasitism of diamondback moth larvae by *D. eucerophaga* and *A. plutellae* was studied. One hundred newly emerged adults of both parasites were maintained at a particular temperature for 12 hours to acclimatize them at that temperature. A cabbage seedling with 200 second instar diamondback moth larvae on its foliage was then placed in the cage containing adult parasites. The parasite and diamondback moth larvae were maintained at a particular temperature for 36 hours. The DBM larvae were then removed and maintained at a rearing temperature of 25°C. When they all turned to pupae, their number and that of the parasites were recorded and the percentage of parasitism was computed. This study was conducted at 10°, 15°,

20°, 25°, 30° and 35°C. At each temperature, three cages were used; each cage represented one replicate.

Effect of larval stage on parasitism. In this experiment, the parasitism by both *Diadegma* and *Apanteles* of various instars of diamondback moth larvae was studied. One hundred diamondback moth larvae of each of the four instars were transferred on one-month old cabbage seedlings. Larvae of a particular instar were transferred on four seedlings, each seedling representing one replicate. The seedlings with larvae were then exposed to two- to five-day old adults of *Diadegma* or *Apanteles* maintained in large cages. After 24 hours during which the parasites oviposited in the diamondback moth larvae, the cabbage seedlings with larvae were transferred to other cages in a rearing room to allow larvae to become pupae. When all the larvae pupated, the number of parasite and DBM pupae were recorded, and the percentage of parasitism was calculated.

Parasitism in two DBM strains. In this experiment the influence of various larval strains of diamondback moth on the parasitism by *Diadegma* and *Apanteles* was studied. Two strains, one insecticide-susceptible and one insecticide-resistant, were compared. The susceptible strain was maintained at AVRDC and was routinely used for mass rearing parasites for at least 40 generations. Pupae of the highly-resistant strain were collected from Luchu township and reared in the laboratory along with the susceptible strain until adults emerged and laid eggs. Two hundred second instar larvae of each strain were placed on two potted cabbage seedlings in an individual nylon net cage and exposed to either parasite for oviposition. Each cage, containing 200 larvae of each strain, represented one replicate, and there were three replicates for each strain. After one day exposure to the parasite adults, the larvae were transferred to rearing cages and maintained in a rearing room until all became pupae. At this stage, the number of DBM and parasite pupae were recorded and the percentage of parasitism was calculated.

Insecticide toxicity to parasites. Four insecticides of different modes of action were used at twice the recommended rates. These included four formulations of *Bacillus thuringiensis* at equivalent concentration of 1 kg product/ha, CME-134 15EC at 75 g a.i./ha, deltamethrin 2.8EC at 100 g a.i./ha, and pirimicarb 50WP at 500 g a.i./ha. Twenty *Apanteles* or *Diadegma* adults were released inside an acrylic jar (15 cm diameter, 30 cm height). Two puffs of insecticide spray from a spray gun (atomizer) were applied inside the jar holding the parasites. This liquid volume was equal to the amount a typical full-grown cabbage seedling would receive when the liquid starts dripping. It was also equal to about 1,000 liters/ha. Soon after spraying, a plastic sheet smeared with honey was hung inside the jar. This served as food to the parasites. The control treatments received only water spray. Insect mortality was recorded one and three days after the treatment.

Diurnal variation in parasitism. Thirty pairs of one- to two-day old adults of either parasite were confined in each of the two nylon net cages. At 0500 h 100 second instar diamondback moth larvae placed on a full-grown potted cabbage seedling were introduced in the parasite cage and maintained inside until 1700 h. One cage was covered with black cloth. At 1700 h the cabbage seedling with old larvae was removed and transferred to a rearing room, and a fresh lot of 100 second instar diamondback moth larvae was introduced inside each parasite cage in a similar manner. One cage was placed under continuous light in the same room. The insects were maintained inside the cage until 0500 h the next day. At this time, the cabbage seedlings with diamondback moth larvae were removed and placed in a rearing room. This experiment was repeated three days in a row. The diamondback moth larvae were reared until they all pupated. The number of parasites and diamondback moth pupae were recorded and the rate of parasitism was calcuated.

Results and Discussion

Effect of temperature on parasitism. The results of the rate of parasitism by both *Diadegma* and *Apanteles* at various temperatures are summarized in Figure 2. At 15°, 20° and 25°C, parasitism of the diamondback moth larvae by *Diadegma* was very high, 85% to 96%. There was no significant

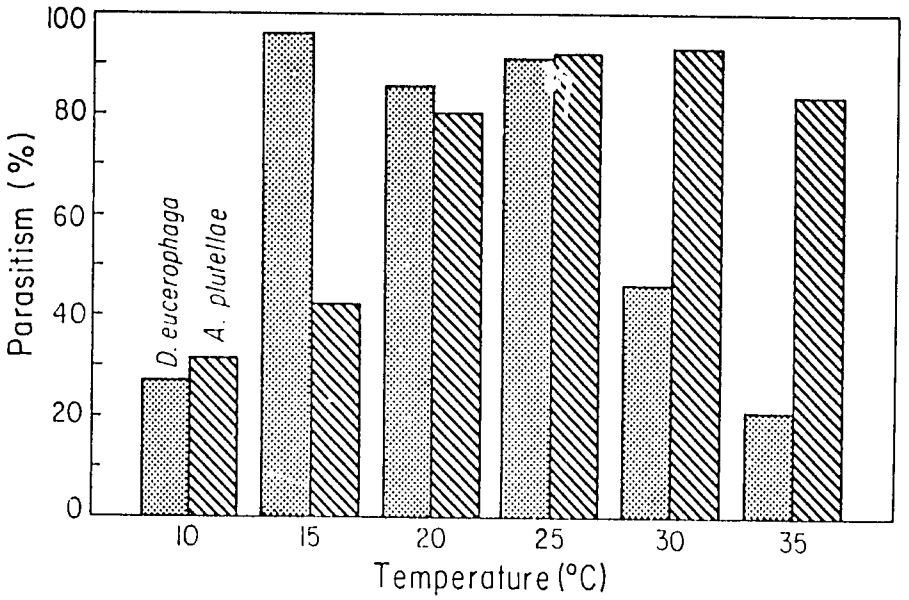

Fig. 2. Parasitism of diamondback moth larvae by *D. eucerophaga* and *A. plutellae* at various temperatures.

difference among the three temperatures. The parasitism rate was moderate at 30°C, but at both extremes, 10° and 35°C, parasitism was adversely affected. *Diadegma* adult mortality was high at 35°C and to some extent at 30°C.

At present, in the tropics, crucifers are grown in the relatively cool highlands where temperature rarely exceeds 30°C. In such places the temperature is ideal for establishment of *Diadegma*. In certain areas in the tropics, such as Taiwan, where relatively cooler winter temperatures make it possible to grow cruciferous vegetables in the lowlands, *Diadegma* has the potential to be established. Indeed, three years after its introduction, this parasite now occurs regularly at the AVRDC campus during January, February and March. No information is available on its summer habitat and alternate hosts in Taiwan.

Apanteles, on the other hand, was quite active at high temperatures between 20° and 35°C as its parasitism of diamondback moth larvae was high between this temperature range. This parasite, therefore, is suitable for establishment at the relatively high temperatures of the lowland winter or summer where crucifers can be grown. *Apanteles* is present in Taiwan throughout the year when and where crucifers are grown and insecticide use is limited.

For successful control of diamondback moth where crucifers are grown under widely fluctuating temperatures, release of both parasites seems to be ideal.

Effect of larval stage on parasitism. The rates of parasitism by both *Diadegma* and *Apanteles* of four different instars of diamondback moth larvae are summarized in Table 3. *Diadegma* parasitism of the second and third instar larvae was significantly higher than those of the first and fourth instar when these larvae were offered for oviposition. The preference for the second and third instar could be due to the higher preference of the parasite for oviposition or larval development and possibly easy pupation. The period between the second and third instar and pupation of DBM also coincided with the period required by *Diadegma* to develop from egg to pupa. This synchronization helped perpetuate the parasite population. The first instar larvae seem to be too small for female *Diadegma*'s ovipositor to puncture and lay eggs in. On the other hand, the duration between DBM's fourth instar and pupation is too short for successful completion of *Diadegma* development from egg to pupa. Hence, the parasite probably does not lay eggs in these larvae or the eggs perish when these larvae become pupae soon after oviposition. Second instar diamondback moth larvae are now used for parasite mass rearing.

Table 3. Parasitization of various instars of diamondback moth by *Diadegma* and *Apanteles*.

Larval instar	Parasitism (%)[z]	
	Diadegma	*Apanteles*
1st	22.5 b	75.7 b
2nd	70.0 a	94.1 a
3rd	79.0 a	77.7 b
4th	0.0 c	65.9 c

[z]Data are means of four replicates. Mean separation in each vertical column by DMRT.

Apanteles parasitized all four instars of diamondback moth larvae. The parasitism was highest during the second instar larvae stage (Table 3). The first and third instar larvae had a similar rate of parasitism. Unlike *Diadegma*, *Apanteles* parasitized the fourth instar diamondback moth larvae. Apparently, *Apanteles* development is accelerated when the parasite lays eggs in the fourth instar host larvae so that it can pupate at the same time as the host larvae, since both parasite and parasitized larvae pupated simultaneously. The ability of *Apanteles* to parasitize all instars of diamondback moth probably makes it a better parasite over *Diadegma*, since in fields where both parasites were released, a greater percentage of diamondback moth larvae were always observed to be parasitized by the former rather than the latter.

Parasitism in two DBM strains. No significant difference in parasitism by either *Diadegma* or *Apanteles* was observed when a diamondback moth strain from Luchu, which is highly resistant to insecticides, or from AVRDC, which is susceptible to insecticides, were exposed to the parasites. This implies that the development of insecticide resistance in the diamondback moth, which is a common phenomenon in tropical-subtropical Asia, will not hinder establishment of either parasite.

Insecticide toxicity to parasites. The mortality of *Diadegma* adults exposed to various insecticides are summarized in Table 4. Dipel, a representative among several *Bacillus thuringiensis* formulations, was not toxic. This is because *B. thuringiensis* is a stomach poison and needs to be eaten to be effective. *B. thuringiensis* has no contact toxicity. In nature, adults of *Diadegma* feed on honeydew secreted by flowers, and thus are not exposed to *B. thuringiensis*. Hence it is not toxic to the adults. Similarly CME-134, typical among the newly developed groups of insect growth regulars (IGRs), does not show any contact toxicity to *Diadegma* adults. These IGRs are also stomach poisons and need to be ingested. IGRs are effective only against larvae which are actively molting from stage to stage. Hence, these chemicals, which are becoming increasingly popular in diamondback moth control, are not toxic to adults. Pirimicarb, a relatively selective chemical against aphids which is frequently used to control them in crucifers is not harmful to *Diadegma* despite its contact action. However, deltamethrin, a commonly used nonselective synthetic pyrethroid, is extremely toxic to the parasite when used in diamondback moth control. Identical results were obtained when *Apanteles* was exposed to these insecticides in similar manner (Table 5). In this test, four *B. thuringiensis* formulations were used instead of one. All were nontoxic to *Apanteles*.

Table 4. Toxicity of certain insecticides to *Diadegma eucerophaga* adults.

Treatments	Mortality (%)[z]	
	1 day	3 days
Dipel	1.2 b	32.5 b
CME-134	1.2 b	17.5 b
Pirimicarb	2.5 b	11.3 bc
Deltamethrin	100.0 a	100.0 a
Control (water)	1.2 b	3.7 c

[z]Data are means of four replicates. Mean separation in each vertical column by DMRT.

For successful biological control of diamondback moth, chemicals with nonselective contact toxicity should not be used. For the control of caterpillar pests, *B. thuringiensis* or IGRs like CME-134 can be safely used. These insecticides will also help control diamondback moth without harming the parasites. For the control of aphids, occasional sprays of pirimicarb will not harm the parasites.

Diurnal variation in parasitism. Both parasites laid eggs in the host larvae only during the light period and were unable to do so during the dark period (Table 6). Light, rather than the diurnal rhythm, was thus important in the oviposition by the parasites. Parasites apparently locate their hosts visually, hence parasitism is greater during the daytime and when there is light.

Table 5. Toxicity of certain insecticides to *Apanteles plutellae* adults.

Treatments	Mortality (%)[z]	
	1 day	3 days
Dipel	0.0 b	2.5 c
Bactospeine	0.0 b	6.2 c
Thuricide	0.0 b	16.2 b
Local Bt	0.0 b	16.2 b
CME-134	0.0 b	2.5 c
Pirimicarb	1.2 b	2.5 c
Control (water)	0.0 b	0.0 c

[z]Data are means of four replicates. Mean separation in each vertical column by DMRT.

Table 6. Effect of light/darkness on parasitism by *D. eucerophaga* and *A. plutellae*.[z]

Time	Light condition	Parasitism (%)	
		D. eucerophaga	*A. plutellae*
Day	Normal	97 a	80 a
	Dark	4 b	8 b
Night	Normal	8 b	9 b
	Lighted	93 a	73 a

[z]Data are means of three replicates. Mean separation in each vertical column by DMRT.

Effect of Neem Extract on Diamondback Moth

Summary

Neem (*Azadirachta indica*) seed and China berry (*Melia azedarach*) seed and bark extracts sprayed on cabbage leaves caused considerable mortality in diamondback moth, *Plutella xylostella*, larvae. These treatments also adversely affected emergence of diamondback moth adults from treated pupae. Both plant materials showed a similar effect as the commercially used insect growth regulators.

Introduction

The extract of seeds of neem (*Azadirachta indica*), a tree native to India, shows a strong feeding deterrent activity to a wide variety of insects, including species of locusts. The active principle, azadirachtin ($C_{35}H_{44}O_{16}$), is a limonoid which occurs only in neem and China berry (*Melia azedarach*). Azadirachtin causes metamorphic disorders in a wide variety of insects, yet it is nonmutagenic and has no apparent mammalian toxicity. This compound has generated wide academic and industrial interest because of its potential in insect control and is, therefore, an ideal candidate for vegetable pest control. The effect of extracts of neem and *Melia* seeds and bark on diamondback moth (*Plutella xylostella* L.), which is probably the most destructive pest of a wide variety of economically important vegetables such as Chinese cabbage, common cabbage, cauliflower, radish, etc., was studied.

Materials and Methods

A sample of neem seed kernel extract (NSKE) of undetermined azadirachtin content was obtained from the International Rice Research Institute (IRRI). A solution of 1,000 ppm NSKE was made in water and 0.1% Citowett was added to act as a sticker. With the help of an atomizer, the solution was sprayed on cabbage leaves until they began dripping. The leaves were air-dried and second instar diamondback moth larvae were released on the detached leaves maintained at room temperature. Larval development was recorded daily until pupation or mortality. When the cabbage leaves became too dry or insufficient, they were replaced by similarly treated foliage. Several tests involving utilization of various NSKE concentrations, different insect growth stages and mode of NSKE application were performed to understand the NSKE mode of action.

Powders of *Melia* seeds and bark were obtained from the Taiwan Forestry Research Institute, Taipei. These powders were suspended and stirred in hot water and the water extract was used for treatments in a similar fashion as NSKE.

Results and Discussion

The effect of applying two NSKE concentrations and different post-treatment feeding modes on DBM are summarized in Table 7. An NSKE at 1,000 ppm caused significant larval mortality over the untreated check. It also significantly reduced pupation. Insects that failed to pupate also died after normal pupation time. An NSKE concentration of 500 ppm was much less active. Between two tests with 1,000 ppm NSKE, the greater the amount to which insects were exposed throughout the growth, the greater was the mortality and the lesser was the pupation. The mode of diamondback moth mortality was not investigated, but several past studies indicated that NSKE interferes with the process of molting in insect larvae.

The effect of spraying diamondback moth pupae with NSKE and *Melia* bark and seed extracts on the emergence of diamondback moth adults was studied in two separate experiments. The botanicals were sprayed on diamondback moth pupae placed on cabbage leaves until the spray liquid started dripping. The treated pupae were maintained on the same leaves in the laboratory until adult emergence. The results are summarized in Table 8.

An NSKE concentration at 1,000 ppm and above adversely affected the emergence of DBM adults from pupae. *Melia* bark extract at 10,000 ppm was not effective, but *Melia* seed extract at that concentration was more effective than neem up to 2,000 ppm in the first test. The adult emergence in the *Melia* seed extract treatment was significantly less than in the bark treatment and it equalled neem at 1,000 ppm in the second test.

In addition the oviposition of diamondback moth on NSKE-treated cabbage and topical toxicity of these extracts to the second instar diamondback moth larvae were examined, but the results were not consistent.

Table 7. Effect of two concentrations of NSKE and post-treatment feeding on diamondback moth larval mortality and pupation.

Test	NSKE concentration (ppm)	Mortality[w] (%)	Pupation[w] (%)
I[z]	500	17 a	76 b
	check[x]	0 b	99 a
II[z]	1000	81 a	0 b
	check	2 b	97 a
III[y]	1000	67 a	12 b
	check	2 b	97 a

[z]Consumed foliage was replaced everyday by treated leaves [y]Treated foliage was offered only on the first days, untreated foliage was offered as replacement daily thereafter. [x]Water spray contained 0.1% Citowett. [w]Mean separation in each vertical column by DMRT. Second instar diamondback moth larvae were used in all tests.

Table 8. Effect of spraying DBM botanicals on the rate of emergence of diamondback moth adults.

Botanicals	Concentration (ppm)		Adult emergence (%)	
	I test	II test	I test[z]	II test[z]
Neem	500	*	80 abc	*
	1,000	1,000	63 c	58 bc
	1,500	*	73 bc	*
	2,000	*	70 bc	*
Melia bark	10,000	10,000	85 ab	75 ab
Melia seed	10,000	10,000	45 d	28 c
Control (water)	–		85 ab	100 a
Control	–		93 a	100 a

*Not tested [z]Mean separation in each vertical column by DMRT.

Testing of *Bacillus thuringiensis* Formulations and Insect Growth Regulators for Diamondback Moth Control

Summary

Certain newly developed insect growth regulators and formulations of *Bacillus thuringiensis* were tested for the control of diamondback moth, *Plutella xylostella*, and imported cabbageworm (*Pieris rapae*), in two field tests. Insect growth regulators BAS 166801 at 60 g a.i./ha, PH70-23 at 75 g a.i./ha, WL115110 at 50 g a.i./ha, IK17899 at 50 g a.i./ha and CME-134 at 37.5 g a.i./ha gave good control of both pests. Among *Bacillus thuringiensis* formulations, Thuricide gave the best control over both pests, resulting in greater yield compared to four other formulations.

Introduction

Insecticides play an important role in the protection of crops, especially vegetables where quantity and quality of the produce determine the net income. Insecticides are widely used by vegetable farmers in Asia, especially to control diamondback moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae), which is the most destructive pest of crucifers throughout tropical-subtropical Asia. As a result of indiscriminate use of insecticide, diamondback moth has become resistant to practically all classes of insecticides presently being used. The indiscriminate use of insecticide also kills parasites and predators of diamondback moth, as well as those of other crucifer pests, which tend to be more sensitive than the host insects to these chemicals. As a result, the diamondback moth has become an even more serious pest than it was before the widespread use of chemical insecticides. Recently, a new class of chemicals called insect growth regulators (IGR), which are specifically toxic to caterpillar pests and safer to natural enemies, have been synthesized and are being registered in different countries. These chemicals have the potential to be very useful in integrated control of various caterpillar pests. In 1987 two experiments which tested some of these chemicals along with a formulation of a well-known bacterial insecticide, *Bacillus thuringiensis*, were conducted to control diamondback moth infestation on common cabbage.

Materials and Methods

The procedures were identical to the ones described in the AVRDC publication titled 'Vegetable Pest Control: Insecticide Evaluation Tests'. In brief, each test included nine insecticide treatments and one untreated check. Each chemical was sprayed using an air-pressurized sprayer once a week to designated plots of 3.3 m × 4.5 m size. Each treatment had four replicates arranged in a randomized

complete block design. Insecticide spraying was initiated from about two weeks after transplanting and discontinued a week before harvesting.

Insecticide efficacy was evaluated at intervals, usually a day before the next weekly insecticide application. At each interval, the number of diamondback moth larvae and pupae found in 10 plants randomly selected from each plot was recorded. When imported cabbageworm, *Pieris rapae* L. (Lepidoptera: Pieridae), infestation became serious during the experimental period, the insecticide treatments were also evaluated for *P. rapae* control in a similar manner as DBM. At harvest, all cabbages were harvested and the weight of marketable heads in each plot was recorded. From this data the weight of each head in every plot was also computed. The insect count and yield data were analyzed by analysis of variance and means were separated by Duncan's multiple range test.

Results and Discussion

The results of an experiment with insect growth regulators are summarized in Table 9. All insect growth regulators gave satisfactory control of diamondback moth and *Pieris rapae*. There was no significant difference between 60 and 90 g a.i./ha BAS 166801 treatments. Among three PH70-23 dosages, the 37.5 g a.i./ha rate did not give as good control as the higher rates. WL115110 at 50 g a.i./ha was as effective as CME-134 at 37.5 g a.i./ha. Although Diaract-M at 75 g a.i./ha gave as good diamondback moth and *Pieris rapae* control as CME-134 at 37.5 g a.i./ha, Diaract-M is totally unsuitable for integrated control of any pest because it contains a synthetic pyrethroid, fluvalinate, which is highly toxic to parasites. Karate, a synthetic pyrethroid, was unsuitable for diamondback moth control. The insect population and yield in this treatment were similar to those of the untreated check. All effective insecticides significantly increased cabbage head size and marketable yield.

The results of tests with *Bacillus thuringiensis* formulations are summarized in Table 10. All *B. thuringiensis* formulations gave excellent control of *P. rapae* but they were slightly less effective against diamondback moth. Among these formulations, ABG162 was distinctly less effective against both insect species, resulting in lower yield in this treatment than in others. Two organophosphorous compounds, salithion and profenofos, did not satisfactorily control diamondback moth but were very effective against *P. rapae*. Both insect growth regulators, IKI7899 and CME-134, gave excellent insect control and these treatments gave the best cabbage yields.

Table 9. Evaluation of insect growth regulators for the control of DBM and imported cabbageworm (ICW) on common cabbage.[z]

Insecticides	Rate (g a.i./ha)	Number of insect larvae + pupae/10 plants						Marketable heads (kg/head)	Marketable yield (t/ha)
		87/1/26[y]	87/2/23		87/3/9		87/3/23		
		DBM	DBM	ICW	DBM	ICW	DBM		
BAS 166801 50SC	60	22.2 a	7.2 c	4.2 b	2.0 c	2.7 b	2.2 c	2.58 ab	81 a
BAS 166801 50SC	90	21.7 a	6.2 c	6.2 b	1.5 c	1.5 b	2.0 c	2.44 ab	76 ab
PH70-23 10EC	37.5	29.5 a	13.7 c	2.0 b	16.2 c	1.7 b	13.5 bc	2.31 b	71 b
PH70-23 10EC	75	35.0 a	10.0 c	1.5 b	6.0 c	0.2 b	5.2 c	2.46 ab	75 ab
PH70-23 10EC	112.5	30.7 a	5.7 c	2.2 b	3.5 c	1.0 b	6.0 c	2.52 ab	78 ab
WL115110 5EC	50	34.7 a	4.5 c	2.2 b	1.7 c	1.0 b	3.2 c	2.51 ab	79 ab
Karate 2.5EC	50	32.5 a	37.0 b	1.7 b	159.7 a	3.5 b	57.5 a	2.04 c	62 c
Diaract-M[x] 15EC	75	38.0 a	2.7 c	3.2 b	1.0 c	0.5 b	0.0 c	2.69 a	85 a
CME-134 15EC	37.5	21.7 a	3.7 c	3.7 b	0.7 c	1.2 b	1.2 c	2.66 a	84 a
Control		30.2 a	51.5 a	45.5 a	100.0 b	44.2 a	26.7 b	1.81 c	56 c

[z]Cultivar: K.Y. Cross; Transplanted 6 January, 1987 and harvested 31 March 1987; Insecticides applied: 27 January, 3, 10, 17, 24 February and 3, 10, 17 March 1987; Data shown are means of four replicates; Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test; Plot size: 15 m^2. [y]Observation made one day prior to the initiation of insecticide spraying [x]A commercial mixture of 5% CME-134 and 10% fluvalinate.

Table 10. Evaluation of insecticides for the control of diamondback moth (DBM) and imported cabbageworm (ICW) on common cabbage.[z]

Insecticides	Rate (g a.i./ha)	Number of insect larvae + pupae/10 plants						Marketable heads (kg/head)	Marketable yield (t/ha)
		87/1/26[y]	87/2/23		87/3/9		87/3/23		
		DBM	DBM	ICW	DBM	ICW	DBM		
Bactospeine[x]	500	12.7 a	23.2 cd	5.0 c	28.7 b	3.2 c	19.0 bc	2.25 bcd	70 bc
Thuricide[x]	500	12.7 a	16.7 cde	2.5 c	16.2 c	1.0 c	21.7 d	2.40 abc	76 ab
Dipel[x]	500	15.5 a	25.2 cd	3.2 c	31.0 b	1.7 c	66.5 ab	2.09 de	64 cd
ABG 162[x]	500	23.2 a	28.5 c	18.5 b	45.0 b	15.5 b	52.2 abc	1.94 ef	58 de
Local Bt[x]	500	19.0 a	34.7 bc	5.0 c	28.7 bc	3.0 c	43.0 c	2.24 bcd	70 bc
Salithion 25EC	500	16.5 a	54.5 a	3.7 c	71.7 a	4.0 c	70.2 a	2.17 cde	66 cd
Profenofos 50EC	500	15.2 a	11.7 de	0.7 c	23.7 bc	1.0 c	38.2 cd	2.30 abcd	70 bc
IKI7899 5EC	50	11.2 a	2.2 e	3.5 c	1.7 c	1.5 c	0.7 e	2.48 ab	77 ab
CME-134 15EC	37.5	20.2 a	3.5 de	2.5 c	0.5 c	1.0 c	1.2 e	2.54 a	81 a
Control		18.2 a	48.0 ab	36.5 a	75.7 a	37.2 a	43.2 c	1.71 f	52 e

[z]Cultivar: K.Y. Cross. Transplanted 8 January 1987 and harvested 3 April 1987; Insecticides applied 27 January, 10, 17, 23, 24 February, 3, 10, 17 March 1987; Data shown are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test. Plot size 15 m^2. [y]Observation made one day prior to the initiation of insecticide spraying. [x]*Bacillus thuringiensis*

Mungbean Breeding

Hybridization

Summary

To combine high yield, early and uniform maturity, and disease resistance, single plants were selected from the segregating population derived from the 1986 factorial design hybridization and intercrossed to further generate recombinations and breaking of linkage blocks. In the fall season, the single plants selected from the first segregating generations were advanced by selfing and crossed with four elite mungbean lines, VC 3890A, VC 2755A, VC 2768A and V 3726, to introduce more favorable alleles in the gene pool. The performance of each population will be evaluated in the advanced generation for desirable traits.

Hybridization and Selective Mating

To combine high yield, early and uniform maturity, and disease resistance, 20 breeding lines and accessions were selected and crossed systematically based on a factorial design II in 1986. This year, both in spring (32nd crossing block) and in summer (33rd crossing block), single plants with desirable characters were selected in the first segregating generation. They were also selfed and intercrossed to further generate recombinations and break the linkage blocks in all directions toward the chosen objectives. In the fall season, single plants were selected from the segregating generation and advanced by selfing as well as crossed with four mungbean cultivars, VC 3890A, VC 2755A, VC 2768A and V 3726, to introduce more favorable alleles into the gene pool. The performance of each population (cycle 1 -- intermating once; cycle 2 -- intermating twice; and cycle 3 -- intermating thrice, etc.) will be evaluated in advanced generations for desirable characteristics.

Implications of Genotype × Environmental Interactions in AVRDC Mungbean Yield Trials

Summary

Because yield trials conducted over years and seasons require considerable expenditure of resources, estimation of genotypes × environmental components will be useful to obtain information on the optimum number and allocation of replicates, seasons and year. Data from two years (1984 and 1986) and three seasons (spring, summer and fall) involving 10 elite mungbean lines were used in this analysis to estimate genotype × environmental components. Based on the results, it was concluded that yield trials conducted over three years, three seasons and three replicates would be the most cost-effective and realistic for mungbean yield trial evaluation at AVRDC.

Introduction

Yield trials conducted to compare elite lines with standard checks are important in crop improvement programs. Selected mungbean breeding lines are consequently evaluated at AVRDC in replicated yield

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trials for at least five years in three seasons, namely, spring (March-May), summer (July-September) and fall (September-November). The existence of genotype × environmental interactions and their limitations on progress from selection are widely recognized, and has been extensively reviewed in the literature. Knowledge of the type and extent of genotype × environmental effects of a particular crop improves the efficient use of available resources, more appropriate use of selection methods, and more genetic gain over time. The yield trials conducted over years and seasons require considerable expenditure of resources. Accordingly, it seemed desirable to obtain the magnitude of genotype × year, genotype × season and genotype × year × season interactions in the yield trials. Using these estimates, it is possible to obtain information on the optimum number and allocation of replicates, seasons and year that should be used in yield trials. Therefore, the purpose of this study was to estimate the genotype × environmental interaction components and discuss their implications in mungbean improvement.

Materials and Methods

Data for two years (1984 and 1986) and three seasons (spring, summer and fall) involving 10 elite lines were used. The experimental details of these trials were: randomized complete block design with three replications; 3 plots of 6 × 1 m^2 per plot as the experimental unit; two rows per plot with 50 cm between rows and 10 cm within row spacing; and two seeds per hill. Standard AVRDC cultural practices were adopted. The following variables measured for each plot were used in this analysis:

- Total seed yield adjusted for 12% moisture level.
- First harvest percentage $= \frac{\text{First harvest yield}}{\text{Total yield}} \times 100$
- Mean number of pods counted on five randomly selected plants.
- 1000-seed weight = (weight of 100 randomly selected seeds × 10).
- Mean maturity index (days) $= \frac{\text{(Days from planting to each harvest} \times \text{yield at each harvest)}}{\text{Total yield}}$

Statistical analysis. Data were subjected to a combined analysis of variance. Years and genotypes were considered random and seasons were considered as fixed.

The form of the analysis of variance and the mean square expectations are given in Table 1. Significance of the variance components was determined using the appropriate F test dictated by the mean square expectations. Pseudo F test, approximating degrees of freedom (df) for the denominator was used when two or more mean squares were combined.

$$\text{Expected variance of genotypic mean} = Gx = \frac{\delta^2 gy}{y} + \frac{\delta^2 gs}{s} + \frac{\delta^2 gys}{ys} + \frac{\delta^2}{rys}$$

where y, s, r are the numbers of years, seasons and replications, respectively.

The Gx for different combinations ranging from one to six years, two to five replicates and three seasons were computed for each variable and the optimum allocation of y and r under constant number of three seasons were estimated.

Table 1. Expected values for mean squares.

Source of variations[7]	Degrees of freedom	Expected mean squares
Genotype (g)	(g-1)	$\delta^2 + rs\,^2gy + rsy\,\delta^2g$
Genotype × years (y)	(g-1) (y-1)	$\delta^2 + rs\,^2gy$
Genotype × seasons (s)	(g-1) (s-1)	$\delta^2 + r\delta\,^2gys + rg\,\delta^2gs$
g × y × s	(g-1) (y-1) (s-1)	$\delta^2 + r\delta\,^2gys$
Error	y × s × (g-1) (r-1)	δ^2

[7]Genotype (g) random effect = 10; years (y) random = 2; seasons (s) fixed = 3; replicates (r) random = 3.

Results and Discussion

Summaries of seed yield and its related variables averaged over genotypes, years and seasons are presented in Table 2. All variables were significantly different for genotypes, years and seasons. The differences between two years were significant for all variables except first harvest percentage. The significant first order and second order interaction effects involving year might be caused by severe yield loss due to typhoon during the 1986 summer season.

Estimates of pertinent variance components are presented in Table 3. The relative importance of the source of variation was indicated by the magnitude of the corresponding component. The genotypic component of the variance was greater than the interaction components for seed weight and vice-versa for seed yield, first harvest percentage, pods/plant and mean maturity. The second order interactions of δ^2gys were of considerable magnitude and greater than those of the first order interaction for seed yield. This indicated one or more aspects of environments for which the pattern

Table 2. Effects of year, season and genotype on seed yield of mungbean and its related variables[z] in mungbean.

Environment	YLD (t/ha)	FHP (%)	PN (no.)	SW (g)	MM (days)
Year					
1984	1.49	75.6	12.4	57.5	80.6
1986	1.32	72.5	8.4	56.3	72.9
Significance levels	*	NS	***	*	***
Season					
Spring	1.89	69.7	10.4	55.1	82.0
Summer	1.23	75.4	13.1	55.9	78.2
Fall	1.11	77.3	7.8	59.6	76.4
Waller Duncan's MSD (KRATIO = 100)	0.64	3.4	0.70	1.02	0.65
Genotype					
V 2010	1.20	66.9	7.4	61.8	78.9
V 2984	1.31	77.4	12.4	40.5	75.6
V 3476	1.32	73.0	11.9	47.8	76.5
V 3726	1.38	82.5	9.5	64.0	74.3
VC 1628A	1.42	75.3	10.4	56.7	76.1
VC 1973A	1.46	78.6	10.5	62.2	76.3
VC 2750A	1.47	72.7	11.0	51.8	77.9
VC 2755A	1.45	72.5	9.6	66.6	77.2
VC 2764A	1.45	68.1	11.2	56.1	78.2
VC 2768A	1.63	73.9	10.4	61.3	77.7
Waller Duncan's MSD (KRATIO = 100)	0.28	6.9	1.37	1.85	1.36

[z]YLD = seed yield/ha; FHP = first harvest percentage; PN = no. of pods/plant; SW = 1000-seed weight; MM = mean maturity; * and *** significant at P = 5% and 0.1%, respectively.

Table 3. Estimates of variance components for seed yield and related variables in mungbean.

Variables	Estimate of variance component				
	δ^2g	δ^2gy	δ^2gs	δ^2gys	$\delta^2\epsilon$
Total seed yield	4.82	12.92	0[z]	36.10	40.10
First harvest %	1.2[illegible]	29.00	4.0	20.10	101.50
Pods/plant	1.20	0.90	0.9	2.70	4.80
Seed weight	65.50	0.10	0	1.00	10.00
Mean maturity	0.92	1.38	0	1.09	4.67

[z]Negative values for which the most reasonable estimate was assumed to be zero.

of variation among seasons differs from year to year. The genotypic effect on the first harvest percentage was negligible and the first and second order interactions and the error component of variance had sizable effect on this trait. This clearly indicated that the first harvest percentage is highly influenced by season within a year and, therefore, management practices which enhance the first harvest percentage in a given season should be studied.

Environmental fluctuations during the growth period may not be consistent over years or seasons. Observation of environmental conditions suggested that the average diurnal temperature, rainfall distribution, seasonal diversity of pest and diseases, coupled with date of planting and date of maturity were the important factors determining the relative performance of mungbean cultivars.

The expected error variance for genotypic mean (Gx) from a series of replicated trials over several years in three seasons for seed yield and its related variables with varying years and replicates in three seasons are shown in Figures 1 and 2. When the numbers of seasons are kept constant, the Gx decreases as the number of years and replicates increase, though showing a decrease in increments with every additional year and replicate. Thus, a critical point is reached as the curve starts to level off; beyond that point an increase in the number of replicates or years provides only a small gain in precision. Trends in decreases of Gx were similar for all five variables including seed yield (Figures 1 and 2).

Although the reduction in Gx, due to an increase in replicates from two to three, is not very significant, the use of fewer than three replicates in each trial is not suggested because of the relatively large error component, less cost per replicate, and the possible but unpredictable factors which may ruin one or more of the replicates. Increasing beyond three years also did not appear to be cost-effective.

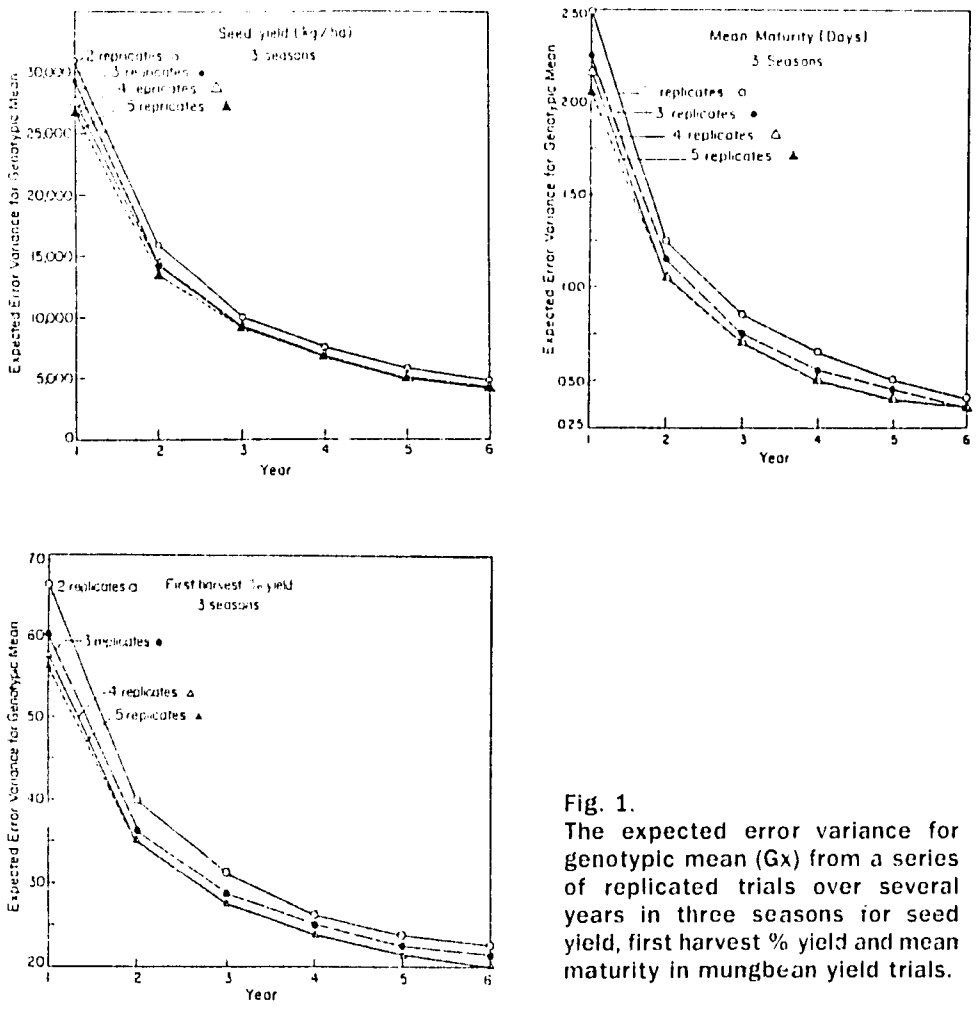

Fig. 1.
The expected error variance for genotypic mean (Gx) from a series of replicated trials over several years in three seasons for seed yield, first harvest % yield and mean maturity in mungbean yield trials.

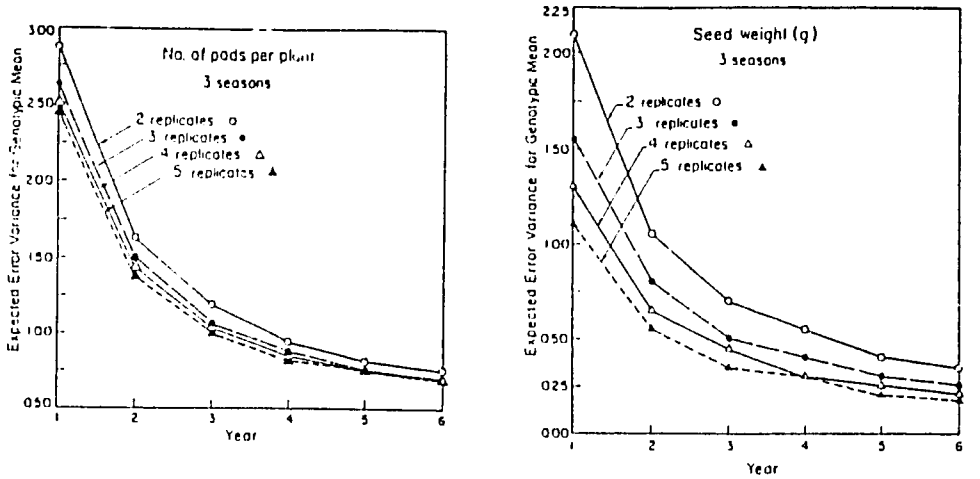

Fig. 2. The expected error variance for genotypic mean (Gx) from a series of replicated trials over several years in three seasons for number of pods/plant, seed weight and mean maturity in mungbean yield trials.

Therefore, based on these results, it can be concluded that three years, three seasons and three replicates probably would be cost-effective and realistic in decreasing the Gx for AVRDC mungbean yield trials.

The 14th International Mungbean Nursery (IMN)

Summary

The 14th International Mungbean Nursery (IMN) trials, consisting of four national cultivars and 16 AVRDC elite lines, were evaluated in many diverse locations to obtain information on adaptability and on the magnitude of genotype × environmental interactions. The location was the major source of variation and attributed 76% of the total variation. Eight lines, V 3426, VC 2750A, VC 2754A, VC 2768A, VC 2802A, VC 3004A, VC 3012B and VC 3061A were considered moderately stable. Three accessions, V 2010, V 2984 and V 3726, and two AVRDC lines, VC 1628A and VC 3012A, were highly sensitive to environmental changes and were, therefore, less stable cultivars.

Introduction

To provide information on the range of adaptability and genotype × environmental (G × E) interactions, IMN trials are conducted annually in many diverse locations worldwide. The 14th IMN consisted of four selected national cultivars and 16 AVRDC elite lines. A total of 92 sets were distributed to 53 cooperators in 32 countries during 1986. At the time of evaluation, IMN data had been received from 17 cooperators, 15 of which with replicated data were included in this analysis. The objectives of this analysis were to evaluate the performance of both national and AVRDC elite cultivars for yield and stability and to determine the factors responsible for low yield in some locations.

Materials and Methods

The suggested experimental procedures recommended for the IMN trials were: randomized complete block design with three replicates; three plots of 6 × 1 m^2 per plot as the experimental unit, two rows per plot with 50 cm between rows and two seeds per hill. Cooperators were encouraged to add one or two of the best available local cultivars as control or checks.

Statistical analysis. A combined analysis of variance assuming fixed genotypic effects and a random model for both sites and environmental effects was performed. Based on the principle of structural relationship analysis (Tai 1971)[1], the genotype × environmental interaction effect of a cultivar was partitioned into two components. They are the linear response to environmental effects which is measured by a statistic $\hat{\alpha}$, and the deviation from the linear response $\hat{\lambda}$. A genotype of $(\hat{\alpha}, \hat{\lambda}) = (0, 1)$ is defined as an average stable cultivar and approximate tests for $\hat{\alpha} = 0$, $\hat{\lambda} = 1$ were carried out according to Tai (1971). The critical values when testing $\hat{\alpha} = 0$ for different $\hat{\lambda}$ values were computed by Tai's (1971) method. The regions corresponding to nonrejectable values (α, λ) were defined in a plot with axis representing linear response and deviation from linear response (Fig. 3). The hyperbola in Figure 3 delineates nonrejectable $\hat{\alpha}$'s (P = 0.95) if the true α is zero. The two vertical lines are the confidence intervals when testing $\lambda = 1$. Genotypes which fall into the region enclosed by the parabola and the vertical lines do not differ significantly from average stability. The environmental index was computed as the mean of three popular cultivars, V 3476, VC 1973A and VC 2768A, minus the grand mean.

Results and Discussion

Partitioning the total variability (sums of squares) attributed to different sources, namely, location, line and their interaction revealed that location was the major source of variation which attributed

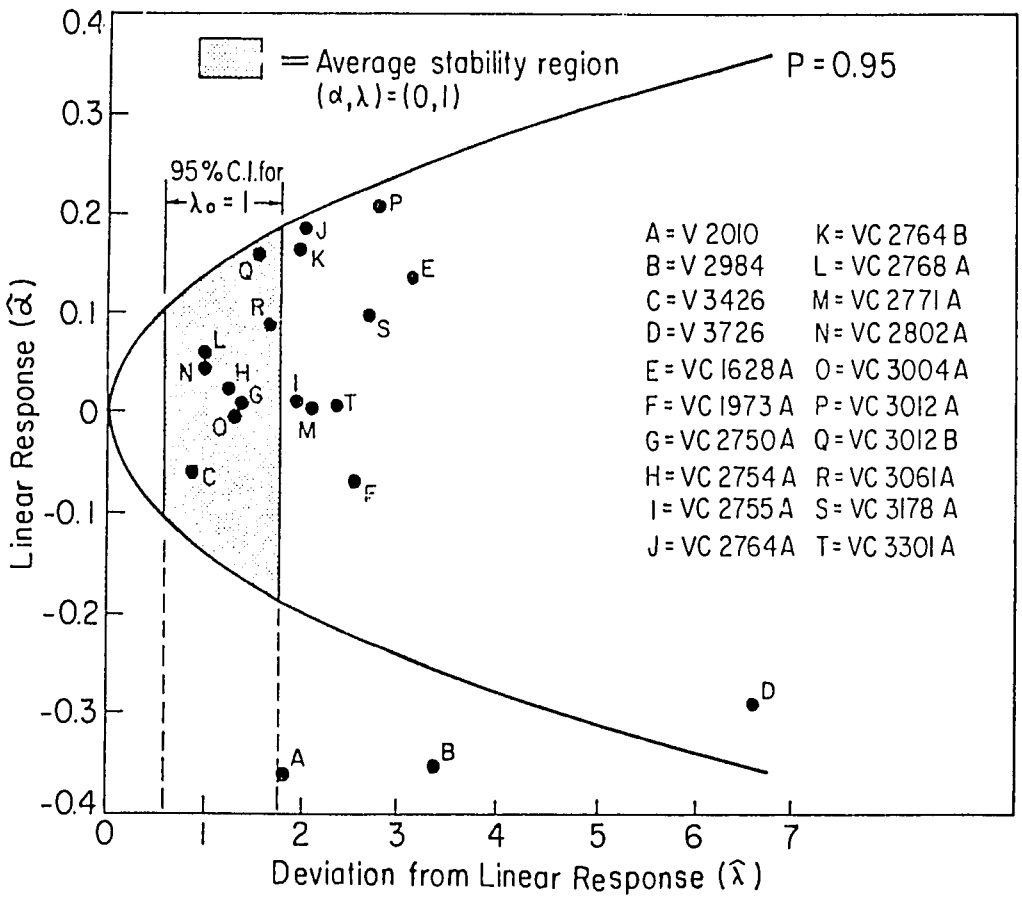

Fig. 3. Distribution of estimates of genotypic stability parameters for seed yield of mungbean lines evaluated in the 14th IMN.

[1]Tai, G.C.C. 1971. Genotypic stability analysis and its application to potato regional trials. Crop Sci. 11:184-190.

76.6% of the total variability (Table 4). Although the effects of line and the location × line interactions were significant, the percentage of variation attributed to them were 2.2% and 10.6%, respectively. This clearly indicated that the yield potential of elite mungbean genotypes was mostly influenced by environmental factors.

Fourteen sites in seven countries covering a wide range of climatic and edaphic conditions were included in this analysis (Table 5). Latitudes ranged from 24°34'S to 37°16'N with a majority in the northern latitude. Mean diurnal temperature during the cultivation period ranged from 22.2° to 28.8°C. The planting time ranged from March to November. Most of the yield variation was due to the environment as indicated by the site means that ranged between 0.31 and 1.77 t/ha. The major factors which reduced seed yield in a particular site were: drought in College Station (USA); cold temperature in Shanhua (fall), Suwon (Korea), Kwangju (Korea) and Botswana; typhoon in Shanhua (summer); insect pests such as thrips and pod borer in Tanzania, Pentatomidae bug (Zanzibar); and virus in Botswana.

The cultivar means varied from 0.74 (V 2010) to 1.13 (VC 1973A). The widely adaptable, high-yielding cultivar, VC 1973A, produced the highest yield in three locations, Phitsanulok (Thailand), College Station (USA) and Suwon (Korea) (Table 6). The early flowering and uniformly maturing accession, V 3726, also produced the highest yield in Shanhua (spring), Sebele (Botswana) and Kwangju (Korea). However, it also produced the lowest yield in Hat Yai (Thailand). In five locations, V 2010 produced the lowest yield. The late-maturing, photoperiod-sensitive line, VC 3012A, produced the lowest yield in three locations. VC 3012B produced the highest yield in Shanhua (spring) and lowest in Zanzibar. A moderately low incidence of Cercospora leaf spot was reported.

The stability statistics of the mungbean lines are presented in Table 7 and illustrated in Figure 3. The stability of eight lines, V 3426, VC 2750A, VC 2754A, VC 2768A, VC 2802A, VC 3004A, VC 3012B and VC 3061A, was considered average. Surprisingly, the stability of widely adaptable

Table 4. Combined analysis of variance for seed yield (t/ha) of the 14th IMN.

Source	df[z]	Sums of squares	Mean squares
Locations	13	191.35 (76.6)[y]	14.72 ***
Replicates (Location)	28	4.63 (1.9)	0.17 ***
Line	19	5.45 (2.2)	0.29 ***
Location × Line	247	26.55 (10.6)	0.11 ***
Error	530	21.93	0.04
Total	837	249.90	

[z]Degrees of freedom. [y]Percentage attributed to the total variation. ***Significant at 0.1% levels.

Table 5. Environmental attributes and mean yield of the sites of the 14th IMN.

Location	Country	Planting season		Latitude	Mean diurnal temperature	Site mean yield (t/ha)[z]
Shanhua	Taiwan	4 March	- 12 June	23°07'N	24.48	1.49
Shanhua	Taiwan	23 July	- 22 October	23°07'N	27.26	0.81
Shanhua	Taiwan	11 September	- 8 December	23°07'N	22.26	0.90
Hat Yai	Thailand	29 April	- 15 July	6°59'N	28.86	1.62
Ilonga	Tanzania	15 March	- 23 June	6°41'S	25.64	1.41
Chainat	Thailand	5 September	- 20 November	15°15'N	28.29	1.47
Phisanulok	Thailand	20 September	- 11 December	16°50'N	26.87	0.71
Kwangju	Korea	2 July	- 8 October	35°07'N	23.00	0.59
Yezin	Burma	14 September	- 20 November	19°51'N	26.16	1.08
College Station	U.S.A.	22 May	- 15 August	31° N	28.08	0.34
Nan	Thailand	31 July	- 30 September	18°46'N	27.99	1.77
Sebele	Botswana	12 November	- 19 January	24°34'S	24.93	0.31
Suwon	Korea	20 June	-	37°16'N	22.40	0.80
Zanzibar	Tanzania		-	-	-	0.40

[z]Mean of three AVRDC checks (V 3476, VC 1973A and VC 2768A).

Table 6. Highlights of the 14th IMN results.

Location	Mean yield (t/ha)[z]	Yield (t/ha) Highest	Yield (t/ha) Lowest	Yield of check (t/ha)	Mean of disease rating CLS[y]	Mean of disease rating PM[y]
Shanhua	1.49	VC 3012B (1.81)	V 2010 (1.19)	-	-	-
Shanhua	0.81	V 3726 (1.16)	V 2010 (0.31)	-	-	-
Shanhua	0.90	VC 2754A (1.06)	VC 2764B (0.77)	-	-	2.8
Hat Yai	1.62	VC 2764A (2.13)	V 3726 (0.96)	1.42	0.6	-
Ilonga	1.41	VC 2755A (1.76)	V 2984 (0.96)	1.48	-	-
Chainat	1.47	VC 2764B (1.98)	V 2010 (0.90)	1.27	1.2	-
Phisanulok	0.71	VC 1973A (1.08)	VC 3061A (0.48)	0.68	-	-
Kwangju	0.59	V 3726 (1.13)	V 2010 (0.33)	0.45	2.1	-
Yezin	1.08	VC 3178A (1.36)	V 2984 (0.53)	0.93	MR	-
College Station	0.34	VC 1973A (0.61)	VC 3012A (0.04)	0.34	-	-
Nan	1.77	VC 1628A (2.19)	V 2010 (1.10)	1.13	1.5	-
Sebele	0.31	V 3726 (0.50)	VC 3012A (0.10)	-	-	-
Suwon	0.80	VC 1973A (1.24)	VC 3012A (0.33)	-	1.8	-
Zanzibar	0.40	VC 3178A (0.61)	VC 3012B (0.18)	-		

[z]Mean of three AVRDC checks (V 3476, VC 1973A and VC 2768A). [y]CLS = Cercospora leaf spot; PM = powdery mildew.

Table 7. Mean seed yield and estimates of stability parameters in the 14th IMN.

Line	$\bar{X}$ t/ha	$\hat{\alpha}$	$\hat{\lambda}$
V 2010	0.74	-.36	1.76
V 2984	0.87	-.35	3.36
V 3426	0.92	-.06	0.84
V 3726	1.00	-.29	6.65
VC 1628A	0.97	.14	3.06
VC 1973A	1.13	-.07	2.52
VC 2750A	0.96	.01	1.38
VC 2754A	0.96	.02	1.22
VC 2755A	0.99	.01	1.91
VC 2764A	0.97	.18	2.06
VC 2764B	0.96	.16	1.91
VC 2768A	1.05	.06	0.99
VC 2771A	0.97	.01	2.06
VC 2802A	1.03	.05	0.99
VC 3004A	0.97	.00	1.30
VC 3012A	0.90	.21	2.75
VC 3012B	1.06	.16	1.52
VC 3061A	1.06	.09	1.61
VC 3178A	1.04	.10	2.68
VC 3301A	0.99	.01	2.29

cultivar, VC 1973A, was considered below average due to its large $\hat{\lambda}$ value. On checking its performance, it was found that VC 1973A produced a higher yield than the expected values in four locations, i.e., Phitsanulok (Thailand), Kwangju (Korea), College Station (USA) and Suwon (Korea). However, in Zanzibar the yield of VC 1973A was lower than the expected yield. Three accessions, V 2010, V 2984 and V 3726, and two AVRDC lines, VC 1628A and VC 3012A, were found to be highly sensitive to environmental changes and, therefore, grouped as below stable.

Levels of Cercospora Leaf Spot Resistance in High Yielding and Early Maturing Elite Mungbean Lines

Summary

The high yielding early and synchronously maturing mungbean lines, V 3726, VC 1628A and VC 1973A, are susceptible to moderately susceptible to Cercospora leaf spot (CLS). The levels of CLS resistance in 13 newly developed, early maturing mungbean lines were evaluated under fungicide-protected and nonprotected conditions along with both resistant and susceptible checks. New lines with high levels of synchronous maturity, large seed and high yield with moderate levels of resistance to CLS, such as VC 3737A, VC 3890A and VC 4050A, were identified. Four other lines, VC 2991A, VC 3664A, VC 3853A and VC 3766-3B-2-B were very high yielding and showed high levels of CLS resistance. However, maturity was only moderately synchronous.

Introduction

Potential yield loss caused by CLS is high during hot and humid weather conditions. Therefore, incorporating a high level of CLS resistance into high yielding lines was one of the major objectives of the AVRDC mungbean improvement program. High yield and disease resistance have been combined already in breeding lines; however, these lines have some defects such as late and nonsynchronous maturity. Thus, in the last few years, the main objective of the mungbean breeding program was to combine CLS resistance and early and uniform maturity. The high yielding, early and uniformly maturing lines VC 1628A and V 1973A are susceptible to CLS. Therefore, this study aimed to estimate the level of CLS resistance in the newly developed early maturing and high yielding mungbean lines.

Materials and Methods

Thirteen early maturing mungbean lines were selected from the 1987 spring yield trials and evaluated for CLS resistance and for agronomic characters. Five check cultivars, VC 1560D, VC 2719A (highly resistant), V 2272, VC 2750A (moderately resistant) and VC 1628A (susceptible check) were also included. This experiment was conducted in summer 1987, (3 July to 15 September) under fungicide-protected and nonprotected conditions, in a split-plot design with three replications. The experimental procedures used are summarized as follows: three plots of 5 × 1 m^2 per plot as the experimental unit; a spacing of two rows per plot at 50 cm between rows and 8 cm within rows; and three seeds/hill.

Fungicide-protected plots were sprayed with 75% Daconil w.p. (500x) at least once a week to reduce the incidence of CLS. The unprotected plots were inoculated twice on 5 and 11 August. The pathogen was cultured on dried carrot leaf extract oat meal agar and the seven-day old culture was used to prepare a spore suspension at a concentration of 1,000-2,000 spores/ml.

Results and Discussion

The CLS resistance levels, yield and other agronomic characters of the new elite lines are presented in Table 8. Four elite lines, VC 2991A, VC 3664A, VC 3853A and VC 3766-3B-2-B, showed high levels of CLS resistance and produced higher yield than the two highly-resistant check cultivars. However, synchronous maturity was moderately low and the seed size was medium. A high level of synchronous maturity, large seed size, higher yield and moderate levels of resistance were observed in three other lines, VC 3737A, VC 3890A and VC 4080A. The yield of VC 3737A was increased tremendously with fungicide protection; however, yield differences were not significant in VC 3890A and VC 4080A between the fungicide-protected and unprotected treatments (Fig. 4). In the susceptible line, VC 4049-B-3-1-1-1-B, the yield reduction was significant; however, without fungicide protection it produced a higher yield than VC 3737A, VC 3890A and VC 4080A. The level of synchronous maturity was low. These results clearly indicated that high levels of resistance and high yield potential have been combined. However, the level of synchronous maturity in these lines needs to be improved.

Table 8. Levels of CLS resistance in high yielding new elite breeding lines.

Line	Parentage	CLS (%)[z]	YLD (t/ha)[z]	FHP (%)[z]	SW (g)[z]
VC 2991A	VC 1131A/VC 1163B	3.0	2.60	50	53
VC 3664A	VC 1482C/VC 2528B	3.7	2.27	52	56
VC 3737A	VC 1168B/VC 1973A	17.3	2.13	73	55
VC 3746A	VC 1482C/V 3726	8.0	2.27	56	53
VC 3766-3B-2-B	VC 2719A/VC 2527A	5.7	1.88	52	56
VC 3849A	VC 3746/VC 3749	10.0	2.04	67	60
VC 3853A	VC 3746/VC 3773	3.3	2.40	55	50
VC 3890A	VC 2750A/VC 2768A	18.0	1.98	72	59
VC 3902A	VC 2768A/VC 2755A	15.3	2.15	57	71
VC 4049-B-3-1-1-1-B	V 6083/VC 2768A	31.3	2.19	55	60
VC 4058-2B-4-B-1-B	VC 1560D/VC 2802A	24.0	1.93	56	58
VC 4080A	VC 2778A/VC 2802A	14.7	1.93	82	64
VC 4096-2B-4-B-2-B	V 6017/VC 1628A	8.7	1.84	63	52
VC 1560D		2.7	1.36	61	56
VC 2719A		4.7	1.76	55	48
V 2272		10.7	1.36	48	31
VC 2750A		10.7	1.93	57	55
VC 1628A		32.7	1.93	68	58
Waller Duncan's MSD (KRATIO = 100)		-	0.23	8.7	2.96

[z]CLS = Cercospora leaf spot; YLD = seed yield; FHP = first harvest percentage; SW = 1000-seed weight.

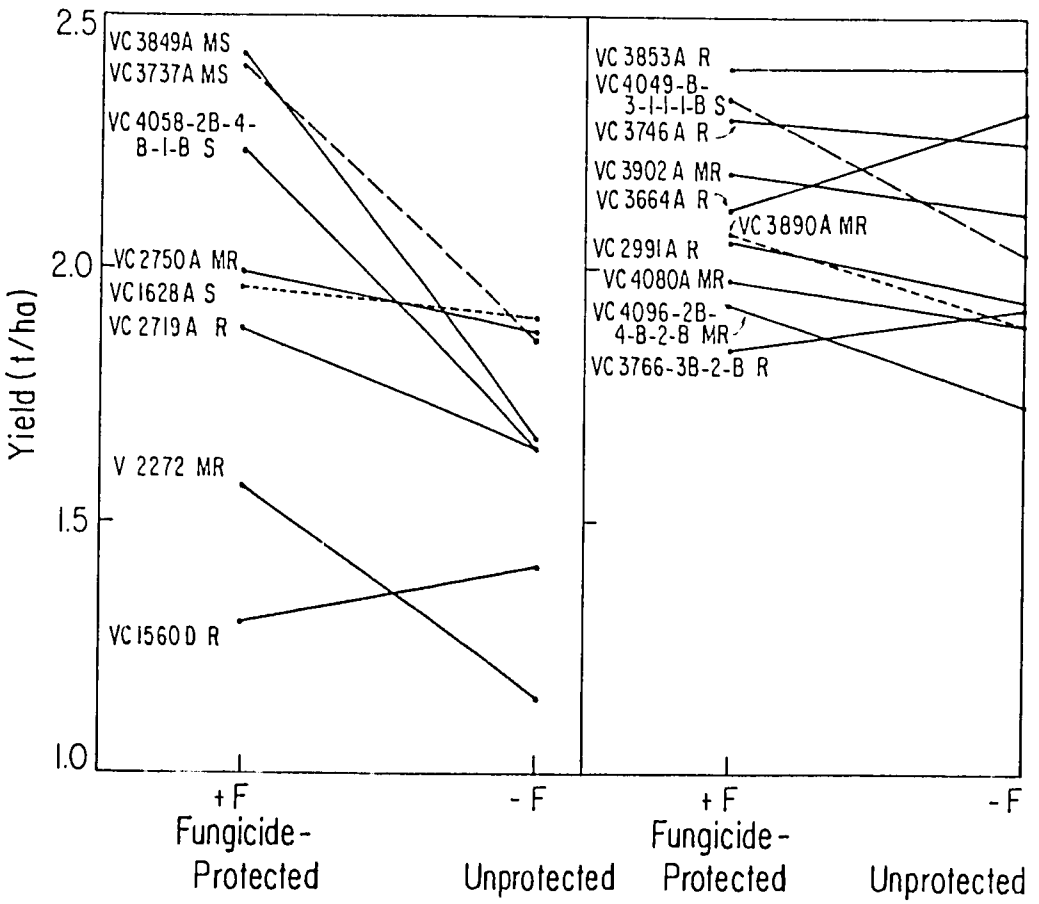

Fig. 4. The level of CLS resistance and yield potentials of early-maturing elite mungbean lines evaluated under both fungicide-protected and unprotected conditions in summer 1987.

Performance of New AVRDC Elite Breeding Lines

Summary

A multivariate technique known as principal component (PC) analysis was used as a means of assessing progress towards achieving the multiple breeding targets of the mungbean breeding program. A hypothetical ideal mungbean cultivar with desirable characteristics was included in the PC analysis along with the new elite lines and check cultivars. The first two principal components accounted for 53% of the information on the desirable traits. The position of the new breeding lines, compared to the check cultivars on the two-dimensional plane, indicated the amount of progress achieved towards meeting the ideal cultivar. The potential mungbean lines which could serve as better parents for future hybridization were also identified.

Introduction

The current goal of AVRDC's mungbean improvement program is to combine high yield, early and uniform maturity, large seed size and resistance to Cercospora leaf spot (CLS) and powdery mildew (PM). Promising breeding lines selected from F_7 generations were evaluated at several yield trials in three successive seasons for these multiple objectives. The characteristics of the new elite breeding lines along with the checks, VC 1973A — widely adaptable, early and uniform maturing line; VC 2768A — high yielding and moderately resistant to CLS and PM; VC 2719A — resistant to CLS and PM; VC 1628A — uniformly maturing but susceptible to CLS and PM, are presented in Table 9.

Assessment of progress towards goals is an important activity in breeding programs. However, since many objectives must be considered collectively in the overall assessment of the breeding program, this generally limits the evaluation of the breeding merit to a subjective assessment. Thus, a metrical approach would be useful in providing an objective means of assessing breeding programs in terms of the likelihood of meeting the breeding goals. This study summarizes a statistical technique which

Table 9. Characteristics of new AVRDC mungbean cultivars.

Line	Parentage	YLD[z] (t/ha)	FHP[z] (%)	DF[z] (days)	SW[z] (g)	Disease rating CLS[z]	Disease rating PM[z]
VC 2991A	VC 1131A/VC 1163B	2.0	57	39	53	1.8	1.5
VC 3853A	VC 3746/VC 3773	2.1	56	39	52	1.3	3.3
VC 3746A	VC 1482C/V 3726	2.3	60	38	59	2.0	2.7
VC 3664A	VC 1482C/VC 2528B	2.2	54	40	55	2.0	3.3
VC 3849A	VC 3746/VC 3749	2.0	68	38	58	2.3	2.0
VC 3902A	VC 2768A/VC 2755A	2.0	62	39	68	2.7	1.7
VC 3737A	VC 1168B/VC 1973A	2.5	62	39	58	3.0	3.0
VC 3890A	VC 2750A/VC 2768A	2.0	75	39	55	2.1	1.3
VC 4080A	VC 2778A/VC 2802A	2.0	80	38	60	3.0	3.0
VC 2719A	Shanhua 1/VC 1163A	1.7	52	40	48	1.0	1.0
VC 1628A	CES-1D-21/PHLV 18	1.9	67	38	58	5.0	5.0
VC 1973A	Pag-asa 1/EG-MG-16	2.0	75	38	60	2.5	5.0
VC 2768A	VC 1482A/VC 1628A	2.2	65	38	55	2.3	3.0
VC 3901A	VC 2764A/VC 3836	2.2	70	39	60	3.0	3.3
VC 3885A	VC 2719A/VC 3836	2.1	75	40	59	2.7	2.7
VC 3944A	VC 1000C/VC 1628C	2.2	72	39	52	3.0	2.0
VC 4111A	VC 3957/VC 3984	2.4	55	41	54	3.3	3.7
VC 3907A	VC 2770B/VC 2750A	2.3	74	41	59	2.4	3.3
VC 3928A	V 6017/VC 2750A	2.2	66	40	54	2.4	2.5
VC 4066A	VC 2572A/VC 3974	2.3	60	42	58	3.0	3.0
Ideal Cultivar		**2.5**	**75**	**38**	**60**	**1.0**	**1.0**

[z]YLD = seed yield/ha, FHP = first harvest percentage; DF = days to flowering; SW = 1000-seed weight; CLS = Cercospora leaf spot and PM = powdery mildew disease resistance score — 1: highly resistant, 5: highly susceptible.

could be effectively utilized in assessing breeding progress and in selecting potential parents for future hybridization programs.

Materials and Methods

A multivariate technique known as principal component (PC) analysis was used as the means of assessing the progress towards achieving the breeding targets. A hypothetical ideal mungbean cultivar was defined with the following characteristics: yield potential of 2.5 t/ha; 75% synchronous maturity, early flowering at 38 days, seed weight of 60 g/1000 seeds; highly resistant to CLS and PM and was included along with the new breeding lines and check cultivars in principal component analysis. The information derived from this analysis is condensed in the form of a few coordinates, and illustrated on a two-dimensional plane; the data points of the elite lines, check cultivars and the ideal cultivar are superimposed on that plane (Fig. 5). The first component which had larger coefficients on synchronous maturity, seed weight, CLS resistance and PM resistance contained 34% of the overall information. The second component which had large coefficients on seed yield explained an additional 19% of the information in the overall six-variable model. Thus, the first two coordinates contained 53% of the information, and contained larger coefficients on major variables.

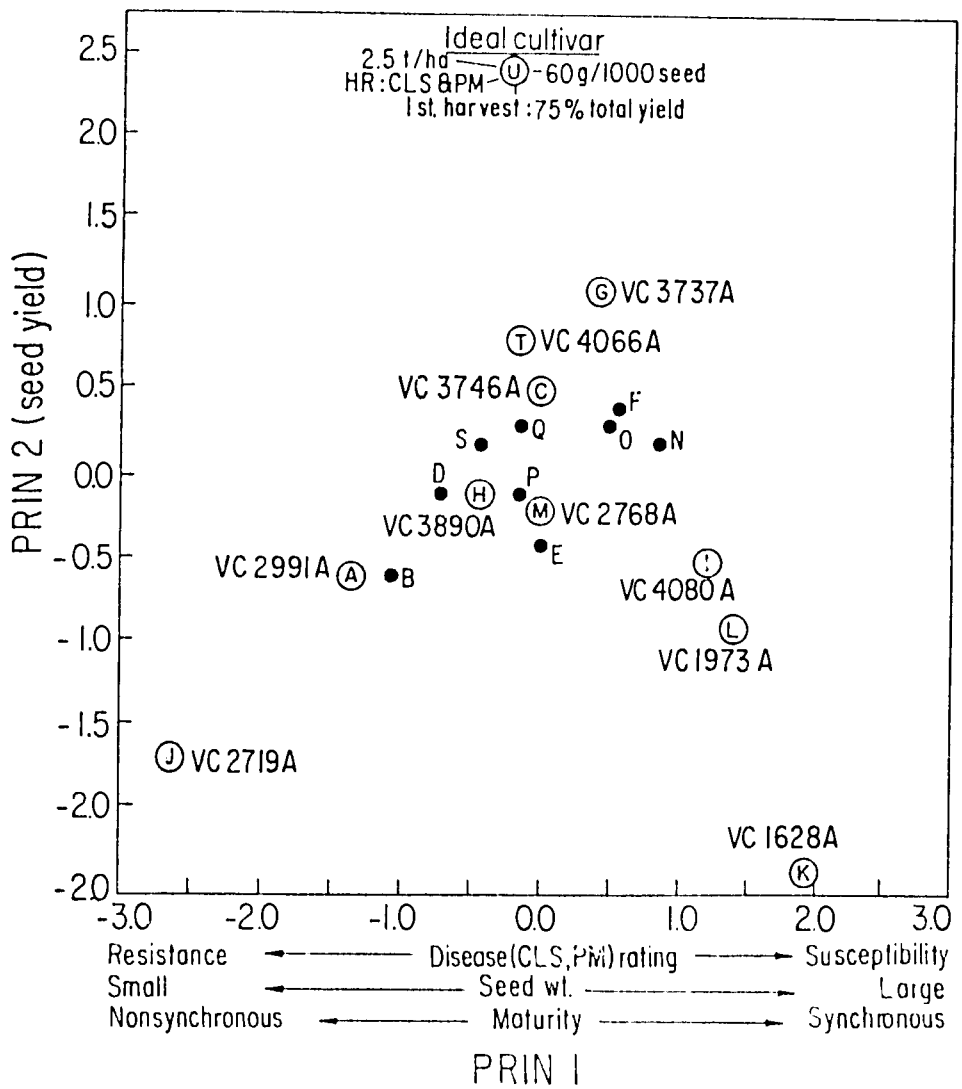

Fig. 5. The positions of elite mungbean lines and the ideal cultivar on the two-dimensional plane between first and second principal components.

Results and Discussion

The first two principal components separated the disease resistant check, VC 2719A, and the susceptible line, VC 1628A, distinctly. Line VC 2991A and VC 3853A can be considered as improvements over VC 2719A, with high yield and disease resistance combined together. VC 4080A and VC 3890A lines had high levels of synchronous maturity and improved level of resistance than VC 1628A. Many lines, such as VC 3737A, VC 4066A and VC 3746A, could be considered as high yielding with moderate levels of other desirable characters. The positions of the new breeding lines on the plane clearly demonstrate the progress achieved towards the target or the ideal cultivar. However, the performances of these new lines are based on AVRDC yield trials only. To make a broader conclusion about these lines, they have to be evaluated internationally. To continuously make progress towards the above multiple targets, the following lines, VC 2991A, VC 4080A, VC 3737A, VC 4066A and VC 3746A, should be intercrossed to combine the favorable alleles to achieve the breeding targets.

Preliminary Evaluation of Mungbean Cultivar Blends for Enhanced Stability

Summary

Two mungbean cultivar blends, each consisting of three mungbean cultivars in equal proportions and their component lines, were tested in the summer and fall seasons at AVRDC to improve the yield stability of mungbean lines under low input, unfavorable environments. The pure line, VC 2768A, produced the highest yield in both seasons. However, the yield differences between the two cultivar blends and/or among the other four component lines were not significant. The results of the sequential yield component analysis revealed that the seed yield was greatly influenced by the pods/peduncle and the proportion of flowering nodes. These two cultivar blends will be further evaluated for yield stability, especially under poor environments in International Mungbean Nursery (IMN) Trials.

Introduction

Mungbean yield is greatly influenced by a number of climatic, edaphic and agronomic factors. The unpredictability of many of these factors, particularly climatic variables such as the amount and distribution of rainfall, the occurrence of temperature extremes and pest and disease epidemics, requires the cultivars to be well buffered or widely adaptable. They must adjust their phenotypic expression in response to unpredictable environmental fluctuation so that they consistently give high seed yields.

In many IMN sites, the average mungbean yields were very low (<0.5 t/ha) and the unpredictable environmental factors were considered as the major cause for such low yields. Moreover, the major world mungbean production is cultivated under low input, unfavorable environmental conditions and therefore, maintaining yield stability is crucially important to these subsistence farming systems.

Crop varieties can achieve yield stability through two main mechanisms: (1) individual buffering which results from the developmental and physiological flexibility of the individuals in a population; and (2) population buffering which results from the coexistence and interaction of different genotypes in the population. Genetically homogeneous populations, such as pure line cultivars, depend solely on individual buffering to stabilize yield. However, both mechanisms could function in genetically heterogeneous populations and, therefore, it has frequently been argued that such populations should be more stable than their genetically homogeneous counterparts. Many investigations concluded after testing in many crops, that genetic heterogeneity can lead to more stable economic yields. In disease resistance breeding, multilines are recommended, especially when a serious disease pressure is caused predominantly by one pathogen and the available individual resistance genes are combined in multilines. Under disease pressure, the yields of multilines are less reduced than the mean yields of the component lines when grown separately. In contrast, no consistent differences between the stability of homogeneous and heterogeneous populations were reported. Therefore, the objective of this investigation was to

compare the performance of homogeneous populations and the heterogeneous populations (blends of pure lines) for yield, yield components and disease resistance in two diverse seasons. Based on these results, the basis of formulating cultivar blends for increasing yield stability will be defined and the cultivar blends will be evaluated for yield stability in forthcoming IMN trials.

Materials and Methods

Two mungbean cultivar blends, each comprising three mungbean cultivars in equal proportion were formulated. The characteristics of the component lines are listed in Table 10. In selecting the component lines for the cultivar blends, much attention has been given to the phenotypic appearance of the seeds, where all component lines had moderate to large-sized, green and shiny seeds. However, other agronomic traits, such as flowering dates, disease resistance and plant types differed significantly among the component lines (Table 10).

These two mungbean cultivar blends (MBCB1 and MBCB2) and their component lines were evaluated at AVRDC in two seasons, summer (July-September) and fall (September-November). The experimental details of these trials were: randomized complete block design with two replications; two plots of 2 × 1 m^2 per plot as the experimental unit; two rows per plot with 50 cm between rows and 10 cm within row spacing. With one seed and two seeds per hill and using this spacing, 200,000 and 400,000 plants were established in summer and fall seasons, respectively. The standard AVRDC cultural practices were adopted in conducting these trials. Because the population density varied between the season, the following yield components were measured and estimated for 1 m^2 area:

- Total seed yield adjusted for 12% moisture level/m^2
- Plant population/m^2 at harvesting
- Total number of nodes/m^2
- Total number of peduncles/m^2
- Total number of pods/m^2
- Weight of 100 seeds

From these variables the following variables were estimated:

$$\text{Peduncle: Node ratio} = \frac{\text{Peduncles}/m^2}{\text{Nodes}/m^2}$$

$$\text{Pods per cluster} = \frac{\text{Pods}/m^2}{\text{Peduncles}/m^2}$$

$$\text{Seeds per pod} = \frac{\text{Seed yield}/m^2}{(\text{Pods}/m^2 \times \text{weight/seed})}$$

Table 10. Characteristics of component lines in mungbean cultivar blends.

Component lines	Synchronous maturity	Days to flowering	Seed size (g/1000 seeds)	Disease resistance[z]	
				CLS	PM
MBCB1					
VC 2768A	Moderate	Moderate	60	MR	MR
VC 1973A	High	Early	62	MR	MS
V 3476	Moderate	Moderate	50	MS	S
MBCB2					
V 3726	High	Early	65	S	S
VC 2719A	Low	Moderate	50	HR	HR
VC 2755A	Moderate	Moderate	67	MR	MR

[z]CLS = Cercospora leaf spot; PM = powdery mildew. Disease rating: MR = moderately resistant; MS = moderately susceptible; HR = highly susceptible; S = susceptible.

Statistical Analysis. A combined analysis of variance was performed and the significance of season, cultivar and their interactions on seed yield and its components were tested.

To measure the contribution to seed yield by its yield components and to assess the effects of cultivar blends and seasonal effects on those contributions, a sequential yield component analysis (SYCA) was performed. SYCA partitions the total yield variation among orthogonal yield components and is suitable to crops where yield is the product of the sequence of developmental processes. The yield components were calculated as ratios of the observed variables:

Y_1 = Number of nodes/m^2
Y_2 = Peduncles/node
Y_3 = Pods/peduncle
Y_4 = Seeds/pod
Y_5 = Weight/seed
YLD = Seed yield/m^2

and transformed to natural logarithm so that an additive model could be constructed with its variables ordered according to their presumed developmental sequence;

$$\ln YLD = \ln Y_1 + \ln Y_2 + \ln Y_3 + \ln Y_4 + \ln Y_5.$$

In yield component analysis using a multiple regression model, the estimates of regression coefficients are often biased when the yield components are correlated and not independent. In this analysis, multicollinearity was assumed to result from the sequential formation of components during development and the dependency of each new component on earlier ones.

With these assumptions, the yield components were first standardized or scaled (mean = 0, SD = 1) and were orthogonalized in the order presented by the model. The first component remained the same and each of the others was calculated as the residual from a multiple regression with no intercept on developmentally earlier ones as follows:

Log transformed, scaled and orthogonalized variables

- Nodes/m^2 $X_1 = Y_1$
- Peduncles/node $X_2 = Y_2 - [\beta'_1 X_1]$
- Pods/peduncle $X_3 = Y_3 - [\beta_2 X_2 + {}_3 X_1]$
- Seeds/pod $X_4 = Y_4 - [\beta_4 X_3 + \beta_5 X_2 + \beta_6 X_1]$
- Weight/seed $X_5 = Y_5 - [\beta_7 X_4 + \beta_8 X_3 + \beta_9 X_2 + \beta_{10} X_1]$

Regression Coefficients. Yield could then be expressed without residual error from the orthogonal independent variables in a multiple regression model. The magnitude of the standardized partial regression coefficients will reflect the contribution of individual components on seed yield.

Results and Discussion

The significance of treatment effects on seed yield and its components are presented in Table 11. The results clearly indicated that the seasonal effects were significant for total yield, pods/m^2, pods/peduncle, seeds/pod and seed weight; however, the number of vegetative nodes and peduncles per unit area was not different between summer and fall seasons. The high yield obtained in summer season was not attributed to more nodes or more peduncles per unit area but was due to more seed set/pod and more pod set (pods/peduncles) resulting in more pods per unit area (Table 12). These results showed that to increase seed yield, especially in the fall season, both pod and seed set need to be improved. The cultural practices which improve these aspects need to be investigated to enhance mungbean yield during the fall season.

The genotypic effects were significant for all yield components except for the number of nodes/m^2 and the peduncles/nodes (Table 12). The highest seed yield was produced by mungbean cultivar VC 2768A and the lowest yield was produced by cultivar V 3726, an early flowering line. However, the yield differences between the two cultivar blends or among the other four component lines were not significant. Although the cultivar blends did not produce the highest seed yield, the yield performances were comparable with the high-yielding component lines. In addition to high seed yield, the MBCB lines had a better level of resistance than some of their component lines (Table 12). Because of their heterogeneous nature, the cultivar blends may produce more stable yield under stress

Table 11. Significance of treatment effects[z] on seed yield and its components.

Variables	Season	Line	Seasons × Line
Total yield	xxx	xxx	NS
Nodes/m^2	NS	NS	NS
Peduncles/m^2	NS	xx	NS
Peduncles/node	NS	NS	NS
Pods/m^2	xxx	xxx	x
Pods/peduncle	xxx	xxx	x
Seeds/pod	NS	xxx	NS
Weight/100 seed	xxx	xxx	xx

[z]x, xx, xxx significant at P = 5%, 1%, and 0.1%, respectively; NS = not significant.

Table 12. Effects of genotype and season on mungbean yield and its components.

	YLD (t/ha)	NOD (no./m^2)	PED (no./m^2)	PED/NOD	POD (no./m^2)	POD/PED	Seed (no./pod)	100-SW (g)	CLS	PM
Line:										
VC 2768A	1.82	345	121	0.37	356	2.91	9.5	5.5	2.3[w]	3
VC 1973A	1.34	353	109	0.31	266	2.48	9.0	5.6	2.5	5
VC 3476	1.18	293	107	0.37	275	2.58	9.4	4.7	3.5	5
MBCB1[z]	1.27	319	106	0.34	272	2.59	8.6	5.5	2.5	3
V 3726	0.97	318	100	0.33	220	2.17	7.5	5.8	4.0	5
VC 2719A	1.37	361	125	0.36	371	3.03	8.1	4.6	1.0	1
VC 2755A	1.25	320	117	0.37	260	2.21	8.1	5.0	2.5	3
MBCB2[y]	1.31	301	112	0.38	277	2.49	8.4	5.6	2.0	3
MSD[x] (KRATIO = 100)	1.78	NS	12.1	NS	34	0.33	0.7	0.19	–	–
Season:										
Summer	1.53	324	113	.358	344	3.06	8.84	5.1	–	–
Fall	1.09	330	112	.349	230	2.05	8.30	5.7	–	–

[z]MBCB1: Mungbean cultivar blends composed of VC 2768A, VC 1973A and V 3476 at equal proportion. [y]MBCB2: Mungbean cultivar blends composed of V 3726, VC 2719A and VC 2755A at equal proportion. [x]Waller Duncan's minimum significance difference. YLD = seed yield/ha; NOD = total number of nodes/m^2; PED = number of peduncles produced/m^2; PED/NOD = the proportion of flowering nodes; POD = pods produced/m^2; Seed = seed/pod; SW = weight of 100 seeds; CLS = Cercospora leaf spot; and PM = powdery mildew resistance ratings. [w]1 = highly resistant, 5 = highly susceptible.

conditions. Under AVRDC conditions, the two MBCB lines did not differ much; however, their performances might differ in other locations under stress conditions. The preliminary findings were encouraging and these two cultivar mixtures will be included in the forthcomming IMN for international evaluation.

Yield component analysis. The results of the sequential yield component analysis are presented in Table 13. A significant inverse relationship was observed between the number of nodes and the proportion of flowering nodes. This indicated that increasing more vegetative nodes in these improved mungbean lines may not necessarily result in more peduncles. The number of pods/peduncle appeared to be a very important determinant of seed yield. The number of vegetative nodes or peduncles/node did not influence pods/peduncle. The environmental and cultural aspects which increase pods/peduncle will also increase seed yield significantly. No negative relationship between seeds/pod and the previously occurred events, pods/peduncles, peduncles/node and nodes/m^2 was observed. However, all other yield components had a negative effect on seed size, especially the pods/peduncle. Since pods from the same peduncle compete for photosynthate from the same source, synchronous pod development and more pods/peduncle might reduce seed size. Thus, yield component compensation is clearly evident between seed size and the other components. Overall, the seed yield was gready influenced by pods/peduncle and peduncles/node. Both breeding and crop management practices should concentrate on increasing these two components to enhance the yield potential of mungbean while maintaining the seed size.

Table 13. Interrelationships among mungbean seed yield and its yield components.

	Log transformed, standardized & orthogonalized yield components					
	X_1	X_2	X_3	X_4	X_5	R^2
ln Y_2[z]	-0.82[y]	–	–	–	–	0.67
ln Y_3	-0.08	0.08	–	–	–	0.01
ln Y_4	0.01	0.32	0.38	–	–	0.17
ln Y_5	-0.02	-0.13	-0.63	-0.18	–	0.42
ln YLD	0.12	0.45	0.76	0.24	0.27	0.99

[z]Log transformed and standardized but not orthogonalized yield components. X_1 = nodes/m^2; Y_2 or X_2 = peduncles/node, Y_3 or X_3 = pods/peduncle, Y_4 or X_4 = seeds/pod; Y_5 or X_5 = weight/seed; and YLD = seed yield/m^2. [y]Standardized partial regression coefficients.

Evaluation of Moving Mean Covariance Analysis for Error Control in Yield Trials

Summary

Mungbean is very sensitive to microsoil variation in the experimental sites within the same location and season. A large fertility gradient or microsoil variation in the experimental sites is an impediment to reliable estimation of cultivar effects. Therefore, the effectiveness of moving mean (computed from two to five adjacent plots) covariance analysis compared with randomized complete block design (RCBD) for error control in mungbean yield trials was investigated. The results clearly indicated that covariance adjustment using moving means computed from five adjacent plots gave better control of the experimental error and is, therefore, recommended in situations where a large number of lines are evaluated in a site with a large fertility gradient.

Introduction

Almost all fields in which agricultural experiments are carried out have fertility gradients to a greater or lesser degree. In the presence of a large fertility gradient, there is a likely possibility that the treatment effects in large block experiments (e.g. yield trials with many entries) may be biased. Mungbean is very sensitive to microsoil variation in experimental sites within the same location and season. At AVRDC large yield differences are commonly observed for the same cultivar in different trials when grown in the same season. Therefore, larger fertility gradients or microsoil variation in the experimental sites are impediments to reliable estimation of cultivar effects. Experimental errors are usually inflated under these circumstances and high CV values are usually associated with mungbean yield trials. The objective of this study was to evaluate the effectiveness of using moving mean covariance analysis for error control in mungbean yield trials.

Materials and Methods

Various experimental designs were considered for controlling local trend effects in the experimental sites. The conventional method is to use a randomized complete block design (RCBD) or alternatively, rows and columns (Latin squares), in error control. The RCBD is generally suitable for a small number of treatments and the Latin squares requires a rectangular array of plots which can restrict the choice of sites and sometimes forces the experimental area into unsuitable land to arrange for all treatments to occur. Lattice designs are recommended for trials consisting of many treatments; however, the analysis is usually complicated and also has restrictions in treatment arrangement.

Check plot designs, in which a systematic arrangement of checks are superimposed on an RCBD, have been proposed as an alternate method of error control in experiments with a large number of treatments. The performance of a cultivar is expressed as the differences between it and the adjacent control plot or as a percent of the control plot assuming that a high correlation between the control plots and the test plot exists. Hence, inappropriate adjustment could result from the control plots provided

with inadequate representation of the soil variation. Furthermore, the check plot method has the disadvantage of requiring additional area.

To preclude such error in check plot design, analysis of covariance was suggested in which the moving mean, i.e. the mean of the neighboring plots excluding the test plot in question, is used as the concomitant variable or covariable which provides a measure of fertility of the test plot. When there is no linear association between the moving mean and the test plot yield, the regression coefficient of the covariable will be zero and over adjustment will then be avoided.

The statistical model of the moving mean covariance analysis is:

$$Yij = \mu + Bi + Gj + \beta 1\ (Xij) + \epsilon ij$$

where:

Yij = Yield of the jth genotype in ith block.
μ = Grand mean.
Bi = The effect of ith block.
Gj = The effect of jth genotype.
$\beta 1$ = The measure of linear trend between test plot yield and the covariance.
Xij = The mean yield of neighboring plots of the ijth test plot.
ϵij = Random error.

The number of adjacent plots included in the moving mean computation varied from two to five. The moving mean was calculated using an equal number of plots on each side of the plot in question except at the end of the blocks where the appropriate number of plots nearest the end was used.

The data from the 15th IMN, conducted during the spring season at AVRDC, was used to illustrate this analysis. The experimental details are summarized as follows: randomized complete block design with three replications; three plots of 6 × 1 m^2 per plot as the experimental unit; spacing of two rows per plot at 50 cm between rows and 6 cm within rows; and two seeds per hill at a population density of 400,000 plants/ha. The AVRDC recommended cultural practices were adopted.

Results and Discussion

The results of the ANOVA for the RCBD are presented in Table 14. Nonsignificant block and genotypic effects, high CV and low R^2 clearly indicated the presence of a local trend — microsoil variation in the experimental sites. In Figure 6, the field plot design is presented in which the entry number, the yield, and the yield rank within each row are given. From the yield rank, it was very clear that higher yield was observed in region A while lower yield was observed in region B. The genotypes, under region A produced higher yield, not because they are high yielders, but probably because they occupied the better spot in the field. As a result of the microsoil variation in the experimental site, the magnitude of the error was inflated resulting in nonsignificant genotypic effect (Table 14).

Table 14. Comparison of moving mean covariance analysis with RCBD in error control.

Source	RCBD	Moving mean covariance analysis			
		COV1[z]	COV2	COV3	COV4
Covariance	–	28.6***[y]	32.9***[x]	34.4***	36.6***
Blocks	5.8 NS	0.3 NS	5.3*	7.3**	7.8**
Lines	36.7 NS	38.1**	37.1**	36.3**	35.7***
Error	57.5	30.2	24.[illegible]	22.0	19.8
CV %	19.9	14.6	13.2	12.5	11.9
R2	0.42	0.70	0.75	0.78	0.80

[z]COV1 - COV4, moving means computed from 2, 3, 4 and 5 adjacent plots, respectively. [y]The percentage of total sums of square attributed to the effect. [x]Significance levels of the effects, ***, **, * significant at 0.1%, 1% and 5% levels, respectively.

3	8	4	12	9	20	5	10	19	2
1.8	1.5	1.2	1.7	1.4	2.1	2.3	2.4	2.5	1.7
5	8	10	7	9	4	3	2	1	6
18	15	11	13	16	1	17	14	7	6
3.0	2.3	2.2	1.8	2.2	2.3	3.3	3.2	2.8	2.8
3	6	9	10	8	7	1	2	4	5
17	10	14	8	19	12	11	15	13	4
3.0	2.2	2.2	2.1	2.4	2.4	3.1	3.1	2.7	2.3
3	8	9	10	6	5	2	1	4	7
16	5	6	1	7	3	2	18	9	20
2.5	2.4	2.0	1.9	2.0	2.5	2.6	3.6	2.4	2.7
5	7	8	10	9	4	3	1	6	2
20	19	18	17	16	15	14	13	12	11
2.2	2.5	1.9	2.2	2.0	2.4	2.9	2.9	2.7	2.7
7	5	10	8	9	6	2	1	4	3
1	2	3	4	5	6	7	8	9	10
2.1	1.5	1.8	1.8	2.3	2.5	2.8	3.0	2.0	2.6
6	10	8	9	5	4	2	1	7	3

Rep 3

Entry No.
Yield, t/ha
Yield rank

Rep 2

Rep 1

Fig. 6. Microsoil fertility variations in mungbean yield trials at AVRDC.

The effect of the moving mean covariance analysis on error control is illustrated in Table 14. Without exception, covariance adjustment (COV1 to COV4) reduced the CV and increased the R^2. Both block and genotypic effects became highly significant. The SE of the mean was reduced substantially and the mean yield adjusted for the covariate also differed very much (Table 15). After the covariance adjustment, the yield ranks differed in 15 genotypes out of 20.

This experiment clearly indicated that mungbean yield is very sensitive to microsoil variation and under these circumstances, the observed genotypic means are biased by local trend in the field sites. This study clearly demonstrated that covariance adjustment using moving means of adjacent plots gave better control of the experimental error. The optimum number of adjacent plots to be included in the moving mean would logically vary depending on the variability of the experimental area. However, too large a number should be discouraged because the size of the block would be increased accordingly, making the estimate less sensitive to rapid changes in the microplot environments. In this study, the moving mean computed from five neighboring plots gave the most effective error control.

International Cooperation

Summary

A total of 4,371 seed packets were distributed to 97 cooperators in 41 countries and three AVRDC lines were officially released, one each in Australia, Somalia and Thailand. AVRDC breeding lines performed well in the Bahamas, China, France, Cameroon, Liberia and Korea, and poorly in Bangladesh due to mungbean yellow mosaic virus (MYMV) infection and in Kenya due to PM damages.

Table 15. Comparison of mean yield and the rank between RCBD and moving mean covariance analysis.

Line	Mean yield (t/ha) in RCBD	Rank	Mean adjusted yield (t/ha) in moving mean analysis[z]	Rank
V 2984	2.08	16	2.16	15
V 3476	1.95	18	1.78	20
V 3726	2.02	17	2.09	17
VC 1973A	1.76	20	1.93	18
VC 2768A	2.31	12	2.35	12
VC 2802A	2.42	9	2.55	6
VC 2917A	2.51	6	2.43	8
VC 3004A	2.18	15	2.16	16
VC 3012A	1.91	19	1.83	19
VC 3012B	2.39	10	2.21	14
VC 3061A	2.66	4	2.68	3
VC 3117A	2.28	13	2.39	10
VC 3178A	2.45	8	2.33	9
VC 3300A	2.75	3	2.58	5
VC 3301A	2.61	5	2.51	7
VC 3664A	2.19	14	2.35	11
VC 3737A	2.83	1	2.88	1
VC 3738A	2.82	2	2.80	2
VC 3746A	2.45	7	2.63	4
VC 3888A	2.32	11	2.24	13
Genotypic effect	NS[y]		***[y]	
Standard error	.38		.16	

[z]Covariance computed from five adjacent plots - COV 4. [y]NS = not significant; *** = significant at 0.1%.

Seed Distribution

Distribution of germplasm including advanced breeding lines to international cooperators is emphasized in the mungbean breeding program. A total of 4,371 seed packets were distributed in 1987 to 97 cooperators in 41 countries including 34 sets of the IMN.

Cultivar Releases

In Australia 'Satin' (AVRDC parent V 2013) was registered by the CSIRO Division of Tropical Crops and Pastures because of its high yield, and resistance to lodging and CLS. The Legumes and Oil Crops Section of the Bonka Research Station, Somalia released 'Filsan' (AVRDC cultivar VC 1168B) because of its early maturity and nonshattering quality. The Chai Nat Crops Research Center, Thailand released 'Chai Nat 60' (AVRDC's VC 1178) for its early and uniform maturity, high yield and suitability for rice-based cropping systems.

Country Reports

Bangladesh. Matiur Rahman from the Pulse Improvement Program, Bangladesh Agricultural Research Institute communicated that many AVRDC lines were heavily affected by mungbean yellow mosaic virus (MYMV). The infection was as high as 80% in both VC 2973A and VC 3061A, and 50% in VC 2768A. However, one of the local lines produced the highest yield (798 kg/ha) during the fall season and was less infected by MYMV. Among the AVRDC lines, VC 1482E, VC 2523A and VC 2771A were less affected by this devastating disease.

Bahamas. Leon S. Smith from the Department of Agriculture, Nassau reported that AVRDC breeding lines, VC 1628A, VC 2768A and VC 2768B produced higher yield (> 1.5 t/ha) during the fall season. The soil type was dolitic limestone and the pH was 7.89. However, the widely adaptable

line VC 1973A performed poorly and produced a yield less than 300 kg/ha. The effect of high pH on this line needs further investigation.

Cameroon. Xavier Laurent from comite diocesain de développement, LARA, KAELE reported that two local cultivars, GN 1[illegible] and GN 11, and three AVRDC breeding lines, VC 1628A, VC 2755A and VC 2764A, produced high yields of about 1.5 t/ha in acidic soils.

China. Lin Lifen from the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences (CAAS), Beijing reported that the area under mungbean production has increased from 470,000 to 530,000 ha in 1987. AVRDC mungbean lines, such as VC 1973A, VC 2778A and V 1381 and many others were well received by the farmers in China. VC 1973A was found to be the best as it has early and uniform maturity, resistance to disease, lodging and pod shattering, is widely adaptable, stable and high yielding. Generally, its yield was 20% to 100% higher than the native cultivars. The expansion of the planting areas of VC 1973A, which was started with less than 100 g of seeds in 1983, is expected to reach 20,000 ha by 1987 in Nanyang region, Henan Province alone. The total cultivated area in Henan Province is estimated to be 160,000 ha. Furthermore, inoculation with rhizobial strain No. 008 isolated by Hu Jisheng of the Soil Microbiology Research Institute, CAAS has increased the seed yield of VC 1973A by 9% to 10%. It is expected that the area under cultivation and mungbean production will continue to increase in China. AVRDC has contributed substantially to this achievement.

Yilu Ling from the Institute of Industrial Crops, Jiangsu Academy of Agricultural Sciences also reported that from 1984 to 1986, 19 AVRDC mungbean varieties were introduced and tested in Jiangsu Province. Most of these lines matured earlier than the check varieties with VC 2719A, VC 1973A, VC 1562A, VC 1000C and V 3726 among the earliest. All AVRDC varieties have larger seeds than the local cultivars, with VC 2755A producing the largest at 76 g/1000 seeds. The average yields over three years of the highest yielders, VC 2768B and VC 2768A were 1,520 and 1,411 kg/ha, respectively. A total of 1,520 kg of seeds of these two varieties had been produced and shall be used for further extension. The yield of wheat after mungbean was found to be greater than corn.

France. H.E. Bannerot from the Institut Nacional de la Recherche Agronomique (INRA), Versailles reported that the AVRDC cultivar VC 1973A (locally known as AVR[illegible]) produced the highest yield of 1.7 t/ha in a single harvest after diquat defoliation. Among the other new entries, VC 3738A and VC 3984-2B-2-1-3-B produced comparable yields.

Kenya. G. Njuguna from Simlaw Seeds, Nairobi reported that AVRDC breeding lines VC 1628A, VC 1973A and VC 2768A performed poorly and flowered late (67 days after planting), and were seriously affected by PM which led to very poor grain yield.

Korea. Yeong-Ho Lee from the Crop Experiment Station, Rural Development Administration (RDA), Suweon evaluated observational and preliminary yield trials of two breeding lines, VC 3738A and VC 3117A which produced comparable yields (1.2 t/ha) as the local cultivar, Seonhwa-nogdu (AVRDC line VC 1973A). However, none of the small-seeded breeding lines produced as high a yield as the local check. During summer, the flowering dates of AVRDC breeding lines ranged from 47 to 67 days.

Lao, PDR. In 1985, 2,422 t of mungbeans were produced in 3,670 ha. Mungbean is considered a cash crop, and is normally grown at the end of the rainy season following upland rice, maize or other early crops. The new price policy and the introduction of high-yielding varieties are expected to increase mungbean production. A total of 100 AVRDC mungbean lines have been introduced since 1983 and are being evaluated at the Haddokkeo Research Station. Three AVRDC lines, VC 1168B, VC 2750A and VC 1560D were selected because of their high yield and resistance to PM, and are to be released in the near future.

Liberia. Saye Diagor, Jr., Lowland Trial and Demonstration, Nimba evaluated AVRDC accessions. Two lines, V 3726 and V 3484, performed well.

Nepal. A.K. Deo, Agricultural Development Officer Dang reported that a mungbean yield trial was damaged by continuous rainfall at pod maturity. However, the following AVRDC breeding lines appeared to be promising based on vegetative and reproductive growth and resistance to disease: VC 2755A, VC 1973A, VC 3061A and VC 3301A.

Tanzania. J.A. Asenga from the Agricultural Research Institute, Ilonga noted that the local cultivar 'Imara' (AVRDC accession V 1380 released in 1983) produced the highest yield of 1.41 t/ha during the rainy season in the March planting. AVRDC breeding lines which produced comparable yield to the local cultivars were: VC 1628A, VC 2768A, VC 2768B and VC 2778A. He also indicated that the characters which need to be improved in AVRDC lines were drought tolerance, bruchid resistance and early maturity.

Vietnam. Duong Minh, Faculty of Agriculture, University of Cantho, Haugiang reported that 60% of the mungbean area under cultivation in the Mekong Delta is planted with three AVRDC varieties, DX91 (VC 1560D), DX102A (VC 2768A), DX113 (VC 2763A), which are recommended in alluvial soils. Furthermore, VC 2763A was tolerant to aluminum (120 ppm) and VC 1482C, VC 21628A and VC 2763A produced good yields under salinity. AVRDC accession V 1080 was also tolerant to water logging.

Mungbean Entomology

Selection for Beanfly Resistance in High Yield Potential and Beanfly-Resistant Breeding Progeny

Summary

Three agromyzid species, *Ophiomyia phaseoli*, *O. centrosematis* and *Melanagromyza sojae*, are important pests of mungbean from tropical to subtropical Asia, Africa and the Pacific. In 1979 AVRDC identified a mungbean accession, V 4281, which had a moderate level of beanfly resistance. This accession which has poor agronomic characters and is susceptible to Cercospora leaf spot is being utilized at AVRDC to breed lines with beanfly resistance. In 1987 two sets of progenies which were bulked through seven generations and selected in F_8 on a single plant basis were screened for high yield potential. In the screening of the first set of progeny comprising 144 entries, 17 entries had low beanfly infestation similar to the resistant check, in two observations. In the second set comprising 50 progenies, eight entries had low beanfly infestation similar to the resistant check. These 25 entries already carry disease resistance and high yield potential. Their actual yields under high beanfly population pressure will be evaluated in 1988 before they are made available to the national programs.

Introduction

Three species of agromyzid flies, *Ophiomyia phaseoli* (Tryon), *O. centrosematis* (De Meijere) and *Melanagromyza sojae* (Zehntner) (Diptera: Agromyzidae), are important pests of mungbean and other legumes from tropical to subtropical Asia, Africa and the Pacific. The insect larvae bore inside the stems of young seedlings, thereby weakening the damaged plant and reducing the seed yield significantly. In Indonesia, where the pest population is especially high, beanfly infestation, at times, kills the plants which necessitates resowing.

In 1979-80 one mungbean accession, V 4281, which consistently showed a moderate level of resistance to beanflies was found. This accession is being used in AVRDC's mungbean breeding program which aims at incorporating beanfly resistance in mungbean breeding lines which are disease-resistant and have high yield potential.

Materials and Methods

Two series of progenies, for which the original crosses were made in 1982 and 1983, were screened. Each entry was planted as a single row in 5-m long and 0.75-m wide beds. Each entry was replicated in three plots arranged in randomized complete block design. Starting soon after germination, a large number of laboratory-reared beanflies (*O. phaseoli*) was released uniformly over the entire planted area, to augment ambient population and ensure high infestation. At three and five weeks after germination, 20 plants from each plot were uprooted and the stems were cut open; the number of beanfly larvae and pupae found inside each stem were recorded. The number of plants within the sampled plants with visible beanfly damage was also recorded. The insect count and percentage of plant damage data were subjected to analysis of variance, and means were compared by Duncan's multiple range test.

Results and Discussion

First series. The progenies included in this screening were bulked through F_7. In F_8, with the help of the plant breeders, single plant selections were made based on vigorous growth, disease resistance, desirable yield components and higher seed yield. One hundred and forty-four progenies were evaluated with one resistant and two susceptible parents. The performance of selected entries under beanfly infestation is summarized in Table 1. The 17 entries had similar beanfly infestation as the resistant check. These entries have higher yield potential and disease resistance than the resistant parent which has neither. In selecting resistant progeny, greater emphasis was placed on fewer number of larvae and pupae per plant than plant damage. This is because in resistant plants, at times, the insect larva dies after causing initial damage to the plant; but such damage due to premature death of the larva is of no consequence.

Second series. In this series, 50 progenies selected for disease resistance and high yield potential were evaluated with nine susceptible parents or checks and one resistant parent in a similar manner as the first series. The results are summarized in Table 2. Six breeding lines had low beanfly infestation similar to the resistant parent. These lines also have disease resistance and high yield potential. Also in this selection, major emphasis was placed on the presence of beanfly larvae + pupae in a plant sample rather than in the percentage of damaged plants.

The 17 entries selected from the first series and six entries from the second series will be given to the plant breeder for evaluation of yield potential and other desirable agronomic characters, such as seed color and texture during 1988.

Evaluation of Insect Growth Regulators for Beanfly Control

Summary

Among the three selective insect growth regulators tested for the control of beanflies (*Ophiomyia phaseoli*, *O. centrosematis* and *Melanagromyza sojae*) on mungbean, cyromazine at rates between 75 and 150 g a.i./ha gave control comparable to omethoate, a standard broad-spectrum organophosphorous insecticide which gives excellent control of beanflies.

Introduction

A new class of pesticide chemicals, commonly known as insect growth regulators (IGRs), are now increasingly used in insect pest control. These chemicals interfere in chitin synthesis in insect larvae and are specific to the larval stage of various insect species. They are relatively safe to predators and parasites, and are thus ideal for integrated pest management. One of these chemicals, cyromazine (trade name Trigard), gave good control of beanflies in soybean during 1986 testing. In 1987 this chemical was tested for the control of beanflies (*Ophiomyia phaseoli* (Tryon), *O. centrosematis* (De Meijere) and *Melanagromyza sojae* [Zehntner]) in mungbean.

Materials and Methods

A parcel of land was rototilled and worked into 1-m wide raised beds. The beds were further divided into 3 m × 3.3 m plots. Seeds of cultivar Tainan No. 3 were sown in two parallel rows set 40 cm apart on each bed and at a distance of 10 cm between hills at the rate of four to five seeds per hill in each plot. Fertilizer, weeding, thinning, irrigation and other necessary cultural practices were followed to obtain high yield.

There were 10 treatments including a control, replicated four times, and arranged in a randomized complete block design. Predetermined quantities of insecticide formulations were diluted in water and sprayed on each plot with a 10-liter air-pressure sprayer charged to 2.7 kg/cm^2 (40 psi). A

Table 1. Beanfly infestation of selected beanfly resistance breeding progeny, first series, AVRDC, autumn 1987.

Progeny designation	No. beanfly larvae + pupae/20 plants[z]		Beanfly damaged plants (%)[z]	
	3 WAE[y]	5 WAE[y]	3 WAE	5 WAE
VC 3785F3-1B-B-B-B-3B-B-B	1.3 hi	2.7 b-h	40 e-k	38 b-h
VC 3785F3-37B-B-B-B-2B-B-B	1.3 hi	1.0 f-h	37 g-k	33 e-h
VC 3785F3-60B-B-B-B-2B-B-B	1.7 g-i	0.7 gh	32 jk	53 a-h
VC 3786F3-2B-B-B-B-3B-B-B	1.0 i	2.3 b-h	37 g-k	42 b-h
VC 3786F3-13B-B-B-B-2B-B-B	1.7 g-i	2.7 b-h	38 f-k	57 a-h
VC 3786F3-32B-B-B-B-1B-B-B	1.3 hi	2.3 b-h	48 b-k	48 b-h
VC 3797F3-2B-B-B-B-1B-B-B	1.3 hi	1.7 d-h	47 c-k	48 b-h
VC 3797F3-2B-B-B-B-2B-B-B	1.3 hi	2.7 b-h	57 a-k	50 a-h
VC 3797F3-2B-B-B-B-3B-B-B	1.7 g-i	2.7 b-h	48 b-k	58 a-g
VC 3797F3-2B-B-B-B-5B-B-B	1.7 g-i	2.0 c-h	73 a-d	40 b-h
VC 3797F3-2B-B-B-B-10B-B-B	1.0 i	1.7 d-h	43 d-k	52 a-h
VC 3797F3-42B-B-B-B-1B-B-B	1.0 i	2.0 c-h	35 h-k	40 b-h
VC 3797F3-45B-B-B-B-2B-B-B	1.0 i	2.7 b-h	42 d-k	45 b-h
VC 3797F3-45B-B-B-B-3B-B-B	1.0 i	2.0 c-h	45 c-k	45 b-h
VC 3797F3-50B-B-B-B-1B-B-B	1.7 g-i	2.7 b-h	33 i-k	45 b-h
VC 3798F3-31B-B-B-B-1B-B-B	0.7 i	2.0 c-h	45 c-k	47 b-h
VC 3798F3-87B-B-B-B-1B-B-B	1.7 g-i	2.0 c-h	53 a-k	43 b-h
VC 3799F3-69B-B-B-B-1B-B-B[x]	7.3 ab	5.0 a-f	77 abc	80 a
V 4281[w]	1.0 i	1.3 e-h	38 f-k	38 b-h

[z]Data are means of three replicates. Means in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test. [y]3 WAE = three weeks after emergence; 5 WAE = five weeks after emergence. [x]Susceptible entry. [w]Resistant check.

Table 2. Beanfly infestation of selected beanfly resistance breeding progeny, second series, AVRDC, autumn 1987.

Progeny designation	No. of beanfly larvae + pupae/20 plants[z]		Beanfly damaged plants (%)[z]	
	3 WAE[y]	5 WAE[y]	3 WAE	5 WAE
F_8: VC 4035YY-B-B	2.7 d	1.3 bc	62 a-e	35 f-i
F_8: VC 4038ZX-2B-B	2.3 d	1.0 bc	52 a-e	60 a-g
F_8: VC 4039VY-1BX-B	3.0 d	0.3 c	55 a-e	35 e-i
F_8: VC 4041W-3BX-B	2.7 d	0.7 bc	47 cde	18 i
F_8: VC 4041XX-1B-B	2.7 d	0.7 bc	43 de	38 c-i
F_8: VC 4041XX-2B-B	2.3 d	0.7 bc	48 b-e	47 b-i
VC 1647B[x]	6.3 a-d	3.3 a-c	67 a-e	58 a-g
V 4281[w]	2.3 d	1.3 bc	35 e	37 d-i

[z]Data are means of three replicates. Means in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test. [y]3 WAE = three weeks after emergence; 5 WAE = five weeks after emergence. [x]One of the susceptible parents. [w]Resistant parent.

0.5-liter spray volume (50% of the designated quantity of the active ingredient) was applied per plot during the first four applications and 1 liter/plot (1,000 liters/ha) at the succeeding three applications. Each sprayer was individually calibrated with a stopwatch and specific volumes of spray solution could be accurately and uniformly delivered to each plot to ensure that a specified amount of active ingredient was applied. Sprayings were done at 3, 7, 10, 14, 21, 28 and 35 days after emergence (DAE).

Insecticide effectiveness was evaluated at 21 and 35 DAE. Thirty plants were uprooted at random from each plot. Each plant was cut open and the number of larvae and pupae found within the stems was recorded. Likewise, the number of plants with visible beanfly damage, including those without larvae or pupae, was also recorded.

Results and Discussion

The efficacy of several chemicals in controlling beanfly infestation is summarized in Table 3. Cyromazine at all four rates of application controlled beanflies as well as the check insecticide, omethoate, a nonspecific broad-spectrum chemical. Two other IGRs, BAS206 and BAS166 alone and BAS206 with additive BAS09, failed to control the pest. BAS166 and adjuvant BAS09, gave as good control as omethoate or cyromazine but this treatment caused phytotoxicity. The treated mungbean foliage had chlorotic yellow spots. The plants recovered after the treatment was discontinued.

Table 3. Efficacy of insect growth regulators in controlling beanflies on mungbean.[z]

Insecticides	Rate (kg)	No.of beanfly larvae + pupae/30 plants		Damaged plants (%)	
		87/10/16	87/11/6	87/10/16	87/11/6
Cyromazine 10SL	0.075	4.2 bcd	0.5 c	40.8 bcd	37.5 abcd
Cyromazine 10SL	0.100	6.0 abcd	2.2 bc	35.0 cd	25.8 bcde
Cyromazine 10SL	0.125	3.2 cd	0.7 c	32.5 cde	22.5 de
Cyromazine 10SL	0.150	4.0 bcd	1.5 bc	30.8 de	30.8 bcde
BAS206 10SC	0.06	9.7 ab	3.0 abc	55.0 ab	40.0 abc
BAS206 + BAS09[y]	0.06 + 1.0	8.0 abc	3.0 abc	46.6 b	34.1 abcd
BAS166 10SC	0.06	9.2 abc	3.7 ab	44.2 bc	40.8 ab
BAS166 + BAS09	0.06 + 1.0	3.0 cd	1.5 abc	24.1 ef	25.0 cde
Omethoate 50EC	0.50	0.7 d	0.7 c	8.3 f	18.3 e
Control		11.7 a	5.2 a	67.5 a	46.7 a

[z]Cultivar = Tainan No. 3. Planted 23 September 1987. Insecticide sprayed: 30 September; 2, 6, 13, 20 and 27 October; and 3 November 1987. Data shown are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test. Plot size = 10 m^2. Design = RCBD. [y]An adjuvant.

Characteristics of Asiatic Cornborer Damage in Mungbean

Summary

Studies were conducted to understand the characteristics of the Asiatic cornborer (ACB), *Ostrinia furnacalis*, damage in mungbean and to breed cultivars resistant to this pest or develop alternate control measures if resistance is not available. There was a significant positive correlation between plant stem diameter and insect infestation. Similarly, accessions with short internodes were significantly less damaged than those with long internodes. Trichome density on the stem had no bearing on ACB damage. *Vigna sublobata* was generally less damaged than mungbean and among 100 *V. sublobata* accessions, 25 were free of ACB damage. The narrow stems of *V. sublobata* could be responsible for less ACB damage in this species. In a corn and mungbean intercrop, ACB overwhelmingly preferred corn initially but eventually moved to mungbean after most corn plants had been damaged.

Introduction

In recent years, Asiatic cornborer (ACB), *Ostrinia furnacalis* (Gn) (Lepidoptera:Pyralidae), a serious pest of corn, has become an important pest of mungbean in Southeast Asia. In Taiwan this insect attacks mungbean in the summer, but is practically absent from autumn through late spring. The insect larva bores into the stems, branches and green pods. As a consequence of larval feeding inside the mungbean stem, the plant is weakened which at times results in wilting of the entire shoot above the insect feeding point. In 1985 2,000 mungbean accessions and 159 breeding lines were screened for resistance to this pest. Since all entries were damaged, the least damaged ones were tested

in 1986, and nine entries were selected for further screening and studies on the characteristics of ACB damage.

In the second test, 100 *Vigna sublobata* accessions were screened for resistance to stem damage by the ACB, while in the third test, the preference of the pest for corn and mungbean was studied.

Materials and Methods

ACB damage characteristics. Nine least damaged mungbean accessions from the 1986 test were planted with two known susceptible checks. Each entry was planted in four randomly selected single 5-m long rows, with a distance of 0.75 m maintained between two adjacent rows. The planted area was surrounded by three rows of corn, planted one month before the planting of mungbean, on all sides. Laboratory-reared ACB pupae were released on each corn plant to increase the insect population which first attacked corn until it was totally infested and then moved to the mungbean crop when the plants reached the proper stage for infestation (six to seven weeks after germination). Eight to nine weeks after germination, the stems and branches of each plant were observed for ACB damage. At this time, stem diameter at several points, number of nodes, length of each internode and trichome density at five points on the main stem with 5-mm wide circumference were recorded.

ACB resistance in *Vigna sublobata*. Seeds of each of the 100 *V. sublobata* and four mungbean accessions were planted as single 5-m long rows with a distance of 0.75 m maintained between two adjacent rows. Each entry was planted in two randomly selected plots. The planted area was surrounded by three rows of corn. At intervals, starting a month after germination, laboratory-reared ACB pupae were released on the corn to increase insect population and chances of insect infestation of *V. sublobata*. Ten weeks after germination, each *V. sublobata* plant was observed for ACB damage on the main stem and branches. The percentage of plants damaged in each accession was calculated.

Preference of ACB between mungbean and corn. A parcel of land was worked into 0.75-m wide beds. The field was divided into 12 6 m^2 plots arranged in two rows of six plots each, with a distance of 0.75 m between two adjacent plots. Mungbean (cv. VC 1973A) was planted in six selected plots, three in either row, and a local cultivar of corn in the remaining six. Both crops were cultivated using standard cultural practices except that no insecticide was used. In the center of the 0.75 m empty area between two rows of plots, seven insect-release stations (a perforated wooden box mounted on a 1-m high pole) were erected at even distances from one end to the other. Starting two weeks after germination, an equal number of laboratory-reared ACB pupae were released in each station. The adults flew out of the wooden box and infested the crops. Three weeks after the initiation of insect release, insect damage to both corn and mungbean was surveyed by observing each plant in each plot. The number of damaged plants was converted to the percentage of damaged plants per plot. Observations were carried out three times at two-week intervals before mungbean pods were ready for harvest.

Results and Discussion

ACB damage characteristics. The extent of ACB damage to mungbean plants is summarized in Table 4. The insect population was relatively lower than in the past years. Two accessions, V 1006 and V 2166, which were least damaged in previous tests also remained least damaged in this test. There was a significant positive correlation between stem diameter and ACB damage (Fig. 1). Plants with bigger stem diameters can accommodate more ACB larvae boring inside than those with smaller diameters. However, for high yield a vigorous plant with big stem diameter is required. Thus, the resistance associated with narrow stem diameter can not be of much practical value.

Similarly, there was significant positive correlation between the length of internodes on the main stem and ACB damage (Fig. 2). Although the influence of this plant character on ACB infestation of mungbean cannot be explained at this stage, the length of internodes can serve as a useful criterion

Table 4. ACB damage to selected mungbean entries, AVRDC, summer 1987.[z]

Entry designation	Plants damaged (%)[z]
V 2762	9.[illegible] a
V 2719	7.9 ab
V 2555	7.8 ab
V 2433	5.8 b
V 2167	5.8 b
V 2136	5.4 b
VC 1000C	5.4 b
V 2739	5.1 b
VC 1973A	5.1 b
V 1006	4.9 b
V 2116	4.7 b

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

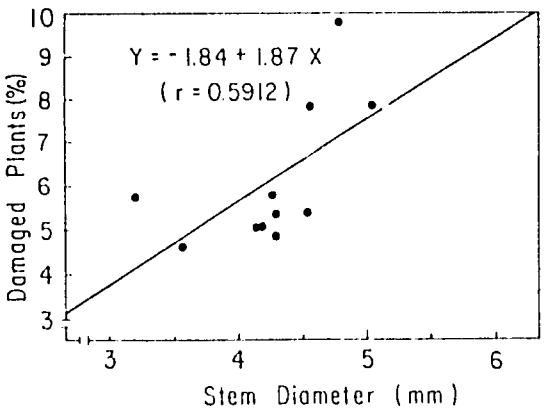

Fig. 1. Correlation between mungbean stem diameter and ACB damage.

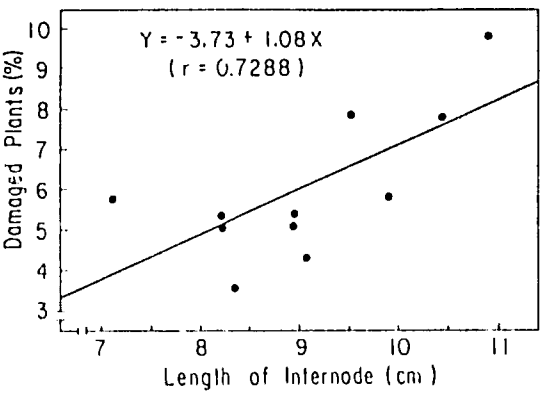

Fig. 2. Correlation between internode length on the main stem and ACB damage.

for selection of plants with less susceptibility to ACB and possibly other stem-boring pests. There was no correlation between trichome density on plant stem and ACB damage.

ACB resistance in *V. sublobata*. Among the 100 *V. sublobata* plants, the ACB damage ranged from 0 to 14.81% of the plants. Twenty-five accessions had no damage at all. Two *V. sublobata* accessions were more damaged than the susceptible mungbean checks. A large number of accessions with no damage indicated that *V. sublobata* is probably less preferred than *V. radiata*. This could very well be due to, in general, the small stem diameter of *V. sublobata* species. This might make *V. sublobata* less useful in breeding mungbean cultivars for *Ostrinia* resistance. This aspect will be investigated before judging the utility of *V. sublobata* in breeding ACB-resistant mungbean.

Preference of ACB between corn and mungbean. Between plants of similar age, ACB overwhelmingly preferred to feed on corn rather than on mungbean (Table 5). However, with time, as more and more corn plants became infested, the insect moved to the mungbean plants. Even when almost 100% of the corn plants were infested, infestation in mungbean was only 38%. This indicated that corn is the primary host and that the insect infests mungbean only if mungbean is in the vicinity or the damaged corn gets harvested before mungbean is ready for harvest. Avoiding planting of mungbean in the immediate vicinity of corn will thus reduce ACB damage to mungbean.

Table 5. Asiatic cornborer infestation of simultaneously planted mungbean and corn, AVRDC, summer 1987.[z]

Crop	Date	Damaged plants (%)[y]
Mungbean	12 July 1987	4.2 b
Corn		31.5 a
Mungbean	11 August 1987	25.7 b
Corn		56.8 a
Mungbean	19 August 1987	38.2 b
Corn		96.0 a

[z]Planting date: 16 June 1987. [y]Data are means of six replicates. Means in vertical columns for each observation interval followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Screening for Bruchid Resistance

Summary

A bruchid, *Callosobruchus chinensis*, causes considerable damage to stored mungbean practically throughout the world. AVRDC identified one black gram accession, VM 2164, which is highly resistant to the pest and initiated a breeding program to develop agronomic mungbean with bruchid resistance. In 1987 two backcross populations, BC_1F_5 and BC_1F_6, were screened for resistance to bruchid in storage. Certain BC_1F_5 populations that showed less bruchid damage were as susceptible in the next generation, BC_1F_6, as the susceptible mungbean check. It was found that although the hybrids of mungbean and VM 2164 were resistant, advanced progenies that carry more mungbean traits were susceptible to bruchid infestation.

Introduction

A bruchid, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae), is a serious pest of mungbean and several other food legumes in storage. The primary infestation begins in the field where adults lay eggs on green pods and the newly emerged larvae bore through the pod cover into the developing seeds. The larva feeds concealed inside the seed. When such seeds are harvested and stored, the bruchid adults emerge and lay eggs on the neighboring seeds and infestation spreads throughout the container.

Since stored mungbean seeds are frequently used for human consumption, the use of insecticides to protect such seeds poses health hazards. To combat this pest, the possibility of developing mungbean cultivars resistant to it is being examined. In this connection, part of the AVRDC mungbean germplasm was screened and one black gram accession, VM 2164, which is very highly resistant to *C. chinensis* was identified. The AVRDC mungbean breeder crossed this accession with a high-yielding agronomic mungbean line and in 1987, one BC_1F_5 and BC_1F_6 population each was screened and selections for further improvements were made.

Materials and Methods

The screening experiment involved exposing mungbean seeds in the laboratory to bruchids; multiplying least damaged entries in the field; harvesting individual plants for further screening; and identifying resistant genes in high-yielding agronomic mungbean lines.

BC_1F_5. The 389 entries included in this test were harvested from BC_1F_4 plants. Seeds from individual plants were confined in individual flasks, and 20 to 50 one- to three-day old bruchid adults were confined with the seeds for one week during which they laid eggs on the seeds. The bruchid oviposited seeds were maintained at 30°C for three more weeks. The number of first generation adults that emerged from the infested seeds was recorded, and the number of insects per gram of seeds was computed for comparison.

BC_1F_6. Two least damaged BC_1F_5 entries from the above test were sown in the field and grown using customary cultural practices except that no insecticides were utilized. At harvest seeds from each of the 48 plants were bulked. In the laboratory the seeds of each of the 48 plants were individually confined in 50 ml Erlenmeyer flasks, and 50 adult insects were held over them for one week for oviposition. The bruchid oviposited seeds were held for an additional three weeks, and the number of first generation adults that emerged from the infested seeds was recorded. At this stage, the total number of seeds and the bruchid damaged seeds were also counted. The number of insects that emerged and the percentage of damaged seeds were analyzed by linear regression to study the correlation between insect emergence and actual damaged seeds. Seeds from two least damaged entries were maintained for a further three weeks to observe the second generation before deciding upon their suitability for further improvement or release.

Results and Discussion

In the first test among the 389 entries, only four had a minimum number of first as well as second generation insects which emerged. These entries were planted in the field to increase seeds and make further selections. However, two entries failed to germinate.

In the second screening of the 48 BC_1F_6 populations, the number of first generation insects which emerged varied from 1.8 to 34.7/g of seeds and the percentage of damaged seeds from 8.8% to 92.7%. Two entries, F_6: IVBC1-1-1-16-20 and F_6: IVBC1-1-1-20-22, had the least number of first generation insects which emerged — 1.8 and 3.4/g — seeds and percent seed damage of 8.8% and 12.6%, respectively. However, these entries were destroyed by the second generation of bruchids.

There was a highly significant positive correlation, r = 0.9384**, between the number of adults which emerged and the percentage of damaged seeds (Fig. 3). In most cases, only one adult insect emerged from one seed.

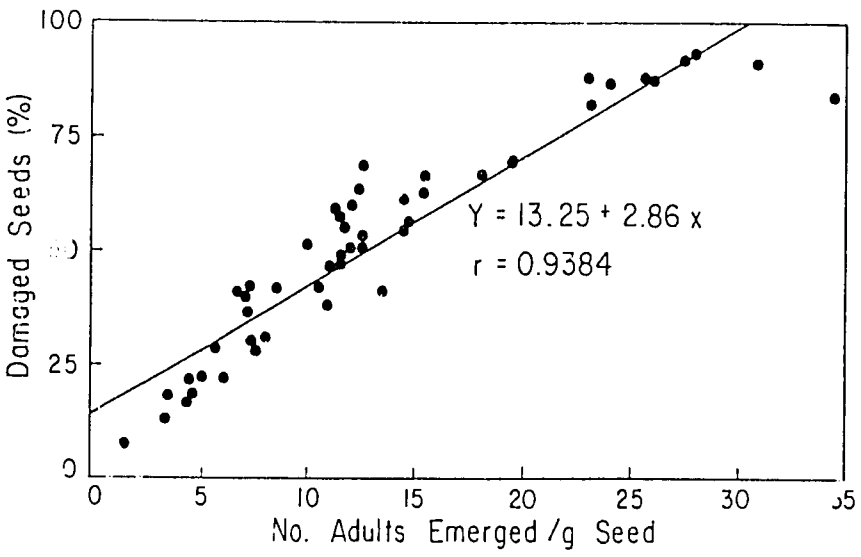

Fig. 3. Correlation between the number of *Callosobruchus chinensis* adults which emerged from seeds and percentage of damaged seeds.

New Sources of Resistance to *Callosobruchus chinensis* in Mungbean

Summary

All 100 *V. sublobata* accessions studied in the search for new sources of resistance to a bruchid storage pest, *Callosobruchus chinensis*, within mungbean or cross-compatible *Vigna* species were found

resistant to it. The insect laid eggs on some accessions but the larvae failed to bore into the seeds. The rough and hard seed coat appeared to be responsible for this. One beanfly-resistant *V. glabrescens* accession, V 1160, also showed a high level of resistance to *C. chinensis*. Among additional mungbean germplasm screened recently, one mungbean accession showed a high level of resistance. The mechanism of bruchid resistance in this accession will be studied in 1988.

Introduction

Callosobruchus chinensis L. (Coleoptera: Bruchidae) is an important pest of mungbean and several other food legumes practically throughout the tropics and subtropics. Although the insect damage is serious in storage its preliminary source of infestation comes from the field where adults lay eggs on developing pods and the newly hatched larvae bore into the seeds. The harvest of such seeds at maturity shifts the infestation to the storage where the newly emerged adults lay eggs on neighboring seeds, thus, spreading the infestation. To control this pest inexpensively without the use of toxic insecticides, AVRDC has been working on developing mungbean cultivars resistant to *C. chinensis*. One black gram accession, VM 2164 which is very highly resistant to this pest, has already been identified. This accession has been used in AVRDC's resistance breeding program but unusual difficulties have been encountered during the breeding process. In addition, screening of progenies has revealed difficulties in getting resistance into seeds which are more of the mungbean type. Therefore, efforts have been renewed to search for newer sources of resistance, if possible in mungbean germplasm itself. Thus in 1986-87, seeds of certain elite mungbean accessions and *V. sublobata* germplasm were screened for bruchid resistance.

Materials and Methods

All tests on mungbean seeds and related species were placed in the laboratory. Seed samples were placed in 60 ml Erlenmeyer flasks and two- to three-day old bruchid adults were confined with the seeds for one week. In that time, the insects laid eggs on the seeds and most of them died. The insects were discarded and the seeds maintained at 30°C for an additional three weeks to permit emergence of the first generation adults. In some cases, in addition to adult emergence, the number of seeds with bruchid damage, as revealed by the presence of holes in the seeds, was also recorded and the percentage of seeds showing such damage was computed to compare their resistance level.

After observations on the first generation were completed, the seeds, in some cases, were maintained in a similar manner for an additional three weeks, and the second generation insects which emerged and the seeds they damaged were recorded. The insect count and the percentage of damaged seeds were analyzed by ANOVA, and means were separated by Duncan's multiple range test.

Results and Discussion

Screening of *V. sublobata*. In this screening, 100 *V. sublobata* accessions were tested, along with one susceptible entry, Tainan No. 3, and the resistant black gram accession, VM 2164. All *V. sublobata* entries were resistant since none of the first generation bruchids emerged from the seed samples. In the susceptible check, on the average, 46 bruchid adults emerged. It was found that in *V. sublobata*, 10% to 20% seeds had bruchid eggs. Microscopic observation revealed that all *V. sublobata* seeds are rough textured and have hard testa. Practically none of the eggs had hatched. Inquiries revealed that it is difficult to germinate *V. sublobata* accessions, and in most cases scarifying of the hard seed coat is required. This hard coat seems to be the major reason for the resistance of these accessions to bruchids.

Screening of VC lines. In this test, 128 high-yielding agronomic mungbean breeding lines were screened for resistance to bruchids. The preliminary test was done with a single replicate and the least damaged entries were screened for the second time in three-replicate tests. All of the 128 breeding lines were found as susceptible as the standard susceptible check, V 2184.

Screening of beanfly-resistant accessions. In this test, seven new mungbean entries — four accessions and three purified selections of another accession were included. All entries had shown moderate to high levels of resistance to the beanflies, mainly *Ophiomyia phaseoli* (Tryon).

The study aimed to see whether beanfly-resistant accessions are also resistant to bruchids. An accession with resistance to two major pests will hasten AVRDC's insect pest resistance breeding program. The methodology used was similar to the one described earlier. Adult emergence is summarized in Table 6.

Except for V 1160, all beanfly-resistant mungbean accessions were as susceptible to bruchid as the bruchid-susceptible check. Accession V 1160, a *Vigna glabrescens* material which is highly resistant to beanfly was also highly resistant to bruchid. This accession is also resistant to several other insects and even diseases. The resistance characters of this accession need to be incorporated into agronomic mungbean lines.

Bruchids lay eggs on the seeds of V 1160 and the larvae bore inside the seed. However, after boring short tunnels, the bruchid larvae died inside the tunnels. In the case of VM 2164, the larvae failed to burrow inside the seed.

Rescreening of selected accessions. In late 1986, in a study on the influence of seed coat color on the oviposition and infestation of mungbean by the bruchid, it was found that one mungbean accession, V 2802, was the least damaged in one nonreplicated and one replicated test. In spring 1987, this accession was planted in an insecticide-free field and soon after harvest it was tested, along with one resistant (VM 2164) and one susceptible (VC 1973A) check for bruchid resistance. The results of the first and second generation adult emergence and seed damaged are summarized in Table 7.

As expected bruchid-resistant check accession, VM 2164, was free of insect damage and no insects emerged from the seeds. In the case of V 2802, very few first and second generation insects emerged from the seeds. Their damage to the seed was minimal. In fact, there was statistically no significant difference in bruchid number and the damaged seeds between VM 2164 and V 2802. VM 2164 is a black gram and its utility in breeding bruchid-resistant mungbean cultivars is limited. V 2802, on the other hand, is a mungbean and its utilization in the breeding program will not have any limitation.

In autumn 1987, V 2802 was planted again in a pesticide-free area, and after harvest the mechanism of bruchid resistance in this accession will be studied before utilizing it in the bruchid resistance breeding program in 1988.

Table 6. Emergence of first generation bruchid adults from selected beanfly-resistant mungbean accessions.

Accession no.	No. of bruchid adults per 10 g seeds
V 1160[z]	9 d
V 4920[z] (brown seeds)	151 ab
V 4920[z] (green seeds)	173 a
V 4920[z] (yellow seeds)	119 bc
V 4947[z]	134 bc
V 5784[z]	169 a
V 5973[z]	115 c
VM 2164[y]	0 d
VC 1973A[x]	147 abc

[z]Beanfly-resistant accession. [y]Bruchid-resistant check. [x]Susceptible check. Data are means of three replicates. Means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Table 7. Infestation of selected mungbean accessions by *Callosobruchus chinensis*.

Accession no.	No. of insects/10 seed[z]		Damaged seeds (%)[z]	
	1st generation	2nd generation	1st generation	2nd generation
V 2802	7.2 b	3.3 b	2.9 b	0.9 b
VN 2164	0.0 b	0.0 b	0.0 b	0.0 b
VC 1973A	156.5 a	92.0 a	78.4 a	12.6 a

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

Pepper Breeding

Strategies in Pepper Improvement

Summary

Based on literature, a questionnaire survey and AVRDC's own observations, problem areas which deserve high priority in the pepper varietal improvement program are resistance to: (1) viruses (TMV, CMV, PVY and CVMV), Phytophthora rot, bacterial leaf spot for both hot and sweet pepper; (2) bacterial wilt (sweet pepper); and (3) anthracnose (hot pepper). Sunscald-tolerance (sweet pepper) and increased pungency (hot pepper) also require attention. Early maturity is essential to make the crop more easily adaptable to various farming systems. More basic studies are needed on fruit development under heat- and virus-stress conditions and on root reaction to excessive soil moisture. Green bell-type sweet peppers of about 100 g were found to be the most widely accepted while consumers' preference for hot peppers varied greatly.

To adapt sweet pepper to the tropics, concurrent backcross programs for each one or two traits, followed by a pyramiding process in one genotype are proposed. In hot pepper, provision of raw and enhanced breeding materials should receive the highest prority to help national programs tackle area-specific problems and hence, will be the major activity of AVRDC. The desired breeding nature of improved genotypes and the desirable type of cooperation with national programs, as well as subject areas which need urgent attention from other disciplines, are discussed.

Introduction

During the first year after selecting pepper as a new principal research crop, the most urgent and essential tasks of the crop improvement program became the establishment of a sound breeding goal, setting of practical objectives based on the crop situation and problems in the major target areas, and definition of working priorities based on available resources and given environmental factors. The information collected from various sources summarized here should lead to a sound prioritization of the pepper crop improvement program in the coming years.

Methodology

Information was collected mainly from four different sources: (1) reports from the previous pepper trials under AVRDC's new vegetable project; (2) questionnaire survey inputs from 58 respondents from 29 different territories/countries specializing in pepper research; (3) literature including monographs, survey reports and review papers on related subjects; and (4) results obtained from the experiments done under various disciplines in 1987.

The AVRDC Progress Reports for 1983-85 have sections for the new vegetable projects and, therefore, were used as an information source of the first category. Questionnaire forms covering a wide range of questions were distributed to 250 professional workers and institutes involved in pepper research, and 57 completed copies were returned, often with answers only to selected questions. The largest number of respondents were breeders followed by pathologists and general horticulturists. Their distribution by country and region is shown in Table 1. Literature on the general situation of the crop

was rather limited, since most information deals with specific subjects. The major sources of information in this category are listed in Table 2. Information from these source categories were quantified as indicators for relative importance among problem areas whenever possible.

Plant growth and development, fruiting, disease and insect incidence and others were observed in monthly plantings, which started at AVRDC in September 1986 with seven sweet and five hot pepper cultivars. Observational results from the virus survey and from visits to other fields, inside as well as outside AVRDC, were also considered.

Table 1. Distribution of respondents of the pepper questionnaire survey, by region and country.

Asian Tropics	15	Africa	5
India	2	Egypt	1
Indonesia	3	Ethiopia	3
Israel	1	Nigeria	1
Malaysia	2		
Philippines	1	Europe	9
Taiwan, China	4	Denmark	1
Sri Lanka	1	France	2
Thailand	1	Italy	1
		Netherlands	1
Temperate Asia	6	Romania	1
Japan	1	Turkey	2
Korea, Rep. of	5	UK	1
America	16	Oceania	7
Argentina	1	Australia	5
Brazil	2	New Zealand	2
Canada	1		
Colombia	2		
Guadeloupe (France)	1		
Peru	3		
USA	6		
		Total: 57	

Table 2. Literature used in identifying priority problem areas and breeding objectives of pepper program.

1. Choudhury, B. 1967. India - the Land and the People - Vegetables. National Book Trust, India. 214 p.
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5. Martin, F.W., J. Santiago and A.A. Cook. 1979. The peppers, *Capsicum* species. Vegetables for the hot, humid tropics, Part 7. ARSEA, USDA.
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7. Sugiura, M., C.M. Bandaranayake and G.H. Hemachandra. 1975. Chili virus disease in Sri Lanka. TARC Tech. Bull. No. 8. 62 p.
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Horticulturally, sweet and hot peppers are two different crops. However, they botanically belong to the same taxon and share the great part of diseases, insects and other problems. Therefore, these two crops are treated together, unless the nature of the subject under discussion makes it otherwise.

The prioritized research objectives and strategies proposed in this report are based on the information gathered and the available resources.

General Situation and Goal

Although peppers originated in the Central and South Americas and are now grown worldwide, more than three-fourths of the production area is within Asia (Table 3). In the tropics, in spite of production constraints which are discussed below, hot pepper is popular, comprising an essential part of the diet, primarily as a spice. On the other hand, sweet pepper is grown only in the highlands and is rather exotic to lowland dwellers.

The goal of the AVRDC pepper improvement program, therefore, should be (1) to help tropical hot pepper growers tackle production constraints through improved genotypes, increased yield and stability and improved marketability and processing quality; and (2) to develop sweet pepper varieties that can be successfully adapted to tropical lowland farming systems.

Major Production Constraints

Diseases are generally considered as the most serious constraint in both hot and sweet pepper production (Figs. 1 and 2). In hot pepper, flooding (including excessive soil moisture problems) is indicated as the second most important problem, especially in tropical Asia (Fig. 1). Although flooding is not a major problem globally in sweet pepper, it is in tropical Asian countries. Lack of suitable varieties to grow in existing farming systems is the next most important production constraint in sweet pepper (Fig. 2). This may be partly related to the fact that farmers do not save sweet pepper seeds from their own fields unlike in hot pepper. This also indicates that sweet pepper is not yet genetically adapted to a wide range of farming environments, especially in the tropics. Insect pests are considered as the third most serious problem in both hot and sweet peppers. Drought and marketing problems are also indicated to be serious for sweet pepper in regions other than tropical Asia. These imply the high-input, market-oriented nature of the crop.

Among the diseases, the virus complex is the most important, regardless of the information source (Table 4). Among the fungal diseases, *Phytophthora capsici*, anthracnose (*Colletotrichum capsici* and *C. gloeosporioides*) and damping off (*Pithium* spp. and *Rhizoctonia* spp.) are generally rated highly serious. Powdery mildew (*Leveillula taurica*), Phoma leaf spot (*Phoma destructa*), Southern blight

Table 3. Production and planted area[z] of peppers, 1985.

	Production area[y]			
	('000 ha)	(%)	('000 t)	(%)
World	1,867	100	11,352	100
Africa	170	9	1,221	11
N. and C. America	97	5	867	8
S. America	20	1	172	2
Asia	1,434 +	77 +	6,683 +	59 +
China	(163)	(9)	(1,825)	(11)
India	(826)	(44)	(2,555)	(23)
Indonesia	(102)	(5)	(205)	(2)
Korea	(118)	(6)	(825)	(7)
Others[x]	(221 +)	(12 +)	(1,273 +)	(11 +)
Europe	146	8	2,408	21
Oceania	?	?	1	0

[z]Sources: Mathukrishnan et al. 1986 in Table 2. India and FAO Production Yearbook 1985 for other countries.
[y]Yield for India and Korea was converted from dry weight by multiplying five times. [x]Statistics are missing for Thailand and Malaysia, where pepper is widely grown.

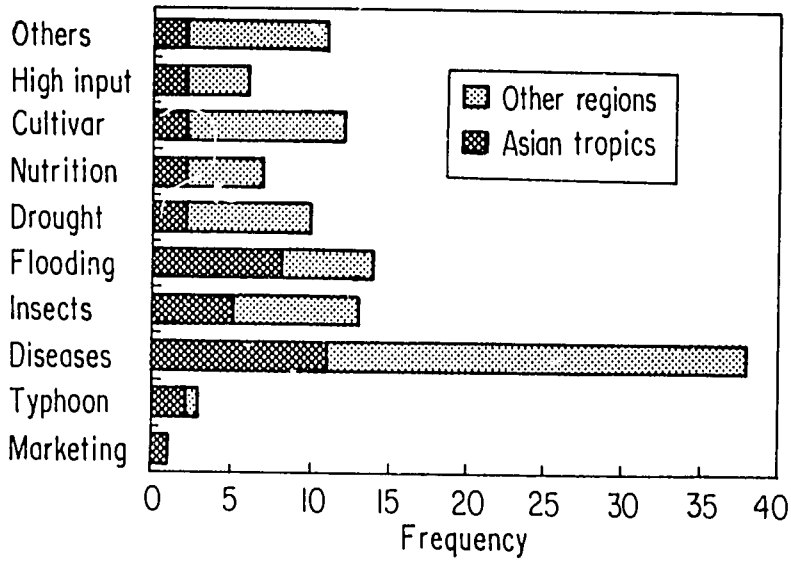

Fig. 1.
Relative importance of hot pepper production constraints as perceived by survey respondents.

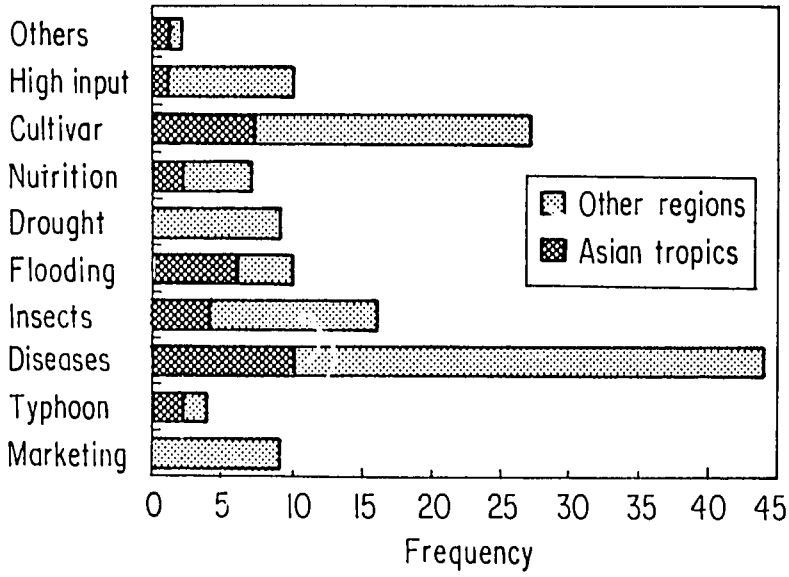

Fig. 2.
Relative importance of sweet pepper production constraints as perceived by survey respondents.

(*Sclerotium rolfsii*), Fusarium wilt (*F. annuum*), and Cercospora leaf spot (*Cercosora capsici*) may become serious in certain regions and seasons. They, however, do not seem to be as widely distributed as the diseases mentioned above. None of them seems endemic in Taiwan during the rainy summer season. Bacterial wilt (*Pseudomonas solanacearum*) and bacterial leaf spot (*Xanthomonas vesicatoria*) are the serious bacterial diseases. AVRDC pathologists noted that a high level of resistance to bacterial wilt exists in some of the tropical hot pepper collection. The nematode situation is somewhat obscure.

Many kinds of viruses are reported to infect the pepper plant. The frequently encountered ones in the literature are listed in Table 5. Considering all the information from different sources, tobacco mosaic virus (TMV), cucumber mosaic virus (CMV) and potato virus Y (PVY) seem to be more important than others. Tobacco etch virus (TEV) may be rather regional, and is prevalent in North America. TEV and pepper mottle virus (PeMV) were previously reported to be problems in Taiwan, the latter being very prevalent. Neither were, however, detected in the intensive survey conducted by AVRDC virologists in 1987. Chili veinal mottle virus (CVMV) is a newly reported virus in

Table 4. Importance[z] of various pepper diseases from different information sources.

	NV Reports[y]	1986-87 observation	Literature[x]	Questionnaire survey[w]	
				Tropical Asia	Other regions
Virus complex	VH	VH	VH	EH (99)	EH (90)
Phytophthora rot	–	VH	VH	VH (49)	VH (52)
Anthracnose	–	H(?)	VH	H (38)	M (19)
Bacterial wilt	VH	H(?)	VH	H (34)	H (20)
Damping off	–	H	H	H (29)	H (34)
Bacterial leaf spot	–	H	H	H (22)	H (42)
Nematode	–	?	M	M (11)	M (17)
Southern blight	VH	?	L-M	L (5)	M (13)
Cercospora leaf spot	–	L	VH	L (4)	L (5)
Powdery mildew	–	L	L-H	L (2)	L (10)
Fusarium wilt	–	L	H	L (10)	L (2)
Others[v]	–	L	L	L (< 10)	L (< 10)

[z]EH = extremely high; VH = very high; H = high; M = medium; L = low. [y]Reports of the New Vegetable Project (Annual Progress Reports 1983, 1984, 1985). [x]Summarized from literatures listed in Table 2. [w]Scores are based on the frequency and importance of the disease. (100 = all respondents rated as the most important disease; 0 = no respondents listed the particular disease). [v]Blackmold, mycoplasma, soft rot, Verticillium wilt, etc. are mentioned depending upon the source of information.

Table 5. Prevalence/importance[z] of various viruses from different information sources.

	NV reports	1986-87 Survey	Literature	Questionnaire	
				Tropical Asia	Other regions
TEV	L	L	H	M	H
TMV	VH	VH	VH	EH	EH
CMV	VH	VH	VH	VH	VH
PVY	VH	VH	VH	VH	VH
PVMV	L(?)	L	M	L	L
PMMV	L(?)	?	L	L	H
TRSV	L(?)	?	L	L	L
TSWV	L(?)	?	L	M	H
TLCV	L(?)	?	M	M	H
PeMV	VH	L	L	L	L
CVMV	–	VH	–	–	–

[z]EH = extremely high; VH = very high; H = high; M = medium; L = low.

Malaysia and it seems highly prevalent not only there, but also throughout the Southeast Asian region, including Taiwan.

Table 6 summarizes the insect pest situation (including mites). Aphids, being the major vector for important pepper viruses, are the most serious. Even when kept to a low population density by chemical and other control measures, they effectively transmit most of the problem viruses through the nonpersistent (stylet-borne) mode of transmission. Thrips and mites are the next most important. Mite population was high in fields sprayed with insecticides (not miticides), but low in those without. The low incidence of mites may have been controlled by the presence of natural parasites kept active when insecticides were not sprayed. Mites, however, should be a problem in most of the farmers' fields because chemical insect control is rather commonly practiced in the cultivation not only of sweet pepper but also of hot pepper (Fig. 3). Their population is lower during the hot season than in the cool season. There are also numerous other insects which attack pepper plants and fruits. Among them are cut worms and fruit worms, which were identified by the respondents during the survey as being serious problems.

Blossom end rot and sunscald are often mentioned as major problems in the literature. The latter, but not the former, was also confirmed as a major problem, especially in AVRDC's sweet pepper plantings during the hot season. It is suspected that fruit setting would be a problem in sweet pepper production under hot temperature conditions. However, all the sweet pepper entries in the

Table 6. Prevalence/Importance[z] of major insects from different information sources.

	1986-87[y] Observation	Literature	Questionnaire[x]	
			Tropical Asia	Other regions
Aphids	H (M – L)	EH	EH (87)	EH (84)
Mites	L (VH)[w]	H	VH (67)	VH (42)
Cut worms	L (L)	L	VH (53)	H (21)
Fruit worms	– (–)	L	H (31)	H (29)
Thrips	H (H)	H	H (41)	M (15)
Pepper weevil	– (–)	H	L (< 10)	L (< 10)
Others	L (L)	L	L (< 10)	L (< 10)

[z]EH = extremely high; VH = very high; H = high; M = medium; L = low. [y]Results from unprotected fields are shown outside parentheses, while results from insecticide-protected fields are shown within parentheses. [x]Scores given in consideration of frequency and importance order (100 = all respondents rated as the most important insect; 0 = no respondents listed the particular insect). [w]Very high only in the insecticide-sprayed fields.

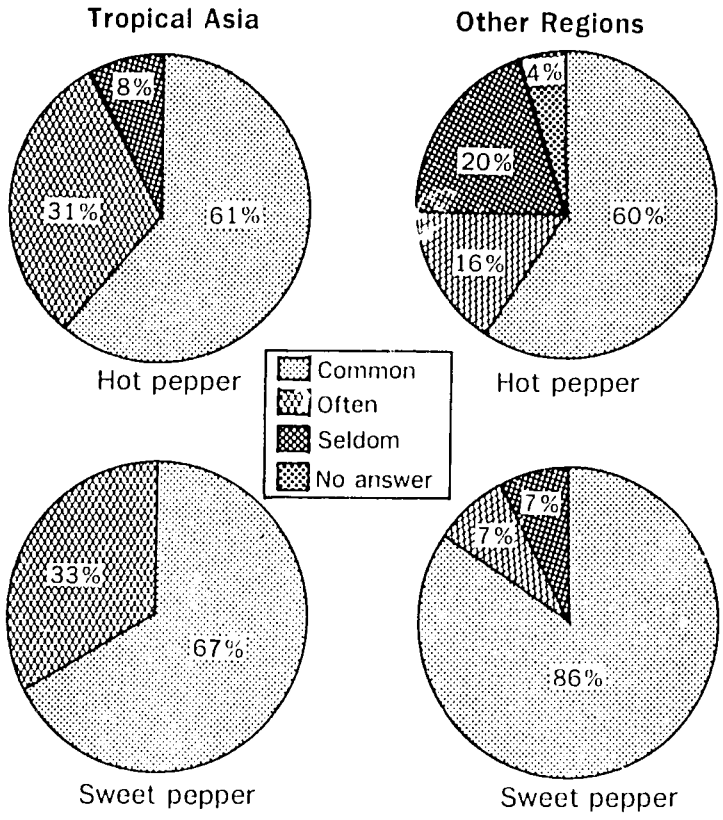

Fig. 3. Status of insecticide use as perceived by the survey respondents.

monthly plantings normally set fruits in the earlier part of reproductive growth, even during the summer season. As the reproductive stage advances, fruit set was observed to decrease more rapidly during the warm season. This seemed to be an indirect effect of rapid virus disease development rather than the high temperature. The more obvious phenomenon observed was reduction of fruit size during the hot season compared to the cool season (Table 7). Fruit size reduction was observed in both sweet and hot cultivars. The ratio of early yield to total yield was much higher in the hot season than in the cool season due to the shortened harvest period. In addition to rapid physiological aging, heat stress on fruit development, as well as rapid disease (especially viruses) development under high temperature, may have shortened the harvest period. The involvement of these factors and the

Table 7. Comparison of the performance of sweet and hot pepper cultivars[z] between cool and hot seasons.[y]

	Hot pepper			Sweet pepper		
	Cool (A)	Hot (B)	B/A (%)	Cool (A)	Hot (B)	B/A (%)
Total yield (t/ha)	30.6	17.4	57	61.7	19.8	32
Total early yield (t/ha)[x]	7.2	12.2	59	18.3	14.3	78
TEY/TY (%)	18.6	73.2	–	30.0	74.0	–
Marketable yield (t/ha)	29.4	15.8	56	47.0	16.3	35
Marketabe early yield (t/ha)[x]	5.6	9.0	62	16.8	12.8	76
MEY/MY (%)	19.6	73.2	–	32.8	79.2	–
Mean unit fruit wt. (g)	18.4	10.6	58	92.0	52.7	57

[z]Means of five hot and six sweet peppers included in both plantings. [y]Transplanting dates for cool and hot seasons were 28 November 1986 and 28 April 1987, respectively. [x]Yield within two and three months from the first flowering of sweet and hot peppers, respectively.

relationship among them are still to be confirmed. Fruit malformation was also observed to increase during the hot season.

Preference

To be well accepted by the growers, a cultivar should possess the desirable preferred traits, which often differ from one location to another. In a breeding program such as AVRDC's, which serves a wide region, it is important to identify not only the characters of most concern but also those most widely preferred.

In hot pepper, pungency, fruit size and color, and fresh fruit shape seem to be equally important in the Asian tropics, while fresh fruit shape is slightly less important in the other regions (Fig. 4). A higher level of pungency is desired by many growers and processors. This was also confirmed by the respondents of the questionnaire survey (Fig. 5). The survey results indicate that elongated or slightly plump fruit of about 20 g is the most widely accepted, although the preference was found to be very diverse and area-specific. A shiny strong red color and smooth skin are important characteristics. High sugar content is preferred in certain countries.

In sweet pepper, fruit size and color are perceived as the most important preference traits, followed by fresh fruit shape and fruit wall thickness (Fig. 6). A 100 g bell type with dark green color is favored by the majority of survey respondents. Thicker fruit wall is generally preferred by the consumers, except in Taiwan where thin fruit wall is regarded as a premium characteristic.

Genetic Variation and Genetic Information

Most cultivated hot peppers, and practically all sweet peppers, belong to *Capsicum annuum*. *C. frutescens* and three more species, *C. baccatum*, *C. chinense* and *C. pubescens*, are also domesticated mostly as hot peppers. There are also 20 to 30 wild species in the genus. Although *C. annuum* holds a great deal of genetic variation, many useful genes, such as high pungency and disease resistance, have been found in other wild and domesticated species. Except for *C. chinense* and *C. frutescens*, *C. annuum* shows a high sterility with other species in different degrees (Lippert et al 1966)[1]. For certain interspecific crosses, useful bridges have been found (Itam and Pickersgill 1986)[2].

[1]Lippert, L.F., P.G. Smith and B.O. Bergh. 1966. Cytogenetics of the vegetable crops. Garden pepper, *Capsicum* sp. Bot Rev. 32: 24-55.

[2]Itam, K.H. and B. Pickersgill. 1986. Barriers to gene exchange between *Capsicum baccatum* and *C. cardenasii*. Proc. Fifth EUCARPIA Meeting on Genetics and Breeding on *Capsicum* and Eggplant. p. 13-17.

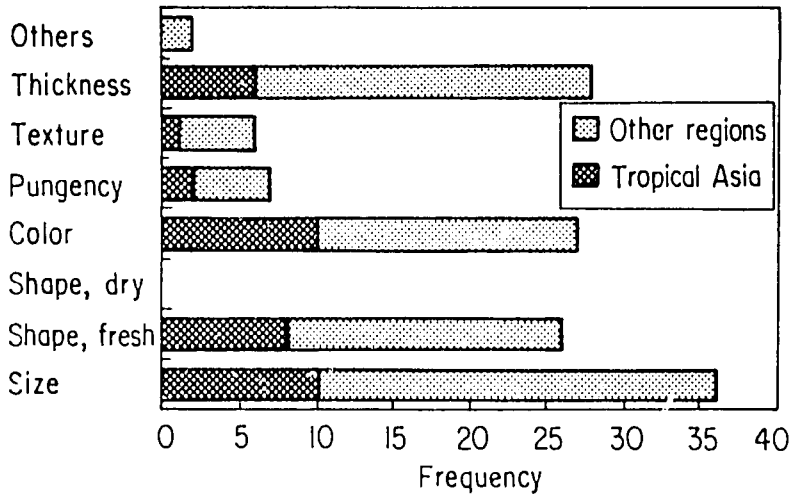

Fig. 4.
Relative importance of fruit characters of hot pepper as perceived by survey respondents.

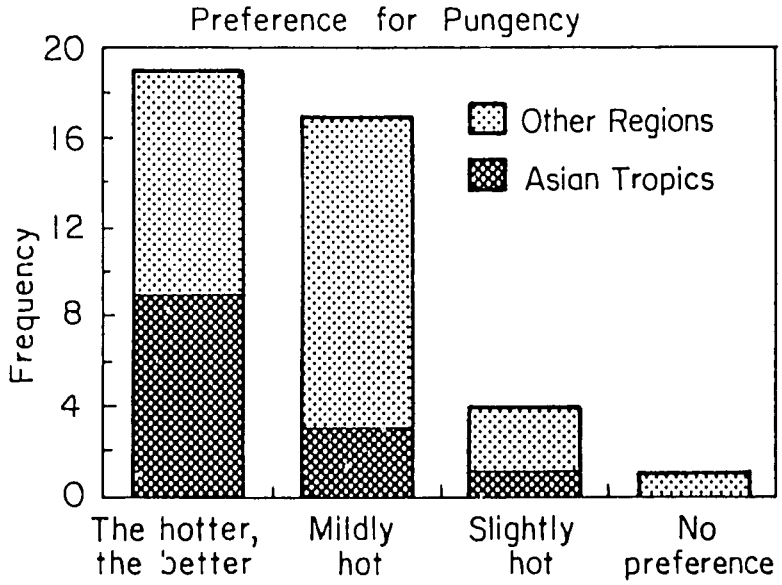

Fig. 5.
Preferred pungency level of hot pepper (respondents in questionnaire).

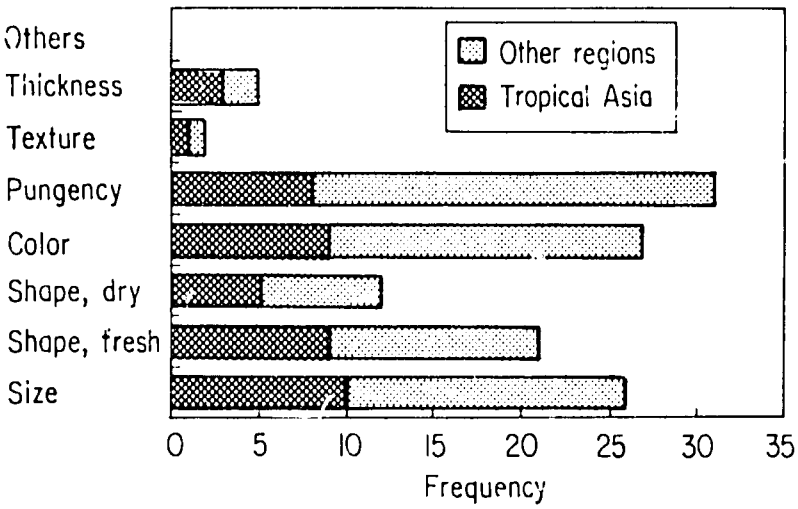

Fig. 6.
Relative importance of fruit characters as perceived by survey respondents.

In spite of *C. annuum*'s sterility, experienced breeders generally agree that it is ofte.: possible to obtain a limited number of seeds from different interspecific hybridization.

Information on inheritance mode is available for many traits, including some major characters of interest to breeders such as pungency, resistance to important diseases and male sterility. Such information was compiled by Lippert et al. (1965)[3] and has recently been updated by Greenleaf (1986).[4]

Ideotypes

Although there have been attempts to determine ideal plant types by a few researchers, a new ideotype for hot and sweet peppers may have to be postulated for tropical growing environments. Early maturity, determinate or compact plant growth habit and collective fruiting deserve consideration in both hot and sweet peppers. The multifruited trait may also have merit in hot pepper. The characteristics for mechanical harvesting may not need immediate attention in the tropical regions. Sunscald would be minimized through sufficient leaf coverage in the ideotype of sweet peppers. In this regard, more studies on crop physiology are needed.

Breeding Strategy

Based on the discussions above, resistance to diseases should be given the highest priority in varietal improvement. Four viruses (TMV, PVY, CMV and CVMV), bacterial leaf spot and Phytophthora rot are the diseases that should be studied in both sweet and hot peppers. Anthracnose has to be added in hot pepper and bacterial wilt in sweet pepper. MC4, which seems to have a high level of heat tolerance and CMV resistance, and a moderate level of anthracnose resistance, and with high yield level; and Dalbon which showed the widest adaptability with bell-type green-colored fruit in the monthly trials, will be included among recipients in several concurrent backcross programs. Further selection for reliable donors in these backcrosses is still required. Some of the potential donors for major traits collect·d in 1987 are listed in Table 8. Each backcross program should aim to transfer resistance to one or two diseases which will be later gradually pyramided in the end product. The available resources, screening technology and further information on relative virulence among diseases of strains

Table 8. Major genetic resources for traits of major interest collected in 1987.

Traits	Source	Donor
Bacterial wilt	MC4*, MC5*	MARDI, Malaysia
Phytophthora rot	PI 201232, PI 201234 PI 188487, PI 189550, PI 201238	KNU, Korea TSS, ROC
Anthracnose	Big Jim*, Hot Long*, New Mexico* Kwangju, Cheongryong	Commercial cvs. MARDI, KNU
Bacterial leaf spot	PI 271322, PI 163192, PI 244670	KNU
TMV	Bruinsma Wonder (L^1), Tobacco (*C. frutescens*; L^2) PI 159236 (*L. chinense*; L^3), PI 260429 (*C. chacoense*; L^4)	IVT, Netherlands
CMV	MC4**, MC5**	MARDI
PVY	Serrano VC (Strain 1-2), Florida VR-2 (Strain 1)	INRA, France
PVMV	HDA 801, HDA 832	INRA
Nematode	HDA 120, HDA 131, HDA 323	OSTOM, France
High pungency	Habanero (*C. chinense*)	Peto Seed Co., USA

*Confirmed at AVRDC during 1986-87. **Bruinsma Seed Co. has identified resistance to the Dutch strain.

[3] Lippert, L.F., B.O. Bergh and P.A. Smith. 1965. Gene list for the pepper. J. Hered. 56:30-34.
[4] Greenleaf, W.H. 1986. Pepper Breeding. p. 67-134. *In* Breeding Vegetable Crops. Avi Publishing Co. Inc., Westport, Connecticut

should determine which of these diseases will be given priority. The recipients are assumed to possess reasonable, if not satisfactory, preference traits.

Recurrent selection will have to be practiced between backcrosses to recover the level of resistance of the donors when the resistance is governed by polygenes. Preference traits have to be monitored in the selection process. For hot pepper, enhancement of pungency as well as utilization of cleistogamy, which is discussed below, will need independent backcross programs. Meanwhile, pure line selection will be applied to improve the genetic purity and other traits of popular and promising tropical open-pollinated varieties such as MC4 and Szechuan. Although different levels of insect damage have been reported by several workers, it does not seem to be highly feasible to use genetic resistance in insect control. In selections, uniform and rapid seed germination has to be sought to reduce damping off which is believed difficult to breed for.

Most farmers in the Asian tropics save hot pepper seeds from their own fields, while sweet pepper seed is almost exclusively purchased from seed distributors. The rate of cross pollination of peppers is usually below 5%, but it can be as high as 60% depending on the environment and genotypes. The genetic impurity of hot pepper cultivars has, therefore, been a problem encountered by many hot pepper growers. Genetic cleistogamy would secure a total self-pollination, if transferred to the cultivated varieties. Male sterility, inherited by cytoplasm and two genic factors are being utilized by some commercial companies mainly for hot pepper hybrids. However, in the AVRDC breeding program, a high, if not absolute, self-pollination rate should be pursued to enable the farmers to save their own seeds, as is usually the practice. On the other hand, male sterility can be considered in sweet peppers which need a higher level of uniformity. Hybrid vigor can also be exploited in certain traits, such as yield and maturity, if intensive researches for better F_1 hybrid combinations are done.

Since the time from sowing to fruit maturity ranges between 120 and 160 days, two generations can be advanced per year with most genotypes, without great difficulty. If a breeding method such as single-seed descent is applied, two-and-a-half generations may be advanced per year.

In major client countries of AVRDC, such as Thailand, Malaysia, Indonesia, China (including Taiwan) and India, pepper breeding programs exist in the research agenda of national and/or private institutes. Considering the diverse preference, disease and other problems which cannot be easily covered by a single breeding program, it is desired, especially in hot pepper, to release not only the finished product but also the segregating materials of AVRDC's breeding program to the cooperators in each country for them to make further selection to meet their local needs.

Areas that Need Further Study

The following problem areas need urgent attention to hasten the improvement of the pepper program:

1. Screening methods for viruses, Phytophthora rot, anthracnose, bacterial wilt and bacterial leaf spot and identification/confirmation of the resistance sources.
2. Crop loss caused by TMV, PVY, CMV and PVMV and strain distribution of PVY and TMV.
3. Multiple disease inoculation method for pyramiding resistance to different diseases.
4. Effect of virus infection and heat stress on size reduction and malformation of fruits.
5. Physiology to postulate the appropriate ideotypes.
6. Root development in relation to moisture stress and nonstaking cultivation.
7. Standard cultural practices.
8. Mass screening method for pungency.

Germplasm Evaluation Trials and Crossing Program

Summary

To identify useful genetic materials for the pepper improvement program, a total of 318 entries were evaluated through two observational, two preliminary and one advanced germplasm evaluation

trials. Promising genotypes for maturity, yield and fruit characters and disease resistance were identifi Eighty-eight different crosses were made among the selected entries for various objectives.

Introduction

To search for genetic materials to be used in the pepper improvement program, observation a evaluation trials were conducted with entries which were randomly chosen from the AVRDC pepp collection based on geographic origins or on their passport data.

Materials and Methods

A total of 181 and 86 entries were included in the first and second germplasm observational tri (GOT), respectively. The first GOT was sown on 30 September and transplanted on 7 Novemb 1986. The second GOT was sown on 28 April and transplanted on 4 and 5 June 1987. There we two rows per bed spaced 50 cm apart and the distance between hills was 45 cm. The bed's cent was 150 cm away from the next bed. GOT I was not replicated, while GOT II had two replicatio with randomized complete block design in each of the three batches. Observations on plant growt and fruit- and yield-related characters were made during frequent field visits.

Preliminary evaluation trials (GPET) were done separately, with two replications on 36 commerc hot peppers and 22 sweet peppers. In sweet pepper GPET, five entries selected from previous year trials under the new vegetable project were also included as part of the monthly trials. One advanc germplasm evaluation trial (GAET) was done with 14 entries selected from GOT I. This trial w replicated three times in randomized complete block design. Data on yield and fruit characters we taken from GPET and GAET.

A plot consisted of 10 to 12 plants in all the trials. The field was mulched with rice straw. Bl Star was used as the check in sweet pepper trials, while Passion and/or Szechuan were used in h pepper trials.

Results and Discussion

Promising entries for maturity, fruiting and virus resistance in GOT I and GOT II are listed Table 9. The characteristics need to be confirmed through replicated trials during the proper seaso All the accessions listed for their virus resistance seemed to be poor in horticultural attribu s. GOT II, which was done during the hot season, dense fruit set was observed mostly in hot peppe probably belonging to *C. frutescens*, while early maturity was observed mostly in *C. annuum*.

Table 9. Promising entries for some important traits in germplasm observational tria (GOT) of pepper.

	GOT I	GOT II
Early maturity	TC 263(SP)[z], TC 310, TC 311, TC 318(SP)[z], TC 323, TC 469, TC 470, PBC 12, PBC 24, PBC 28, PBC 70, PBC 73, PBC 74, PBC 75, PBC 76	TC 884, TC 1087, PBC 97(SP)[z] PBC 92, PBC 94(cl)[z]
Dense fruit set	TC 469, TC 470, PBC 12, PBC 24, PBC 28	TC 29, TC 33, TC 265(Be)[z], TC 471, TC 1087, TC 1261(Be)[z], TC 1294(Be)[z], TC 1485(Be)[z], PBC 208
Virus resistance[y]	TC 274, TC 281, TC 282, TC 283, TC 284, TC 285, TC 286, TC 287, TC 288, TC 289, TC 312	

[z]SP = sweet pepper; Be = Bird eye type of fruit shape; cl = clustered fruits [y]Based on the observation unde natural epiphytotic conditions; horticulturally intermediate between sweet and hot peppers.

Tables 10 and 11 show the yield and other traits of the selected entries from GPET of hot and sweet peppers, respectively. Hot Long, Long Chilli and the check, Passion, had been previously found to have good performance during the summer season. Kiko and IOY34 were comparable to them in yield, and fruit shape and size. All these selected entries are F_1 hybrids. All three highest yielders of sweet pepper possess undesirable preference traits: small size, yellowish color of Gypsy and elongated fruit shape of Big Star and Blue Star. Fruit weight was far less than the regular cool season size of about 100 g.

The best performing entries in hot pepper GAET are listed with their yield level and other traits in Table 12. Hong Shan Ho was confirmed to be a good source of early maturity. The yield level of TC 469 and TC 470 was not as high as some F_1 hybrids such as Passion, but was among the highest in the open-pollinated entries. Twist Green showed good potential for fruit number.

A total of 88 different crosses were made for various breeding objectives using the selections from GOTI as parents. The number and objectives are shown in Table 13. Since the selection of parental genotypes had not been done through replicated trials or systematic screening procedures, generation of these crosses should advance in parallel with further studies on the parental materials.

Table 10. Yield and other traits[z] of some selected entries from a preliminary evaluation trial of commercial hot pepper cultivars.

Entry	Total fruit yield (t/ha)	Marketable yield (t/ha)	Fruit no. harvested per plant	Mean fruit wt. (g)	Fruit shape index
Hot Long	11.3 a-e	10.1 a-f	35 b-h	9 f-j	4.2
Long Chilli	12.5 a-d	11.4 a-e	33 b-h	8 g-k	5.5
Kiko	15.1 a	13.5 a	31 c-i	12 e	5.4
25 IOY	10.6 b-f	9.9 a-f	40 a-f	8 h-m	5.0
34 IOY	13.5 abc	12.6 ab	27 d-j	10 efg	5.8
Passion (check)	13.5 abc	12.5 abc	16 h-l	11 ef	5.9

[z]Mean separation within columns by DMRT at 5% probability level.

Table 11. Yield and other traits[z] of some selected entries from a preliminary evaluation trial of sweet pepper germplasm.

Entry	Total yield (t/ha)	Marketable yield (t/ha)	Fruit no. harvested per plant	Mean fruit wt. (g)	Fruit shape index	Color	No. of locules
Gypsy	30 a	25 a	22 a	37 efg	1.7 d	Yellowish white	2-3
Dalbon	14 c-f	12 cde	7 c-f	62 abc	1.5 def	Green	3-4
Ruby King	20 bc	14 bc	14 b	49 cde	1.4 d-g	Green	3-4
Big Star	22 b	19 b	9 c	54 b-e	2.0 c	Green	2-3
Beauty Bell	13 c-g	11 c-f	8 cd	49 cde	1.2 fgh	Green	3-4
Blue Star (check)	18 bcd	15 bc	7 c-f	73 a	1.5 de	Green	3-4

[z]Mean separation within columns by DMRT at 5% probability level.

Table 12. Yield and horticultural traits[z] of some selected entries in the advanced evaluation trial of hot pepper germplasm.

Entry	Total yield (t/ha)	Marketable yield (t/ha)	Fruit no. harvested per plant	Unit fruit wt. (g)	Fruit shape index	Remarks
Hungarian Wax 672	10.1 bc	8.9 bc	12 de	25 a	3.6	Mildly hot
Twist Green	8.7 cde	7.9 cde	68 a	3 [illegible]	5.0	
Hong Shan Ho	11.4 b	10.7 b	30 b	7 fg	5.7	Early maturity
TC 320	9.6 bcd	8.3 cd	26 bc	12 d	4.3	
TC 469	8.2 cde	7.7 cde	22 bc	8 ef	7.8	
TC 470	10.1 bc	9.2 bc	26 bc	8 f	8.2	
Passion (check)	16.8 a	15.2 a	22 bc	11 de	5.9	

[z]Mean separation within columns by DMRT at 5% probability level.

Table 13. Number and objectives of pepper crosses made.

Objectives	Number
Sweet pepper	
High summer yield × virus-resistance	10
Early maturity × virus-resistance	7
Good fruit traits × virus-resistance	3
Early maturity × good fruit traits	3
Subtotal:	27
Hot pepper	
High early yield × virus-resistance	16
Good horticultural traits × tropical adaptation	10
Virus-resistance × tropical adaptation	20
Pedigree of selected open-pollinated cultivar	15
Subtotal:	61
Grand total:	88

Pepper Entomology

Literature Survey of Insect Pests of Pepper

A detailed survey of the literature on pests (insect and mite) of pepper was conducted to determine the focus of AVRDC research. A total of 293 insect and mite species infest pepper plants in the field and some attack pepper fruit in storage (Table 1). The foliage harbors the largest number of species (111), followed by fruits (71), stems (38), flowers (31) and roots (8). Fourteen species damage pepper fruits in storage and four insect species also attack young seedlings. Some species such as aphids, thrips and mites attack more than one plant part.

A list of the major species that occur in three or more areas/countries of the world is given in Table 2. *Myzus persicae*, an aphid species that is also an important virus vector, is the most widespread insect which infests pepper in 37 countries including several in the tropics. Two other well-known virus vectors, an aphid, *Aphid gossyppi*, and one whitefly, *Trialeurodes vaporariorum*, occur in 13 and 10 countries, respectively. While *A. gossyppi* occurs in the tropics as well as in temperate areas, *T. vaporariorum* occurs mainly in temperate areas of the world. Two mite species, *Hemitarsonemus latus* and *Tetranychus urticae*, are also widespread and are also found in the tropics. At least five species of fruitflies attack pepper, and all of them are present in the tropics.

All insects and mite species that attack pepper are polyphagous. Pepper is not always the primary host. However, because of the presence of other hosts, the pests represent a constant source of infestation to pepper. Except for host plant resistance, the pest management techniques developed to control these pests on the other crops can be adapted and used for pepper.

Table 1. Insect and mite pests of pepper in the world.

Order	No. of species	Number of species attacking various plant parts						
		Leaf	Flower	Fruit	Fruit (storage)	Stem	Root	Seedling
Insecta								
Grylloblattodea	1	–	–	–	–	–	1	–
Orthoptera	4	1	–	–	–	–	–	1
Dermaptera	1	–	–	1	–	–	–	–
Isoptera	3	–	–	–	–	1	2	–
Hemiptera	39	16	1	7	–	1	1	1
Homoptera	33	32	16	–	–	12	–	–
Thysanoptera	8	5	2	2	–	–	–	–
Lepidoptera	68	15	3	23	5	12	3	–
Diptera	47	7	2	30	1	1	–	–
Hymenoptera	2	1	–	–	–	1	1	–
Coleoptera	60	17	6	7	5	10	–	2
Arachnida								
Acarina	27	17	1	1	3	–	–	–
Total	293	111	31	71	14	38	8	4

Data collected from the literature abstracted in the *Review of Applied Entomology*, 1913 to 1987.

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Insect Pests of Pepper at AVRDC

During 1987 a survey of insect and mite pests that infest pepper at AVRDC was conducted. Two 30-m long and 1-m wide beds each were planted to sweet pepper and hot pepper once every month starting January 1987. All customary cultural practices were followed but no insecticide was applied. Once every two weeks, 30 plants of each cultivar type were observed for pest infestation of foliage, stems, flowers and fruits.

In most cases, due to heavy virus infestation, it was not possible to observe insect infestation of flowers and fruits and at times of foliage as well. On some occasions when a few plants did survive until fruit set, thrips and aphids were the major insect pests. Adults and nymphs of thrips were found in flowers, on foliage and on fruits. Their damage to fruits resulted in scratches on the plant parts. On one occasion tomato fruitworm, *Heliothis armigera*, was observed feeding on the fruits and *Spodoptera exigua* on the foliage. Mites were sparingly observed on the foliage.

Since viruses make it impossible to grow the crop without frequent insecticide use, monitoring was discontinued. It is thus planned to study the available literature on insect pests of pepper and develop a data base so that AVRDC cooperators interested in insect pest studies of this crop will have easy access to the information.

Table 2. Geographical distribution of major insect and mite pests of pepper.

Species	No. of areas or countries	Areas or countries
Hemiptera		
Bemisia tabaci	4	Sri Lanka, Sudan, India and Egypt
Empoasca decipiens	3	Egypt, Bulgaria and Spain
Trialeurodes vaporariorum	10	Bulgaria, Egypt, Italy, China, Netherlands, Japan, USA, Germany, Czechoslovakia, and United Kingdom
Homoptera		
Aphis craccivora	5	India, Hungary, Nigeria, Malaysia and Egypt
Aphis fabae	3	USA, Bulgaria and Finland
Aphis gossyppi	13	USA, Bulgaria, Italy, India, Sri Lanka, Venezuela, Puerto Rico, Ivory Coast, USSR, United Kingdom, Nigeria, Taiwan and Indonesia
Aphis nasturtii	4	Hungary, Venezuela, Bulgaria and Czechoslovakia
Hyalesthes obsoletus	4	USSR, Hungary, Bulgaria and Yugoslavia
Macrosiphum euphorbiae	5	USA, Bulgaria, Finland, Canada and Israel
Myzus persicae	37	USA, Germany, Argentina, Spain, Indonesia, Puerto Rico, United Kingdom, Bulgaria, Italy, Hungary, Costa Rica, Czechoslovakia, France, Canada, Venezuela, Egypt, Israel, Romania, Finland, El Salvador, India, Norway, Yugoslavia, Taiwan, Netherlands, New Zealand, Malaysia, Australia, USSR, Argentina, Senegal, Cuba, Switzerland, Zimbabwe, South Africa and Denmark
Thysanoptera		
Scirotothrips dorsalis	4	USA, India, Sri Lanka and Japan
Thrips tabaci	5	Hawaii, Indonesia, India, Bulgaria and Netherlands
Lepidoptera		
Agrotis ipsilon	3	Bulgaria, Turkey and Korea
Heliothis armigera	4	USA, Bulgaria, India and Peru

Table 2. Continued.

Species	No. of areas or countries	Areas or countries
Ostrinia nubilalis	7	USA, Canada, Bulgaria, France, Austria, Hungary and Yugoslavia
Phthorimaea operculella	4	France, Zimbabwe, Egypt and USSR
Plodia interpunctella	3	USA, Bulgaria and Austria
Spodoptera exigua	5	USA, USSR, Italy, Turkey and India
Spodoptera littoralis	4	Turkey, Greece, Egypt and Italy
Diptera		
Asphondylia capsici	3	India, Turkey and Indonesia
Ceratitis capitata	9	USA, Libya, Jordan, Hawaii, Italy, Yugoslavia, Costa Rica, South Africa and Bermuda
Dacus cucurbitae	3	USA, Hawaii and Malaysia
Dacus dorsalis	3	USA, Austria and Malaysia
Dacus ferrugineus	3	Austria, Indonesia and Malaysia
Dacus ferrugineus dorsalis	4	England, Australia, USA and Hawaii
Coleoptera		
Antonomus eugnii	5	USA, Mexico, Puerto Rico, Hawaii and Honduras
Leptinotarsa decemlineata	5	Italy, Bulgaria, Romania, Netherlands and Germany
Tribolium castaneum	3	India, Canada and Nigeria
Acarina		
Hemitarsonemus latus	12	South Africa, Sri Lanka, Netherlands, India, Spain, Thailand, China, Italy, Solomon Islands, Romania, Brazil and Hungary
Tetranychus urticae	10	Turkey, Romania, Netherlands, Canada, Bulgaria, India, Italy, Japan, Poland and Germany

Pepper Pathology

Studies on Fungal and Bacterial Diseases of Peppers

Summary

Viruses, Phytophthora blight, bacterial leaf spot, powdery mildew and anthracnose were the most important diseases of peppers in Taiwan in 1987. The hot pepper cultivar, MC4, was as highly resistant to bacterial wilt as the tomato accession L 285. MC5 and Szechuan were nearly as highly resistant in the tomato bacterial wilt nursery. Two different anthracnose pathogens were found in the field. *Colletotrichum gloeosporioides* caused slightly sunken dark yellow spots on the red, ripe fruit. Its conidia showed a dull or rounded shape at the ends. *Colletotrichum capsici* caused a darker infected area and its conidia were tapered at both ends, resulting in a sharp pointed shape. The symptom caused by *C. gloeosporioides* was more frequently found in the disease nursery. Some very highly resistant or highly resistant lines were found in the resistance screening of anthracnose. The pathogenicity of the isolates of *Phytophthora capsici* showed significant differences either in hot pepper or in the early stage after inoculation in sweet pepper. Seven very highly resistant lines were obtained from the Phytophthora blight resistance screening trial.

Introduction

Peppers are subject to the attack of many diseases affecting roots, leaves, stems and fruits. The severity of any particular disease depends on the season and the region in which the crop is grown. Many of the diseases cause damage only in exceptional years, but a few are prevalent in many areas each year and cause varying levels of damage. The production of peppers in the tropic and subtropic areas has been seriously hampered by diseases. The objective of this study is thus to evaluate the disease occurrence in Taiwan during the whole year and to determine sources of resistance to the major disease organisms.

Materials and Methods

Observation on disease occurrence in Taiwan. To understand disease occurrence on peppers, a survey was conducted in the major production areas in the past year. Disease severity, economic importance, season and location were recorded. In addition to the survey conducted outside the Center, a disease observation nursery was also established in AVRDC's experimental farm. Three sweet pepper varieties (Blue Star, Ching Yeu and 5210) and two hot peppers (Szechuan and 622) were planted at weekly intervals starting January 1987. The plot size of each variety was 25 m^2. No fungicides were applied to the plants. Data on disease occurrence and severity under AVRDC's environmental condition were recorded.

Screening for bacterial wilt resistance. Each of the 10 lines tested was transplanted to the tomato bacterial wilt nursery at 5- to 6-leaf stage. First, the tomato check cultivars, L 390 and L 285, were transplanted to the middle row of each bed and arranged as one susceptible check by one resistant check. The test lines were transplanted on both sides of the middle row. The space between plants within rows was 20 cm and the space between rows was 30 cm. The experiment was designed with

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two replications. Three weeks after transplanting, the mortality of all entries was investigated once a week for two months. The lines which showed the same resistance level as the resistant check L 285 were selected for further studies.

Survey of different anthracnose symptoms in AVRDC. Two different symptoms of anthracnose were observed in the nursery and in the field. A study was undertaken to understand the occurrence and cause of these anthracnose symptoms in the nursery. Twenty randomly chosen fruits of each variety were evaluated in each of the two plantings. Lesion number in each fruit was counted for the evaluation. Another 20 symptomless and red, ripe fruits of each variety were randomly collected in the field. These fruits were washed and dried and then put in plastic trays and covered with a sealed plastic bag. They were incubated at 28° ± 1°C for 11 days to allow disease development.

Screening for anthracnose resistance. Three trials were conducted for resistance to anthracnose. Red, ripe fruits were harvested from the field, washed, dried, punctured using five-needle holes less than 5 mm in diameter and inoculated by placing a drop of a conidial suspension of *Colletotrichum capsici* (Syd.) Butler et Bisby and *C. gloeosporioides* (Pen.) Sacc. on the wound. Before inoculation, the fruits of each entry were placed on a layer of net in a plastic tray. One hundred milliliters of sterilized water were added to each tray, and the tray was sealed in a plastic bag to maintain high humidity for the penetration and development of pathogens. After inoculation, the materials were maintained under room temperature. Resistance was evaluated by measuring the diameter of the lesions that developed on and around the puncture wound at 10 and 14 days after inoculation. The following rating system was used in the trials: very highly resistant (VR) = no lesions developed; highly resistant (HR) = the diameter of the lesion ranged from 0.01 cm to 0.4 cm; moderately resistant (MR) = from 0.4 to 1.0 cm; moderately susceptible (MS) = from 1.0 to 2.0 cm; highly susceptible (HS) = larger than 2.0 cm.

Pathogenicity of different isolates of *Phytophthora capsici* (Leonian). Two greenhouse trials were conducted to compare the pathogenicity of different isolates of *P. capsici*. Blue Star (sweet pepper) and Szechuan (hot pepper) were planted in 17.5 cm clay pots, and thinned to three plants/pot after germination. The plants were artificially inoculated at flowering stage using 1,000 sporangia/ml of the pathogen in both tests and 100 ml of sporangia suspension in each pot. The mortality of each variety to each isolate was investigated at weekly intervals for one month after inoculation.

Screening for Phytophthora blight resistance. Each of the 63 lines was planted in 17.5 cm clay pots on 21 September 1987. Sterilized soil was used in the experiment and the lines were thinned to six plants/pot after germination. Artificial inoculation with sporangia of *P. capsici* (Yang-1) was made on 2 November when most lines were flowering. The concentration of inoculum was 1,000 sporangia/ml with 100 ml of this inoculum added to each pot. Disease evaluation was made one week and two weeks after inoculation.

Results and Discussion

Observation on disease occurrence in Taiwan. Viruses, Phytophthora blight, bacterial leaf spot, powdery mildew and anthracnose were common (Table 1). Virus diseases are very serious and are widely distributed throughout Taiwan. They can completely destroy some pepper fields. Phytophthora blight was very serious in some locations during the rainy season. High mortality from the disease was very common. Hot pepper (Szechuan) was more tolerant to Phytophthora blight than sweet pepper (Blue Star). Bacterial leaf spot was very severe during the rainy season and typhoon period. It caused severe defoliation after serious infection. Powdery mildew is also a serious fungal disease causing severe infection during spring and fall seasons. Fortunately, it can be effectively controlled by fungicide. Anthracnose caused some serious infection after typhoon. In general, sweet pepper should be harvested before the fruits are red ripe, otherwise, fruits can be infected by serious diseases. Some hot peppers are susceptible to this disease. In addition to the above mentioned diseases, sunscald was also very serious from April to August.

Table 1. Occurrence of pepper diseases in Taiwan.

Disease	Disease severity in 1987[z]								
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Virus	+ +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Bacterial leaf spot			+	+ + +	+ + +	+ + +	+ + +	+ + +	+
Powdery mildew	+	+ +	+ + +	+ + +	+ +	+	+ +	+ + +	+ + +
Phytophthora blight	+	+ + +	+ + +	+ + +	+ + +	+ +	+ +	+	
Anthracnose			+	+	+ +	+ +	+ + +	+ + +	+ +
Southern blight						+ +	+		
Soft rot		+	+	+	+	+	+		
Cercospora leaf spot			+	+	+	+	+	+	
Sunscald	+	+ + +	+ + +	+ + +	+ + +	+ + +	+		
Blossom end rot			+	+ +					

[z] + = Few lesions were observed on some plants. + + = Disease was uniformly distributed and may cause yield loss. + + + = Severe infection occurred and caused much yield loss.

Screening for bacterial wilt resistance. The causal organism, *Pseudomonas solanacearum* (E. F. Sm.) E. F. Sm. is the same pathogen causing bacterial wilt on tomato. Therefore, the experiment was set in the tomato bacterial wilt nursery. The pepper cultivar, MC4, showed high levels of resistance similar to that of the most resistant check, tomato cultivar L 285 (Table 2). MC5 and Szechuan also had high levels of resistance to the disease. MC4, MC5 and Szechuan are commercially acceptable hot pepper cultivars. The reaction of the pepper lines ranged from moderately resistant to highly susceptible.

Table 2. Resistance screening for bacterial wilt of peppers in tomato bacterial wilt nursery.[z]

Entry	% of plant survival[y]	
	Mean	Rating[x]
Dalbon (sweet)	41	MS
Hon Shan Ho	52	MS
MC4	100	HR
MC5	94	HR
Blue Star (sweet)	70	MR
Szechuan	97	HR
C 4 (TC 254)	0	S
C 6 (TC 256)	0	S
C 8 (TC 258)	0	S
C 178 (TC 312)	36	S
L 390 (check)	0	S
L 285 (check)	100	HR

[z]Date transplanted: 20 May 1987; No. of plants transplanted: 20. [x]Rating based on the following: >85%; Highly resistant (HR); 76-85%, Resistant (R); 56-75%, Moderately resistant (MR); 41-55%, Moderately susceptible (MS); <40%, Susceptible (S)

Survey of different anthracnose symptoms in AVRDC. Two different symptoms which were caused by two different pathogens were found frequently in the disease observation nursery and in the field during the summer season (Table 3). One of the symptoms was caused by *Colletotrichum gloeosporioides*. The causal organism usually attacks red ripe fruit and develops small, indefinite, slightly sunken dark yellow spots on the fruit surface. The spots enlarge and sometimes coalesce as the fruit matures. Black brown acervuli develop in the center of the spot and are usually arranged in concentric rings, giving a target-like appearance to the spots. The ends of the conidia are rounded. The other symptom, caused by *C. capsici*, is very similar to that caused by *C. gloeosporioides*, but the infected area is darker because more vigorous setae develop from darker acervuli. The ends of these conidia taper to a sharp point.

A field evaluation of two plantings showed that lesions found in the five varieties studied were caused by *C. gloeosporioides*. Green fruits did not seem to be easily infected. Sweet pepper developed more lesions than hot pepper, and therefore, appeared to be more susceptible.

The result of the incubation experiment also showed many more lesions caused by *C. gloeosporioides* (Table 4). Hot pepper varieties, Szechuan and 622, did not develop lesions and seemed to have a high level of resistance to anthracnose. However, this needs to be studied further.

Table 3. Occurrence of different symptoms of anthracnose on peppers in AVRDC.[z]

Planting	Variety[y]	Green fruit		Red fruit	
		Colletotrichum capsici	*Colletotrichum gloeosporioides*	*Colletotrichum capsici*	*Colletotrichum gloeosporioides*
1 June 1987					
	Blue Star	0	0	24[x]	38
	Ching Yeu	0	0	33	57
	5210	2	0	36	93
	Szechuan	0	0	0	7
	622	0	0	0	7
2 July 1987					
	Blue Star	0	0	26	37
	Ching Yeu	0	0	11	108
	5210	0	0	12	86
	Szechuan	0	0	0	4
	622	0	0	0	13
	Total lesions/ 200 fruits	2	0	142	450

[z]Date evaluated: 15 October 1975, natural infection. [y]Blue Star, Ching Yeu and 5210 are sweet peppers while Szechuan and 622 are hot peppers. [x]Lesion numbers were evaluated from 20 fruits of each variety in each planting.

Table 4. Development of anthracnose on the red ripe, symptomless fruits of field-grown pepper varieties after incubation.[z]

Variety	Lesion no. on 20 fruits[y]	
	Colletotrichum capsici	*Colletotrichum gloeosporioides*
Blue Star (sweet)	1	4
Ching Yeu (sweet)	0	43
5210 (sweet)	0	7
Szechuan (hot)	0	0
622 (hot)	0	0
Total lesions/100 fruits	1	54

[z]Date incubated: 16 October 1987. Temperature: 28° ± 1°C. Date evaluated: 27 October 1987. [y]Fruits of each variety were randomly collected in the field.

Screening for resistance to anthracnose. Three trials were conducted to evaluate resistance to anthracnose (Tables 5, 6, and 7). Out of a total of 179 cultivars, 33% or 59 cultivars were rated highly or very highly resistant and 30% were rated highly susceptible. Most of the very highly resistant lines showed no disease development. All of the resistant cultivars were hot pepper types. Those cultivars that were rated highly or very highly resistant will be retested to confirm their level of resistance.

Table 5. Screening pepper germplasm for resistance to anthracnose (I).[z]

Disease reaction	No. of entry	%
Very highly resistant (VR)	18	20
Highly resistant (HR)	27	31
Moderately resistant (MR)	15	17
Moderately susceptible (MS)	19	22
Highly susceptible (HS)	9	10
Total	88	

[z]Inoculated: 4 September 1987; five fruits/variety were inoculated. Inoc. conc.: 3.5 x 10^6 spores/ml. Evaluated: 11, 15 and 18 September 1987. Check varieties: Blue Star and Ching Yeu.

Table 6. Screening pepper germplasm for resistance to anthracnose (II).[z]

Disease reaction	No. of entry	%
Very highly resistant (VR)	2[y]	3
Highly resistant (HR)	9	15
Moderately resistant (MR)	3	5
Moderately susceptible (MS)	20	34
Highly susceptible (HS)	25	42
Total	59	

[z]Inoculated: 15 October 1987; six fruits/variety were inoculated. Inoc. conc.: 3.8 x 10^6 spores/ml. Evaluated: 22, 27 and 30 October 1987. Check variety: Blue Star. [y]Two VR lines: C00513 and C01284.

Table 7. Screening pepper germplasm for resistance to anthracnose (III).[z]

Disease reaction	No. of entry	%
Very highly resistant (VR)	0	0
Highly resistant (HR)	3[y]	9
Moderately resistant (MR)	1	3
Moderately susceptible (MS)	8	25
Highly susceptible (HS)	20	62
Total	32	

[z]Inoculated: 12 October 1987; ten fruits/variety were inoculated. Inoc. conc.: 3 x 10^6 spores/ml. Evaluated: 19, 22 and 26 October 1987 by Mr. Yeong Woo Yoo. [y]Three HR lines: C00071, PBC93 and OCNH-011.

Pathogenicity of different isolates of *Phytophthora capsici*. The isolates of *P. capsici* were collected from different locations. As shown in Tables 8 and 9, pathogenicity varied with pepper cultivars and among the isolates. The isolate Yang-1 was the only isolate with a high level of virulence to the hot pepper cultivar. The isolates also differed in their rates of disease development on the sweet pepper cultivar. The virulence of the isolates was closely related to the success of disease resistance screening. More isolates will be collected and evaluated before determining the presence of physiologic specialization.

Screening for Phytophthora blight resistance. More than 87% of the 63 entries showed high levels of susceptibility to *P. capsici* in this trial (Tables 10 and 11). Most of the entries were completely destroyed by the pathogen. However, seven entries were not visibly affected by *P. capsici* and, therefore, were rated very highly resistant to this pathogen. Among these entries, Acc. 1176A, 2227, 2230, 2284 and 2289 had been reported resistant by the Taiwan Seed Propagation and Improvement Station. These very highly resistant entries will be screened again and should be very useful for the resistance screening program in the future.

Table 8. Pathogenicity of different isolates of *Phytophthora capsici* in peppers.[z]

Variety	Isolate	Percentage of infection				
		9/21	9/29	10/5	10/12	10/19
Blue Star	Yang-1	100	100	100	100	100
	Yang-2	80	93	100	100	100
	Chun-1	40	47	80	93	100
	Chun-2	60	67	93	100	100
Szechuan	Yang-1	13	27	27	33	47
	Yang-2	0	0	0	7	7
	Chun-1	0	0	7	7	7
	Chun-2	0	0	0	0	0

[z]Date inoculated: 14 September 1987.
Inoc. conc.: 1,000 sporangia/ml.
100 ml sporangia suspension/pot, three plants/pot and four pots/isolate per variety were used.

Table 9. Pathogenicity of different isolates of *Phytophthora capsici* in peppers.[z]

Variety	Isolate	Percentage of infection			
		10/6	10/13	10/20	10/27
Blue Star	Yang-1	100	100	100	100
	Yang-2	67	75	100	100
	Chun-1	83	100	100	100
	Chun-2	100	100	100	100
Szechuan	Yang-1	33	50	50	75
	Yang-2	0	0	0	0
	Chun-1	0	0	0	0
	Chun-2	0	0	8	17

[z]Date inoculated: 29 September 1987.
Inoc. conc.: 1,000 sporangia/ml
100 ml sporangia suspension/pot, three plants/pot and five pots/isolate per variety were used.

Table 10. Disease reaction of germplasm to Phytophthora bilght of peppers.[z]

Disease reaction	No. of entry	%
Very highly resistant (VR)	8	13
Highly resistant (HR)	0	0
Moderately resistant (MR)	0	0
Moderately susceptible (MS)	0	0
Highly susceptible (HS)	55	88
Total	63	

[z]The isolate Yang-1 was used in this trial.

Virus Monitoring of Pepper at AVRDC

Summary

Ten successive plantings of five *Capsicum* cultivars selected for breeding were monitored at 25- to 35-day intervals for the presence of viruses in AVRDC fields. Four viruses, chili veinal mottle virus (CVMV), cucumber mosaic virus (CMV), potato virus Y (PVY) and tobacco mosaic virus (TMV), were found. Viruses were first detected around 29 days after transplanting. CMV and CVMV generally appeared first, followed by PVY. TMV incidence was generally low and occurred later (55 to 60 DAT).

Table 11. Results of resistance screening for Phytophthora blight of peppers.[z]

Rating	Accession no.	Rating	Accession no.	Rating	Accession no.
Highly resistant	C00113	Highly susceptible	C00069	Highly susceptible	C00159
	C02227		C00092		C00159A
	C02230		C00095		C00159B
	C02284		C00095A		C00160
	C02289		C00098		C00161B
	C01176A		C00100		C00161C
	TC 3191		C00104		C00162A
Highly susceptible	C00001		C00105		C00162C
	C00002		C00112		C00165B
	C00003		C00116B		C00178
	C00005		C00131		C00197A
	C00006		C00133		C00200
	C00010		C00147		C00202
	C00011		C00148		C00205
	C00012		C00152		C00212
	C00015		C00153		C00213
	C00016		C00153A		C00129
	C00023		C00154		C00269
	C00045		C00154A		C00270
	C00050		C00157		Szechuan
	C00057		C00157C		Blue Star
	C00067		C00157D		Ching Yeu

[z]Planted: 21 September 1987. Inoculated: 2 November 1987. Inoc. conc.: 1,000 spores/ml, 100 ml/pot. Evaluated: 9, 16 and 23 November 1987. [y]Rating scale used: >80%, Highly resistant (HR); 60-80%, Moderately resistant; 30-59%, Moderately susceptible (MS); <30%, Highly susceptible (HS).

Introduction

Since pepper is a relatively new research crop for AVRDC, it is important to determine the types of viruses which occur in AVRDC plantings and the time of infection during the growth of the crop. The present study is investigating this.

Materials and Methods

Eight successive plantings of five *Capsicum* cultivars (Szechuan, Gypsy, Blue Star, Passion and Hungarian Wax), selected by the breeder as breeding materials, were monitored at approximately 25- to 35-day intervals for the presence of CMV, CVMV, PVY, TMV, AMV (alfalfa mosaic virus), PeMV (pepper mottle virus), TEV (tobacco etch virus) and TSWV (tomato spotted wilt virus). Each cultivar was planted in a 1.5 × 5 m plot (12 plants per plot, 45 cm between plants) with two replications. The field size was 230 m^2. The field was sprayed weekly with insecticide.

Pooled leaf samples, consisting of three to five leaves (from the top and the middle of the plant) each of the 12 plants in one plot of each cultivar were tested by ELISA as previously described.

Results and Discussion

There were no great differences observed in virus infection at different planting dates (Fig. 1a-d). Only four viruses were found throughout the sampling period: CVMV, CMV, PVY and TMV. This corresponds to the islandwide survey, in which only these four viruses were also detected.

Virus can be detected as early as 29 days after transplanting (DAP), indicating that infection probably takes place before that time. Generally, the first viruses detected were CVMV and CMV. PVY was detected slightly later. Infection with TMV occurred later, between 55 and 60 days after transplanting and was found to be very low. It was detected only on two of the five cultivars.

The results of this study and the islandwide survey clearly indicate that three viruses are important on pepper in Taiwan, namely, CVMV, CMV and PVY (in order of importance). Initial virus infection

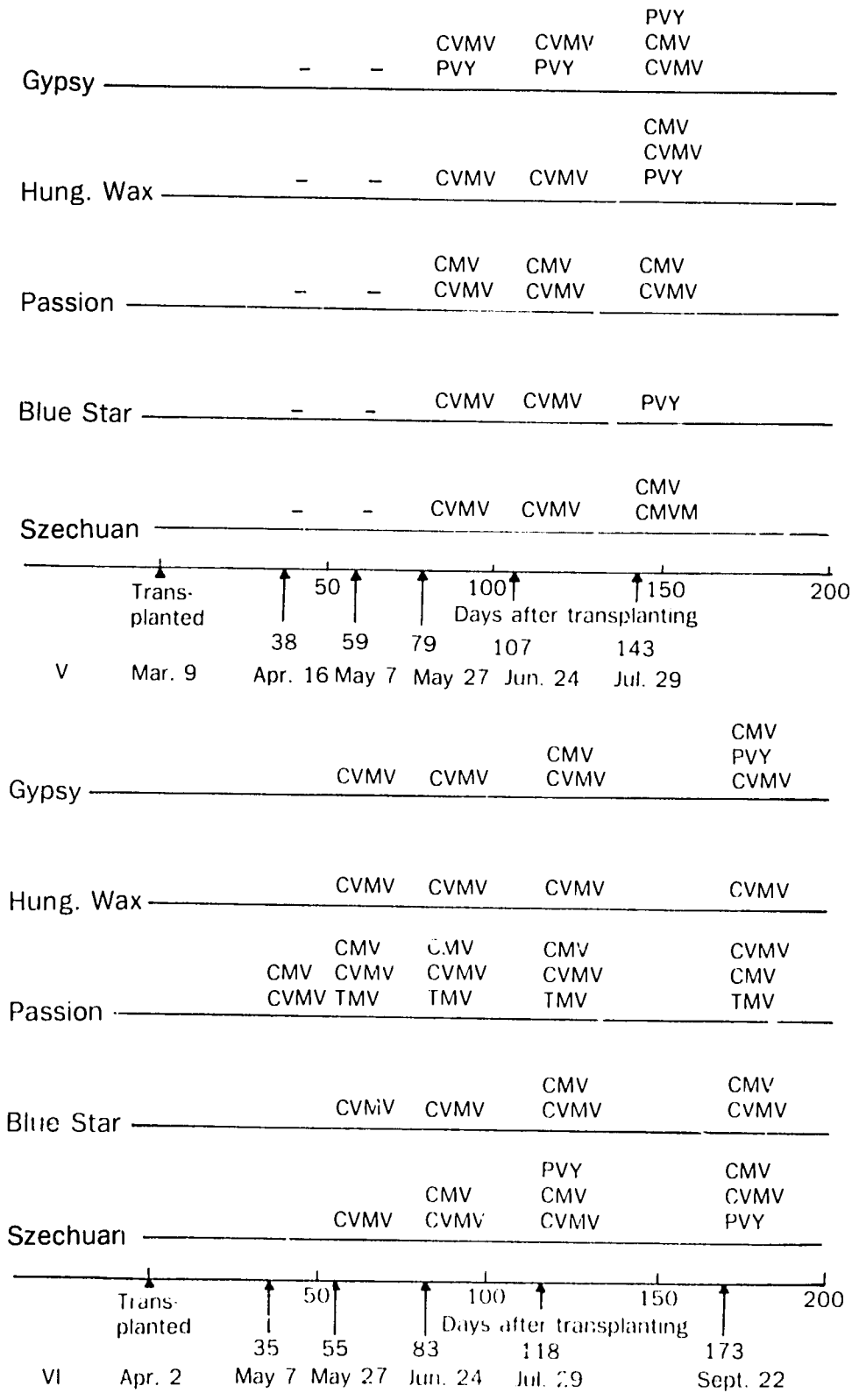
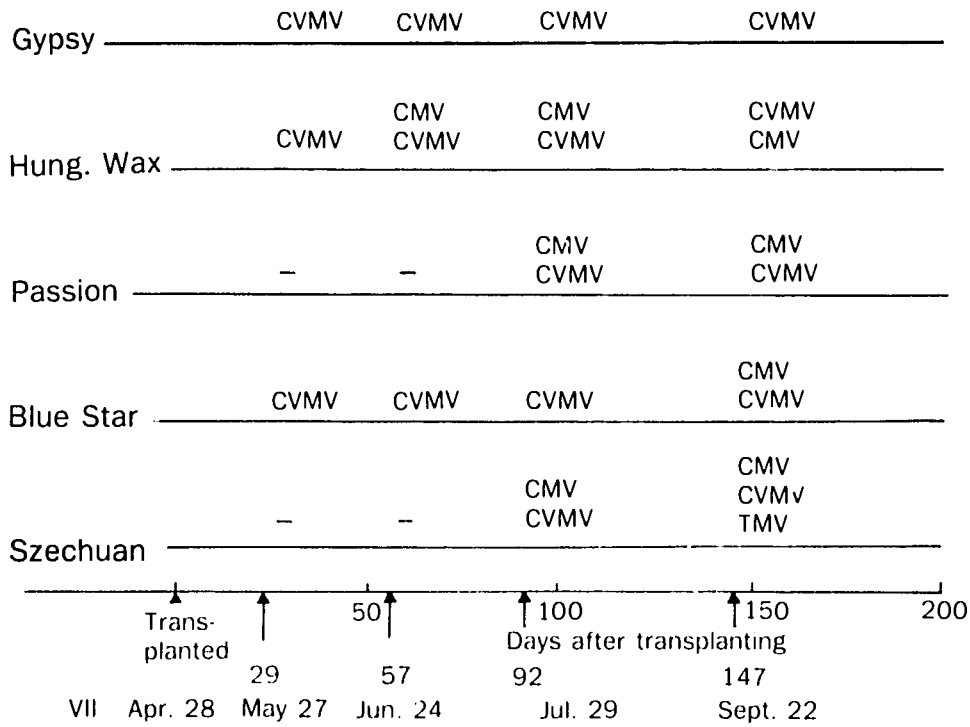


Fig. 1a. Virus detection in sequential pepper plantings at AVRDC.



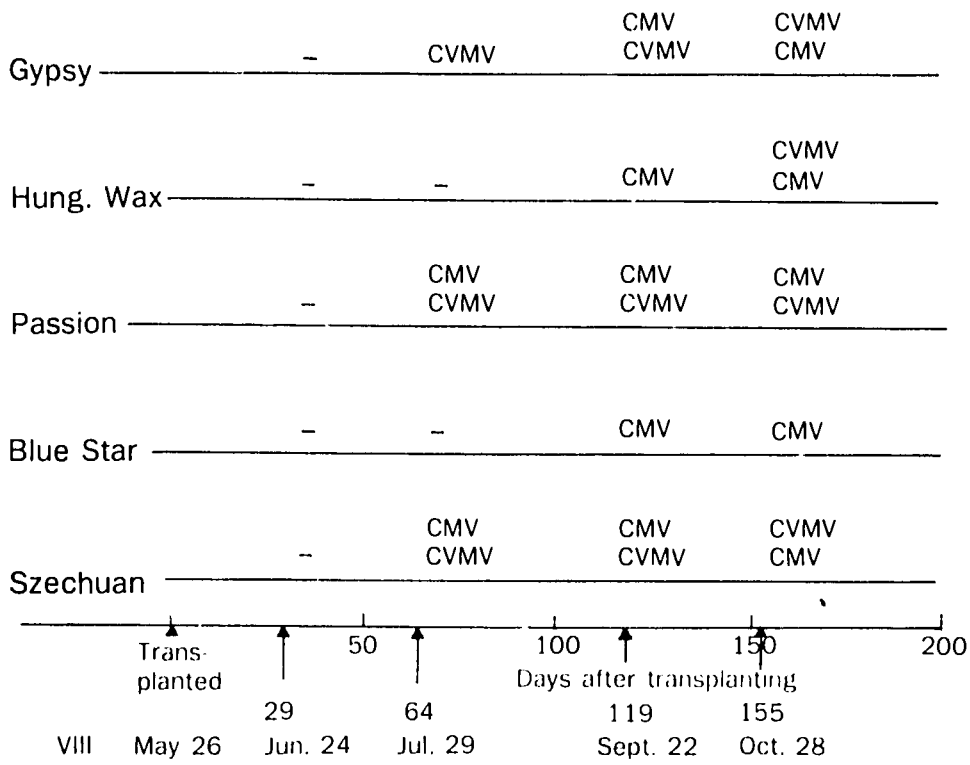


Fig. 1b. Virus detection in sequential pepper plantings at AVRDC (Cont'd).

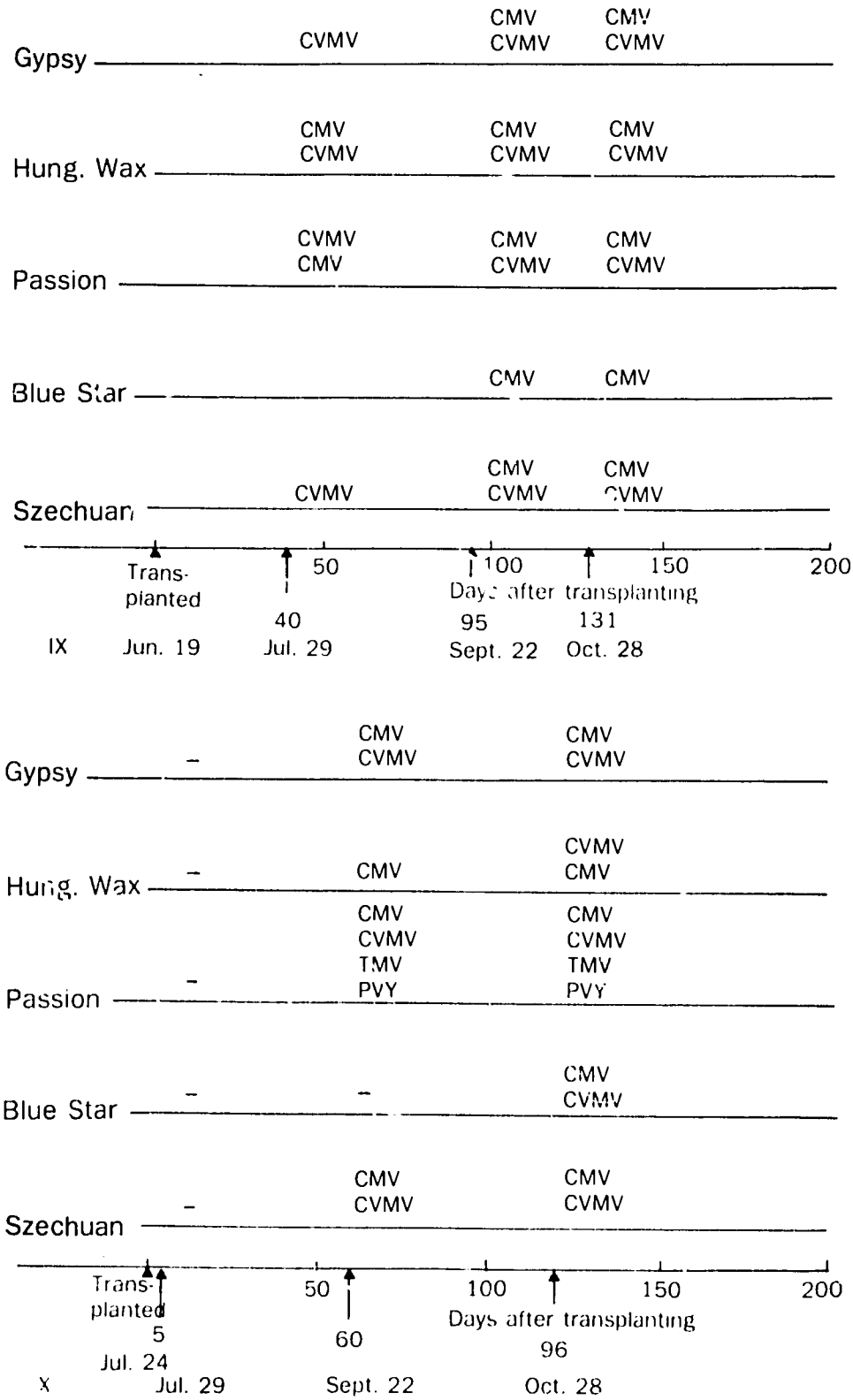


Fig. 1c. Virus detection in sequential pepper plantings at AVRDC (Cont'd).

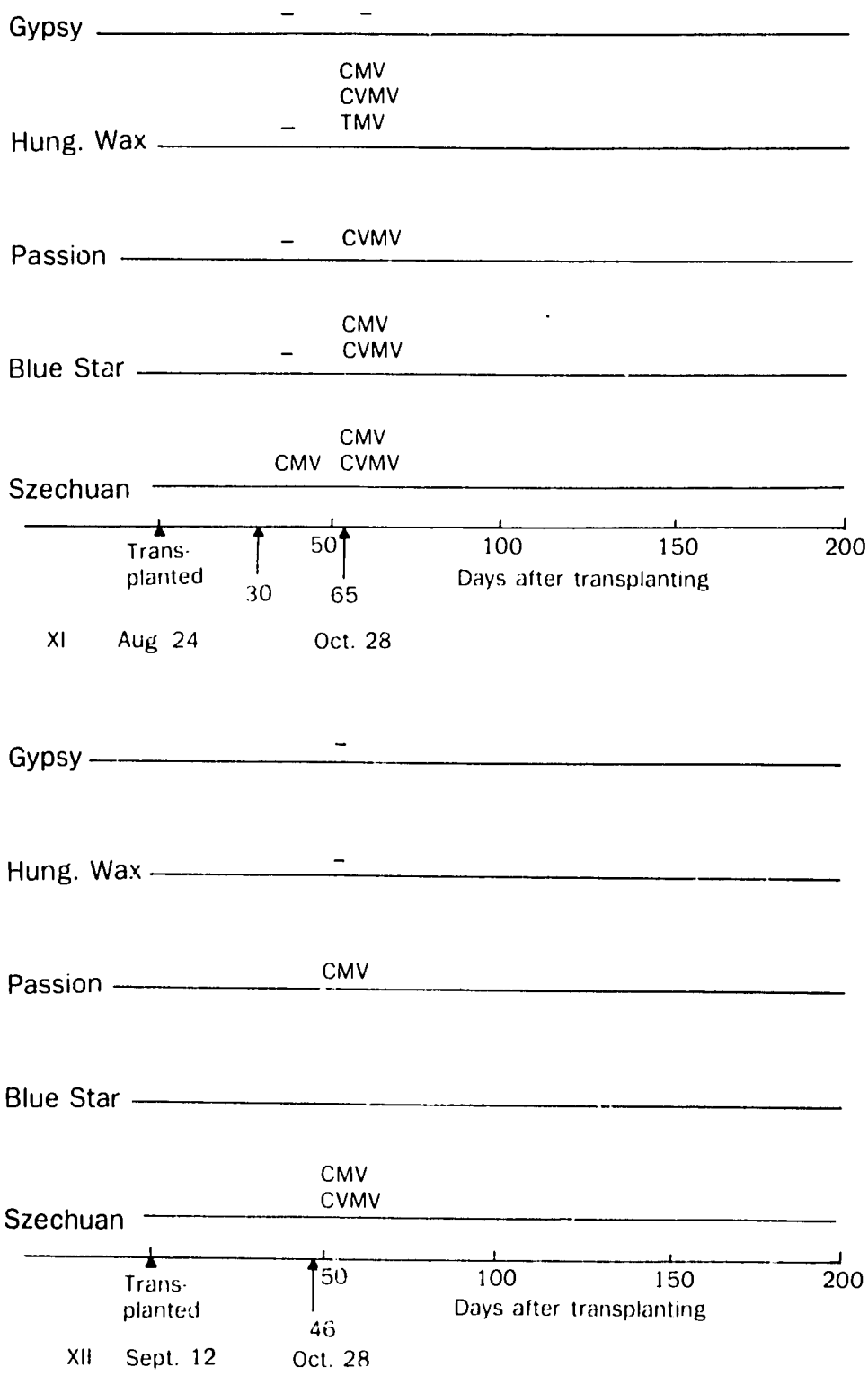


Fig. 1d. Virus detection in sequential pepper plantings at AVRDC (Cont'd).

probably takes place within 30 days after transplanting. It is, therefore, recommended to apply protective measures such as aphid repellants (reflective mulches or aluminum strips above the crop) during that time and possibly longer, up to 60 DAP.

Since three of the viruses are nonpersistently aphid-transmitted viruses, the use of insecticides to reduce the aphid population will have no effect on virus incidence.

Survey of Pepper Viruses in Asia — Virus Isolation and Strain Typing

Summary

A survey of pepper viruses was conducted in Taiwan and Thailand. A total of 1,037 leaf samples were collected from Taiwan and 139 from Thailand and tested by ELISA for the presence of 12 viruses (CMV, PVY, PeMV, PVMV, CVMV, TEV, TMV, PVY, TSWV, AMV, TBRV and TRSV). Only four viruses, CVMV, CMV PVY and TMV, were detected. Pure isolates of each virus have been recovered. Preliminary strain typing indicated that PVY-0 and TMV-0, TMV-1, TMV 1.2 are present in Taiwan.

Introduction

Virus diseases are among the major limiting factors of successful pepper cultivation in the tropics and subtropics. An extensive review of the literature indicated that CMV, PVY, TEV, PeMV and TMV are the most important viruses worldwide in terms of incidence. Other viruses, such as TSWV, AMV, PVMV (pepper veinal mottle virus) and CVMV, are only of regional importance. CVMV has so far only been reported in Malaysia. From Taiwan, so far PVX (potato virus X), PeMV and TMV were reported[1]. The objective of this survey was to determine which viruses occur on peppers in Taiwan and the other Asian countries, and to isolate the most important viruses for use in AVRDC's resistance screening program.

Materials and Methods

A total of 1,037 leaf samples of sweet and hot peppers were collected from 15 September 1986 to 21 October 1987 in some of the major pepper-growing areas of Taiwan and Thailand. The samples were homogenized in extraction buffer and tested by DAS-ELISA for the presence of 12 of the most common pepper viruses: CMV, PVY, PeMV, PVMV, CVMV, TEV, TMV, PVX, TSWV, AMV, TBRV (tomato black ring virus) and TRSV (tomato ring spot virus). Coating immunoglobulins were used at dilutions of 1:500 (AMV, CMV, PeMV, TEV, TBRV, TRSV), 1:1000 (CVMV, PVMV, PVY, PVX, TSWV) or 1:1500 (TMV). The concentrations of the enzyme conjugates were 1:500 for AMV, CMV, PeMV, TEV, TBRV, TRSV; 1:1000 for PVMV, PVX, TSWV; 1:2000 for CVMV, PVY; and 1:1500 for TMV. The major viruses of Taiwan were isolated by inoculation of differential hosts and subsequent single lesion isolation on the appropriate local lesion hosts. Antisera to TMV, PVY, CMV and AMV have also been prepared at AVRDC.

Results

The results of the survey are shown in Table 12.

Four of the viruses, namely, CMV, PVY, TMV and CVMV were detected in samples from Taiwan and Thailand. CVMV appeared to be the most important virus in Taiwan, in terms of incidence, followed by CMV and PVY.

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[1]Chen, Tsang-hai and Y.T. Lu. 1982. Studies on three elongated viruses affecting pepper (*Capsicum annuum* L.) in Taiwan. MS Thesis. National Chung Hsing University, Taichung, Taiwan.

Table 12. Survey of pepper viruses in Taiwan and Thailand.

	Total no.	CMV	PVY	TMV	CVMV	PVMV	PeMV	TEV	PVX	AMV	TSWV	TBR	TRSV
Thailand survey													
Kampangsan	64	16	15	4	5	0	0	0	0	0	0	0	0
Chiang Mai	75	8	16	2	3	0	0	0	0	0	0	0	0
Total	139	24	31	6	8								
		(17%)	(22%)	(4%)	(6%)								
Taiwan survey													
North	59	10	6	10	13	0/30	0	0	NT	0/30	0/29	0	0
Central	184	40	18	6	88	0/57	0	0	NT	0/114	0/52	0	0
South + Penghu	576	110	109	73	135	0/81	0	0/527	NT	0	0/242	0/130	0/31
East	218	68	62	15	77	0/129	0	0	NT	0/138	0/89	0/9	0/9
Total	1037	228	195	104	313								
		(22%)	(19%)	(10%)	(30%)								

In Thailand PVY and CMV were most frequently detected, followed by CVMV. It is, thus, obvious that CVMV is not confined to Malaysia alone, but occurs in other regions of Asia as well. It is recommended that the pepper virus resistance project at AVRDC focus initially on these four viruses.

Pure virus isolation was difficult because the plants collected from the field were generally infected simultaneously with several viruses. Only 12 pure isolates of CMV and 21 of CVMV were recovered (through three successive single local lesion transfers on *N. tabacum* 'White Burley'). Thirty pure isolates of PVY and 21 pure isolates of TMV were obtained. Strain typing of the PVY and TMV isolates is in progress. The three isolates of PVY strain typed so far are PVY-0. Preliminary strain typing of TMV indicated that most of the isolates are TMV-0.

Pepper Physiology

Water Uptake, Growth and Fruit Set of Peppers

Summary

Preliminary studies on hot and sweet peppers under greenhouse conditions revealed that both peppers consumed more than 70 liters of water throughout the 120-day growing period, and carried certain levels of heat tolerance in terms of fruit setting. A larger proportion of dry matter was diverted to the stem of hot pepper, which had high dry matter production; the leaf and stem had high nitrogen content.

Introduction

Water use and productivity are intimately linked together, since both are dependent upon the amount of radiant energy and the ambient temperature, and influenced by plant and other environmental factors that control gaseous transfer between plants and the atmosphere. Not much is known about water uptake or water requirement of sweet and hot peppers as related to growth and yield under different temperature conditions. The polyvinyl formate (PVF) system offers the opportunity for studying the growth of peppers as related to water uptake. Three plantings of hot and sweet peppers were conducted in February, July and November 1987. Since both July and November experiments are still in progress, the present preliminary report describes only the February planting experiment.

Materials and Method

Seedlings of sweet pepper (Blue Star) and hot pepper (Szechuan) were transplanted to wooden boxes underlaid with PVF strip as a water carrier on 27 March 1987. The plants were grown in the greenhouse and water uptake was recorded daily. Four plants, randomly sampled from three replicates 30, 60, 90 and 120 days after transplanting, were measured for dry matter production, leaf area, flower and fruit number and yield.

Results and Discussion

There was no difference between the two peppers in leaf area accumulation during 120 days of growing in the PVF set up under greenhouse conditions. However, hot pepper had higher photosynthetic potential, as indicated by higher net assimilation rate, than sweet pepper at a later growth stage (Fig. 1), which resulted in higher dry matter production (Fig. 2). Hot pepper had higher leaf transpiration per unit leaf area and water use efficiency than sweet pepper (Fig. 3); thus more water, about 85 liters/plant, were consumed by hot pepper during the whole growing period (Table 1).

Both hot and sweet peppers started to set fruit at 30 days after transplanting (Table 1). They produced a large amount of flowers, a total of 296 and 103 flowers for hot and sweet peppers, respectively, but only few set fruits (Table 1). Interestingly, when plants were grown under high temperature conditions, i.e. 34°-36°C/23°-26°C (mean month max/min), in the greenhouse at later growth stage, they still produced fruits with fully mature seeds (Table 1). Results clearly indicate that both peppers possessed the ability to produce an abundant number of flowers, an indicator of heat tolerance, to compensate for poor fruit set under high temperature conditions.

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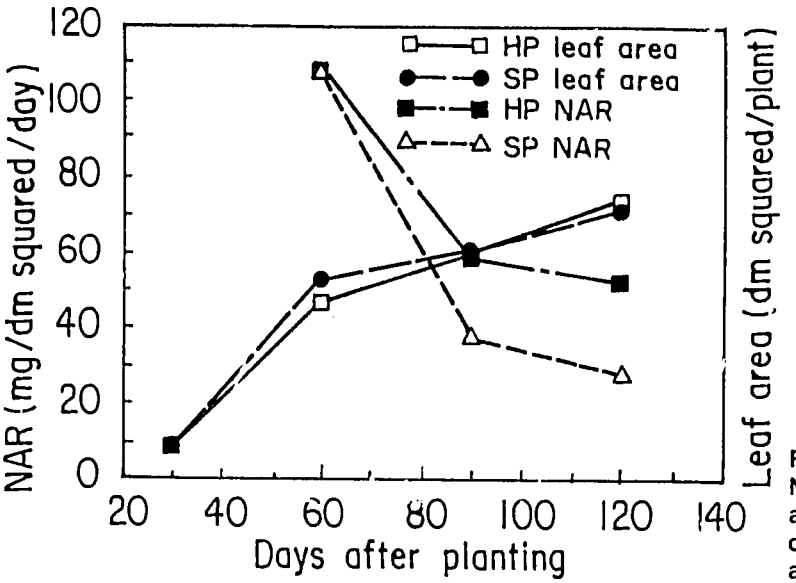

Fig. 1.
Net assimilation rate (NAR) and leaf area development of hot and sweet peppers at 30-day intervals.

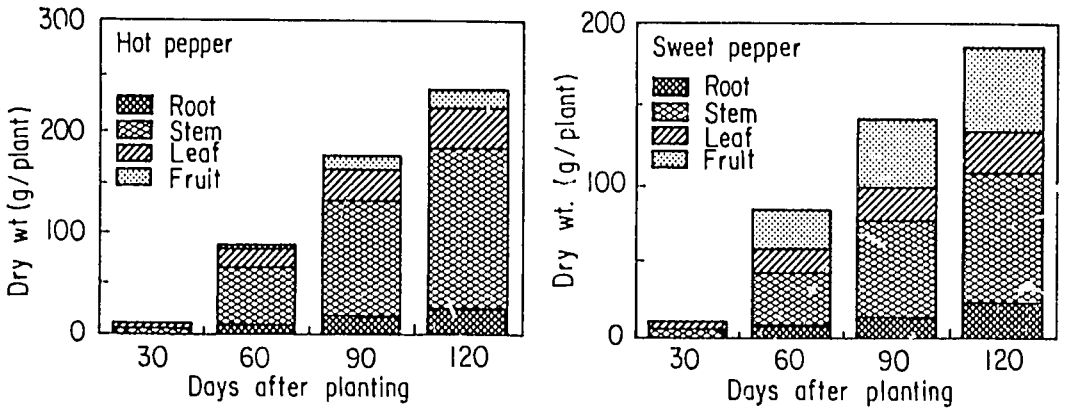

Fig. 2. Total dry matter production and dry matter partition of hot and sweet peppers at 30-day intervals.

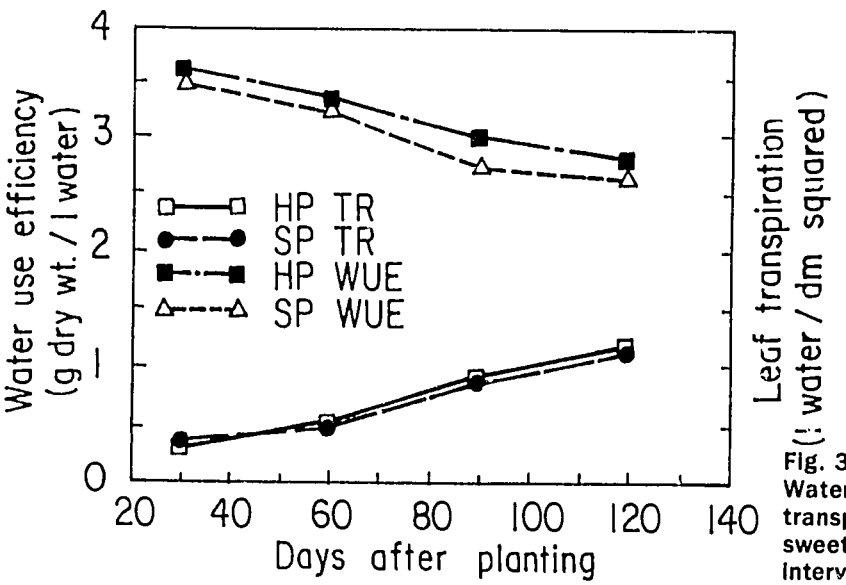

Fig. 3.
Water use efficiency and transpiration of hot and sweet peppers at 30-day intervals.

On the other hand, only few flowers set fruits at the first 30 days of growth under temperatures of 31.6/20.3°C (max/min). This could be due to too much fertilizer applied. The analysis of N, P and K in the leaf, stem and root (Table 2) revealed that much more K was accumulated in the stem, and more N and P accumulated in the leaf and stem of both peppers at 30 days after planting than during the later stages. The poor fruit-setting situation was later improved. Whether this high accumulation of N and K in the stem has any detrimental effect on the fruit set still deserves further studies. However, hot pepper accumulated more N and less K in the leaf and stem, which may explain why a larger proportion of dry matter was accumulated in the leaf and stem of hot pepper, even with more dry matter production (Fig. 2).

Table 1. Fruit yield, yield components, seed number and water consumption of hot and sweet peppers grown under greenhouse conditions.

Stage	Pepper	Fruit yield (g/plant)	Fruit size (g/fruit)	Fruit no. /plant	Seed no. (/fruit)	Water use (l/plant)
30 DAT[z]	Hot	0	–	0.0	–	3.0
	Sweet	1	–	0.1	–	2.8
60 DAT	Hot	67**[y]	3.4*	19.4*	18*	26.7
	Sweet	367	39.1	9.6	70	27.0
90 DAT	Hot	88*	3.1**	28.7*	17*	58.4
	Sweet	555	56.5	9.9	82	53.6
120 DAT	Hot	123*	3.3**	39.8*	20*	85.3
	Sweet	636	55.5	14.9	90	72.9

[z]DAT = days after transplanting. [y]**, * = Significantly different between species at 1% and 5% levels, respectively.

Table 2. Contents of N, P and K (% dry weight) in different plant parts of hot and sweet peppers.

	Hot pepper			Sweet pepper		
	Leaf	Stem	Root	Leaf	Stem	Root
Nitrogen						
30 DAP	5.96 a[z]	3.97 a	2.77 a	5.75 a	3.71 a	3.27 a
60 DAP	4.63 b	1.39 b	1.58 c	3.95 b	0.99 b	2.44 b
120 DAP	2.88 c	0.88 c	1.81 b	2.92 c	0.74 bc	2.02 b
Phosphorus						
30 DAP	0.44 a	0.42 a	0.22 b	0.53 a	0.50 a	0.25 bc
60 DAP	0.19 b	0.16 b	0.15 b	0.29 b	0.19 b	0.38 a
120 DAP	0.16 bc	0.09 c	0.46 a	0.21 c	0.11 c	0.35 ab
Potassium						
30 DAP	6.10 a	8.74 a	4.37 a	6.82 ab	7.30 a	4.59 a
60 DAP	5.48 a	4.25 b	2.74 b	7.18 a	5.04 b	3.79 b
120 DAP	4.17 b	2.37 c	2.26 c	5.28 c	3.60 c	3.15 c

[z]Mean separation within column of specific nutrient by Duncan's multiple range test at 5% level.

Soybean Breeding

Hybridization

Summary

The modified backcrossing procedure of Fehr (1987)[1] was adopted to develop productive good quality vegetable soybeans. Specific crosses were made to combine narrow leaflet, high yield and resistance to soybean rust, downy mildew, stinkbug and defoliators. Crosses were also made to enhance the seed size and seed quality of improved AVRDC selections. Selections are being made for a desirable combination of traits from the inbred generations of the crosses. The inheritance of a few specific characters is being studied.

Introduction

Developing improved vegetable soybeans with high, acceptable pod yield combined with desirable horticultural characteristics is one of the key breeding objectives. In addition resistance to soybean rust, bacterial pustule, downy mildew, stinkbug and defoliator resistance need to be bred into the AVRDC materials.

Materials and Methods

The newly released vegetable soybean, Kaohsiung No.1 (AGS 292) was crossed with narrow leaflet AGS 129 using the modified backcrossing method (Fehr 1987). Tzurunoko, Ryokkoh and Vesoy No. 4 were used as different non-recurrent parents to accumulate the desirable characteristics from them to AGS 292. In another modified backcross, Ryokkoh, Vesoy No. 4 and HL76-56 were involved to improve the yield potential of Ryokkoh.

AGS 129 was crossed with PI 171444 to combine the stinkbug and defoliator resistance from the latter to the former.

PI 459025 was reported to have the best level of resistance to Taiwan races 80-2 and 72-1 of the soybean rust through a single dominant gene, Rpp4Rpp4 (Hartwig 1986)[2]. It is also resistant to downy mildew. AGS 129 was crossed with PI 459025 and the F_1 was backcrossed to AGS 129. The BC_1F_1's were evaluated in the greenhouse for soybean rust. Plants with narrow leaflets and rust reaction similar to PI 459025 were selected and backcrossed to AGS 129. BC_2F_1's were again inoculated with rust and selection was made to recover AGS 129 type with rust resistance similar to PI 459025. After four backcrosses the seeds of AGS 129 type with rust resistance were selfed.

To improve their seed size, the following newly released/developed AVRDC soybeans were crossed with AGS 292, a productive large-seeded selection: Tropical, AGS 313 (released as Tidar in Indonesia), AGS 129 (Kaohsiung No. 10), AGS 181, AGS 269 and G 9947-21-9.

In a cooperative project with the National Taiwan University, Taipei to study the inheritance of moisture imbibition of seeds, reciprocal crosses were made between PI 219653 (G 8748) and PI 79593

[1]Fehr, W.R. 1987. Breeding method for cultivar development. Pages 249-293. *In* Soybean: Improvement, Production and Uses, Second edition, J.R. Wilcox, ed. American Society of Agronomy. Series 16, Madison, Wisconsin, U.S.A.
[2]Hartwig, E.E. 1986. Identification of a fourth major gene conferring resistance to soybean rust. Crop Science 26(6):1135-1136.

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(G 760). These two accessions have distinct differences in their moisture imbibition pattern. Specific crosses were also made for genetic studies.

Results and Discussion

Among the 36 crosses made, 20 of them were either backcrosses or modified backcrosses. For vegetable soybeans seven modified backcross populations have been developed. After a generation of inbreeding, an additional backcrossing will be made prior to further inbreeding and selection.

AGS 129, PI 171444, their F_1's, BC_1F_1's and F_2's are ready for evaluation for both stinkbug and defoliator resistance.

Although PI 459025 appeared highly resistant, tan type lesions were observed on it when evaluated along with BC_2, BC_3 and BC_4 generations. However, differences in the rate of disease development could be observed between PI 459025 and AGS 129 or TK 5. Seeds from different levels of backcrossing are currently undergoing evaluation in the field for rust and downy mildew resistance and yield.

Evaluation of Introductions

Summary

New germplasm and improved varieties are introduced and evaluated for additional useful genes for the breeding program. Of the 175 new accessions from five countries, sufficient seeds for 110 introductions were evaluated in three different trials. None of the entries were better in yield compared to the AVRDC checks. Seven entries were selected for their better seed quality and soybean rust resistance/tolerance which however need to be confirmed in further trials.

Introduction

Soybean germplasm indigenous in specific countries may contain valuable genes for the development of improved tropical soybeans. A number of the tropical and temperate countries have developed improved soybean varieties which would be useful for AVRDC's clientele. Therefore, continuous assembly and collection of germplasm from various sources is important to strengthen its breeding program. The germplasm received were evaluated for agronomic traits. Since only small quantities of seeds were received, they were first evaluated in small plots in an observational trial. After the seeds were multiplied, the promising ones were evaluated in progressively larger plots in a yield trial and preliminary yield trial.

Materials and Methods

In 1987, a total of 175 accessions from five countries were received. Three yield trials were conducted in the spring (February planting), summer (July planting) and autumn (September planting) seasons. The entries included in the three trials differed depending on the quantity of available seeds. The number of entries, plot size and other details for spring planting are given in Table 1. AGS 129 and AGS 302 were used as checks for comparison.

Table 1. Experimental details on the evaluation of new introductions.

Experiment	No. of entries	Plot size (m)	Design	Replications	Date
Observational trial (OT)	40	1 × 0.5	RCBD[z]	2	13 Feb. 1987
Yield trial (YT)	21	4 × 1.0	RCBD	2	6 Feb. 1987
Preliminary yield trial (PYT)	49	3 × 2.0	LATTICE[y]	2	6 Feb. 1987

[z]RCBD = Randomized complete block design; [y]LATTICE = Lattice design.

Results and Discussion

In all the three trials, none of the introductions was higher yielding than either of the checks. The yield of the entries in the observational trial was relatively higher and the CV larger compared to that of the yield trial and preliminary yield trial, as shown by yields of the two check varieties in three trials (Table 2). Therefore, as plot size increased, yield and CV for all entries decreased. However, caution should be exercised in making selection for yield in observational trials.

The late flowering gene has been reported by Kiihl et al. (1985)[3] as useful for developing tropical soybeans. AGS 129 and AGS 302 flowered in 45 and 41 days, respectively. A large number of introductions were significantly later flowering than the check varieties; however, their yields were significantly lower than the checks. Therefore, it appears that late flowering did not contribute to higher yield. The phenotypic correlation between days to flowering and yield is insignificant (-0.1372) which supports this conclusion. From preliminary observations, the entries shown in Table 3 appear to have some desirable seed quality and soybean rust resistance, which need to be confirmed from additional trials.

Table 2. Comparison of yield and CV between different trials with different plot sizes.

Plot size (m)	Yield (kg/ha)		CV (%)
	AGS 129	AGS 302	
1 × 0.5	8,400	5,133	30
4 × 1	4,588	3,681	12
3 × 2	4,250	3,609	20

Table 3. Introductions with desirable traits, spring 1987.

Entry name or number	Origin	Yield (t/ha)	Days to maturity	Seed quality	Rust (%)
UFV-2	Brazil	6.0[z]	123	3	23
Uniao	Brazil	5.1[z]	104	3	27
FT-5	Brazil	3.8[y]	111	2	30
PI 399045	Korea	4.0[x]	98	2	–
PI 417569	Japan	4.0[x]	100	3	–
PI 417563	Japan	3.8[x]	99	2	–
PI 399044	Korea	3.7	98	2	–
AGS 129	AVRDC	8.4[z]	105	3	40
		4.6[y]	107	3	60
		4.2[x]	101	3	–
AGS 302	AVRDC	5.1[z]	104	3	47
		3.7[y]	110	3	50
		3.6[x]	100	3	–

[z]OT: The differences in yield between AGS 129 and the others were significant at 5%. [y]YT: The differences in yield between the check and the others were insignificant. [x]PYT: The differences in yield between the check and the others were insignificant.

Yield Trials

Summary

Selected pedigrees were evaluated at various stages for their yield potential combined with disease resistance, seed quality, maturity duration and other desirable agronomic characteristics. Genotypes, such as GC 82341-7-2, GC 81038-18-3, GC 81075-36, PI 379618, GC 81075-16, GC 81080-13 and AGS 269 had either similar or higher yield potential in the spring and/or summer seasons and a better level of bacterial pustule and downy mildew resistance than AGS 129 (check). Although

[3]Kiihl, R.A.S., L.A. Almeida and A.D. Agnol. 1985. Strategies for cultivar development in the tropics. Pages 301-304. *In* Richard Shibles, ed. World Soybean Research Conference III. WestView Press, Boulder, U.S.A.

genotype × environmental interaction was predominant, multilocational yield trials were still carried out to find genotypes that have wide adaptability.

Introduction

Selected breeding lines were evaluated at various stages for their yield potential. Preliminary (PYT) and intermediate yield trials (IYT) were conducted in three seasons to compare these lines with improved checks so that high-yielding, agronomically desirable genotypes can be selected.

Materials and Methods

Details of the trials are given in Table 4. The plot size for both PYT and IYT was 3 m × 2 m. Data on yield and other agronomic traits were collected and analyzed. Selection of genotypes was based on yield, resistance or tolerance to diseases, days to maturity, seed quality and adaptation to specific or multiple seasons.

Results and Discussion

Although high yield potential was one of the criteria for selection, the objectives in both PYT and IYT were to identify genotypes which have yields similar to or higher than AGS 129, combined with resistance to both bacterial pustule and downy mildew and good seed quality. AGS 129 lacked downy mildew resistance.

In both PYT and IYT, a number of genotypes were selected using the above criteria (Tables 5, 6, 7, 8, 9 and 10). Although the combined analyses for three seasons have not been completed, as in the past, genotype × season interaction was expected to be significant. Since the yield trials were conducted at one location (AVRDC) for three seasons, the response of genotypes to specific season and the genotype × season interaction could be estimated. Season specific genotypes and genotypes adapted to multiple seasons could be selected. However, selection for wide adaptability was restricted.

Table 4. Planting dates and experimental designs for PYT and IYT in 1987.

Experiment	No. of entries plus (checks)	Design (replication)	Date of planting
PYT-1	79 (2)	9 × 9 Lattice (2)	6 February 1987
PYT-2	47 (2)	7 × 7 Lattice (2)	6 February 1987
IYT-1	19 (2)	RCBD (2)	20 January 1987
IYT-2	23 (2)	RCBD (2)	20 January 1987

Table 5. Selected genotypes with desirable traits in PYT-1, spring and summer 1987.

Cross no. or variety name	Yield (t/ha)		Days to maturity		100-seed wt.(g)		BP[y]
	Spring	Summer	Spring	Summer	Spring	Summer	
GC 82341-7-2	5.1 a[z]	3.1 a-h	112 a-c	102 b-e	21	16	R
GC 81038-18-3	5.0 ab	2.7 b-k	115 a	102 b-e	17	11	R
GC 82344-29-2	4.5 a-d	3.4 a-c	110 a-g	102 b-e	23	19	MR
GC 83011-18-1	4.4 a-f	2.8 a-j	111 a-f	102 b-e	33	22	MR
GC 82362-47-1	4.4 a-g	2.8 a-j	105 m-s	103 b-d	27	25	MR
GC 82350-18-2	4.2 a-i	3.6 a	110 a-g	98 e-h	19	16	MR
GC 81118-26-8	4.1 a-j	3.5 a	105 m-s	98 e-h	16	14	MR
GC 82345-26-3	3.5 d-j	2.9 a-j	97 t-u	98 e-h	19	17	R
GC 81055-7-1	3.5 d-j	2.6 d-l	98 q-u	100 d-e	18	16	R
GC 81029-16-1	3.6 d-j	3.5 ab	101 k-u	99 d-e	16	14	MR
AGS 302 (check)	3.5 d-j	1.6 mn	102 h-u	103 b-d	22	23	MR
AGS 129 (check)	4.0 b-j	3.5 a	104 c-s	100 d-e	19	18	R

[z]Values followed by the same letter within the column are not significantly different at 5% level according to DMRT.
[y]Data from summer season for bacterial pustule; R = resistant, MR = moderately resistant, S = susceptible.

Table 6. Genotypes selected for high yield in PYT-2, spring 1987.

Name of variety or number	Origin	Yield (t/ha)		Days to maturity		BP[y]
		Spring	Summer	Spring	Summer	
GC 81075-36	AVRDC	5.3 a[z]	2.8 b-h	101	94	MR
311-14D	Philippines	4.6 abc	3.1 ab	106	98	R
Khsb-2	India	4.4 a-d	3.1 a-c	130	105	R
Gaurav	India	4.4 a-d	3.5 a	109	107	MR
Durga	India	4.1 a-f	2.9 b-f	119	102	R
AGS 302 (check)	AVRDC	4.3 a-e	1.1 m	106	104	S
AGS 129 (check)	AVRDC	5.2 ab	3.0 b-d	100	99	R

[z]Values followed by the same letter within the column are not significantly different at 5% level according to DMRT. [y]Data for bacterial pustule; MR = moderately resistant, R = resistant, S = susceptible.

Table 7. Highest yielding selections in IYT-1, spring 1987.

Entry name or cross number	Yield (t/ha)	Days to		Seed quality	Downy mildew	BP[w]
		Flowering	Maturing			
PI 379618	4.8 a[z]	65 a	125 a	2	NSy	R
GC 00062-31	4.3 ab	62 b	108 ef	1	NS	R
GC 00097-56-6	4.3 ab	62 b	114 bc	1	NS	R
GC 81075-10	4.2	57 e	114 bc	2	NS	R
AGS 129 (check)	4.0 cb	55 f	112 cd	1	MSx	R
AGS 302 (check)	3.8 cbde	51 g	114 bc	1	NS	R

[z]Values followed by the same letter are not significantly different at 5% level according to DMRT. [y]NS = no symptom; [x]MS = moderately susceptible; [w]Data for bacterial pustule: R = resistant.

Table 8. Selections from IYT-2 based on desirable agronomic traits, spring 1987.

Cross no.	Yield (t/ha)	Days to		100-seed wt. (g)	Seed quality	Downy mildew	BP[w]
		Flowering	maturity				
GC 81075-16	4.2 ab[z]	57	117	18	2	NS[y]	R
GC 00131-99-6	4.1 ab	61	117	10	2	NS	R
GC 81090-48	3.9 abc	56	117	21	2	NS	R
GC 81078-12	3.7 a-d	54	117	28	2	NS	MR
GC 81079-12	3.8 abc	56	110	20	2	NS	R
AGS 129 (check)	4.1 ab	54	113	17	1	MS[x]	R
AGS 302 (check)	3.4 a-e	51	113	23	1	NS	MR

[z]Values followed by the same letter are not significantly different at 5% level according to DMRT. [y]NS = no symptom; [x]MS = moderately susceptible; [w]Data for bacterial pustule; R = resistant, MR = moderately resistant.

Table 9. Selections from IYT-1, summer 1987.

Cross no.	Yield (t/ha)	Days to maturity	100-seed wt.(g)	Seed quality	BP[y]	Downy mildew
GC 81077-14	2.4 a	96	17	2.0[z]	R	MS[x]
GC 81080-13	2.2 ab	92	21	2.5	R	NS[w]
GC 81084-51	2.1 abc	93	17	2.0	R	NS
GC 00062-107-6	1.9 a-f	105	13	3.0	R	NS
AGS 129	2.2 ab	94	15	2.0	R	MS

[z]Seed quality rated: 1 = best and 5 = poor; [y]Data for bacterial pustule, R = resistant; [x]MS = moderately susceptible; [w]NS = no symptom.

Table 10. Selections from IYT-2, summer 1987.

Entry name or cross no.	Yield (t/ha)	Days to maturity	100-seed wt.(g)	Seed quality	BP[z]	Downy[y] mildew
269	2.1 a-c	92	16	2	R	NS
GC 81079-12	2.1 a-d	98	18	2	R	NS
GC 81083-42	2.1 a-d	97	14	2	R	S
GC 81090-8	1.9 a-d	96	16	2	R	NS
AGS 129 (check)	2.3 a	93	15	2	R	MS
AGS 302 (check)	1.4 e	99	21	2	MS	NS

[z]Data for bacterial pustule, R = resistant, MS = moderately resistant. [y]NS = no symptom, S = susceptible, MS = moderately susceptible.

To effectively select for wide adaptability, there is a need to have multilocation yield tests in addition to multiseason testing to account for diversity in soil, biotic and micro environments.

Breeding for Soybean Rust Tolerance

Summary

Soybean rust is an important yield-limiting constraint for soybean production in the tropics and subtropics in Asia. Significant genotype × fungicide interaction was observed in the yield trials. Genotypes AGS 302, SRE-D-14A and GC 00138-29 had higher yield potential with lower rust tolerance level. SRE-C-56A and SRE-D-14B had a high level of rust tolerance but they had relatively low yield potential. Crosses between the former and the latter groups are proposed to combine high yield and a high level of rust tolerance. The correlation between percent rust infection and yield was highly significant. In the two yield trials, 52% and 69% of the yield loss are attributable to reduction in 100-seed weight. The importance of evaluating and incorporating good seed quality along with high yield potential and rust resistance is emphasized.

Introduction

Since the inception of AVRDC, soybean rust caused by *Phakopsora pachyrhizi* Syd. has been recognized as one of the major constraints in profitable soybean production in tropical and subtropical countries in Asia. Breeding for soybean rust resistance had been going on for years in Taiwan, India, Australia, the Philippines, Thailand and the U.S.A. Resistant varieties have been developed but due to the rapid development of new races of the pathogen, which overcame vertical resistance, resistance has been short lived, at least in Taiwan. Previous studies showed that soybean genotypes PI 200492, PI 230971, PI 462312 and PI 459025 each carried a single dominant gene conferring resistance to a specific soybean rust isolate (Hartwig 1986). Since the resistance to rust appears to be easily overcome by compatible virulent isolates of the pathogen, breeding focus at AVRDC has been shifted to soybean rust tolerance.

Materials and Methods

Since 1974 a number of crosses were made to combine vertical resistance to soybean rust, high yield and early maturity. Due to lack of an appropriate screening technique and instability of vertical resistance, the program could not develop any rust-resistant genotypes. However, the rust tolerance approach was recognized in 1980 as a potential avenue to combat the problem. A number of selections were made under heavy soybean rust disease pressure. They were evaluated with and without fungicide protection.

Advanced yield trials of selected genotypes were conducted with and without fungicide protection in a split-plot design. The advanced yield trial was planted on 20 January 1987. The unprotected plots were inoculated with rust suspension on 13, 19, 27 March and 10 April 1987 while the fungicide-treated plots were sprayed with Dithane M-45 on 3 and 31 March and 3 April; they were sprayed

with Bayleton on 17 and 24 April. Selection criteria used were: early maturity, high yield, tolerance to rust and the seed fill of the pod. Soybean rust infection was rated at R_6 growth stage. The trials were conducted in the spring and autumn seasons but only data from the advanced yield trials (AYT) in spring 1987 are presented.

Results and Discussion

The analyses of variance of yield in AYT-1 and AYT-2 are presented in Tables 11 and 12, respectively. Significant differences between fungicide treatments and genotypes were observed. There was also significant interaction between fungicide treatment and genotypes (Figs. 1 and 2). Variation between fungicide-protected and unprotected treatments within the genotype was considerably large compared to the variation between genotypes within the fungicide-protected treatment.

AGS 302, G 9947-21-9 and AGS 181 had the lowest yield loss due to rust (Fig. 1). Among these three genotypes, only AGS 181 had one parent with a single gene resistance (PI 230971). Both the parents of AGS 302 were less sensitive to photoperiod and moderately resistant to bacterial pustule.

By evaluating the fixed inbred lines at various stages with and without fungicide protection, a high level of tolerance to rust had been developed in SRE-C-56A and SRE-D-14B. However, they were relatively low yielders under the fungicide-protected treatment (Fig. 2).

Although the tolerance levels of AGS 302, SRE-D-14A and GC 00138-29 were lower, their genetic yield potentials were higher than AGS 181, SRE-C-56A and SRE-D-14B. To combine the higher level of tolerance and higher yield potential, it is logical to cross SRE-D-14A with AGS 302.

Selection for high yield potential using a reference tolerance genotype, such as AGS 302 or SRE-D-14A, would enable the identification of genotypes with higher yield potential and level of tolerance (Figs. 1 and 2). Therefore, future selections should use this strategy.

Soybean rust-infection in the rust inoculated, nonfungicide-treated plot ranged from 15% to 41% in AYT-1 and 17% to 45% in AYT-2. The major objective in selecting a genotype is to look for high-yielding materials. High yield with low rust infection is preferable, although high yield either with high or moderate level of rust infection (tolerance) is already desirable.

The correlation between percent rust infection and grain yield was highly significant (r^2 = 0.4467 for AYT-1 and 0.5848 for AYT-2). Genotypes which were susceptible, such as GC 82200-7-12-19 in AYT-1 with only 30% rust, yielded less than 1,148 kg/ha (Fig. 3, entry 11) while AGS 129 with 33% rust infection yielded 1,760 kg/ha (Fig. 3 entry 12). Similarly in AYT-2, GC 00051-7-2 yielded only 992 kg/ha when it had 44% rust infection (Fig. 4 entry 4). But with 36% rust, SRE-B-15C was able to produce 2,038 kg/ha (Fig. 4 entry 9). SRE-D-14A and AGS 302, both with 28% rust infection yielded more than 2,200 kg/ha (Fig. 4, entries 11 and 14, respectively).

Table 11. Analysis of variance of yield in AYT-1, spring 1987.

Source of variation	DF	SS ($.10^{-6}$)	MS ($.10^{-6}$)	PR >F
Fungicide (F)[z]	1	25.30	25.30	0.0019
Genotypes (G)	13	4.11	0.32	0.0001
F * G	13	2.33	0.18	0.0001

[z]MS for F * G was used as the error term.

Table 12. Analysis of variance of yield in AYT-2, spring 1987.

Source of variance	DF	SS ($.10^{-6}$)	MS ($.10^{-6}$)	PR >F
Fungicide (F)[z]	1	30.25	30.25	0.0025
Genotypes (G)	3	5.74	4.10	0.0001
F * G	14	10.47	0.75	0.0001

[z]MS for F * G was used as the error term.

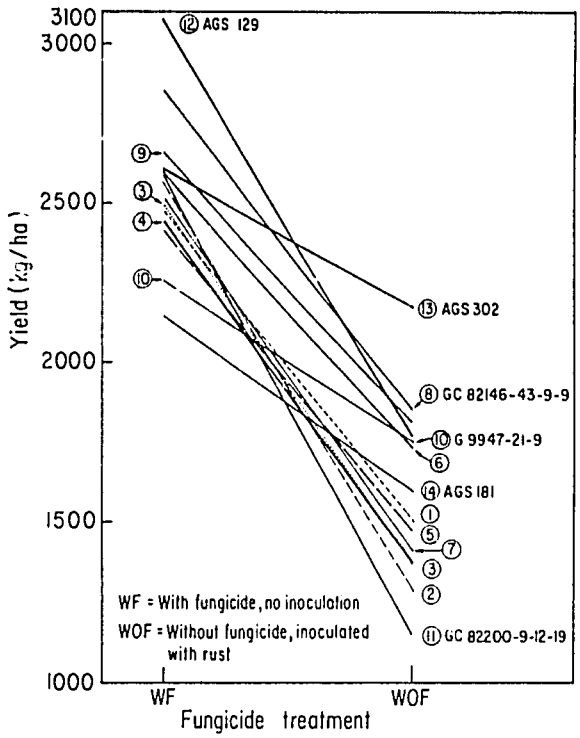

Fig. 1.
Yield differences between genotypes with and without fungicide treatment in AYT-1, spring 1987.

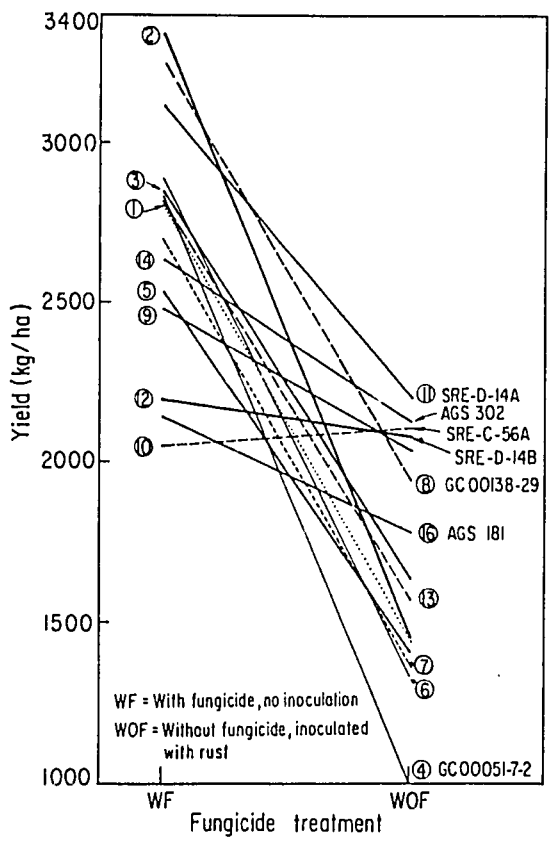

Fig. 2.
Yield differences between genotypes with and without fungicide treatment in AYT-2, spring 1987.

Soybean rust is known to influence the three major yield components, namely, the number of pods per plant, seed number per pod and 100-seed weight. Since the 100-seed weight was significantly reduced in the nonfungicide treatment, yield loss was regressed on 100-seed weight reduction. In AYT-1 and AYT-2, 52% and 69% of the yield loss, respectively, can be explained by the reduction in 100-seed weight (Figs. 5 and 6). Therefore, while making selections in the nonfungicide treatment 100-seed weight should be given due consideration.

Seed Quality Evaluation. The results of the accelerated aging test conducted on the seeds from fungicide-treated plots showed that in AYT-1, AGS 129 had the highest germination (62%) after accelerated aging. However, the rust-tolerant AGS 302, AGS 181 and GC 82146-43-9-9 had only 4%, 11% and 0% germination, respectively. In AYT-2 AGS 129, GC 00002-100, GC 00070-110 and GC 90001-66 had 50% to 66% germination. All the rust-tolerant selections had less than 30% germination after the accelerated aging test. Therefore, in releasing AVRDC rust-tolerant genotypes to cooperators, it is important that the level of seed quality be specified. It is essential to combine good seed quality and rust tolerance. The need to use good seed quality genotype as a parent in rust resistance breeding and monitoring the seed quality at various stages of selection should be considered.

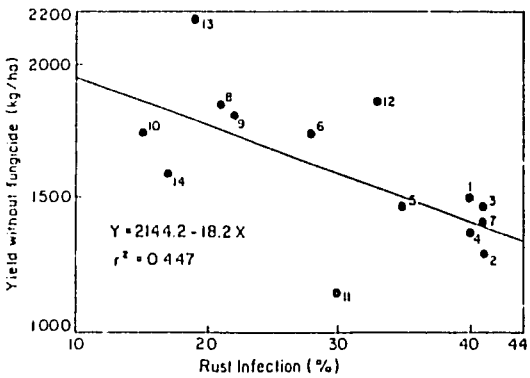

Fig. 3. Relationship between percentage of rust infection and yield without fungicide in AYT-1, spring 1987.

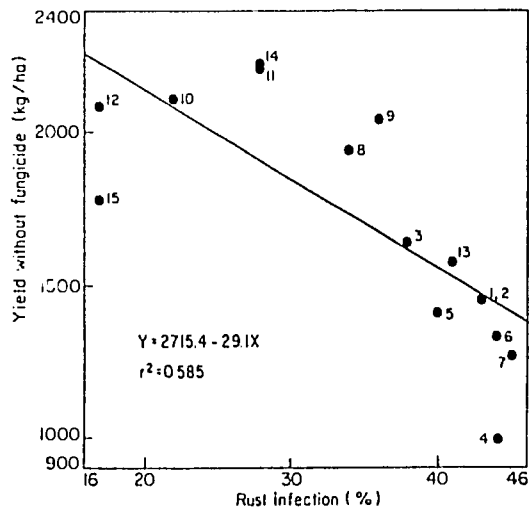

Fig. 4. Relationship between percentage of rust infection and yield without fungicides in AYT-2, spring 1987.

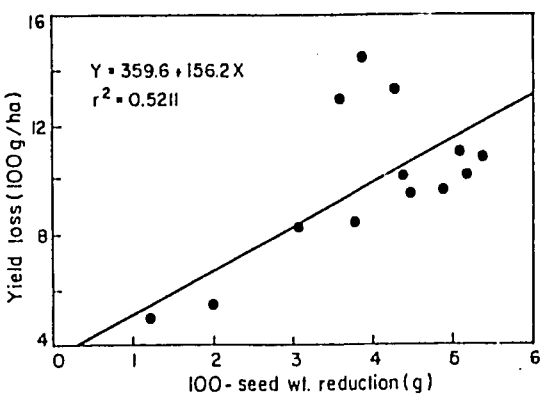

Fig. 5. Regression of yield loss due to rust on 100-seed weight reduction in AYT-1, spring 1987.

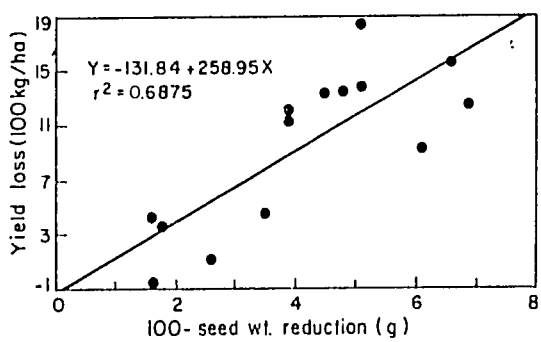

Fig. 6. Regression of yield loss on 100-seed weight reduction in AYT-2, spring 1987.

The characteristics of a few selected genotypes from AYT-1 and AYT-2 from the spring and summer seasons are given in Tables 13 and 14.

Table 13. Selected genotypes from AYT-1 and AYT-2 and their characteristics, spring 1987.

AVRDC cross no. or name	Parents	Yield (t/ha)		100-seed weight		Accelerated aging test[y]	BP[x]	DM[w]
		WF[z]	WOF[z]	WF	WOF	G %		
GC 00138-29	(CH #1 x Anoka) x (Clark 63 x 64-64)	3.3**[v]	1.9	18.5	14.0	38	R	NS
SRE-D-14A	G 5422 x G 4919	3.1**	2.2*	25.2	19.1	12	R	NS
SRE-C-56A	G 6154 x Shih Shih	2.0	2.1	24.4	22.8	26	R	NS
GC 82146-43-9-9	G 257 x AGS 157	2.8**	1.8**	18.8	14.4	0	MR	NS
GC 00002-100	Shih Shih x (CH #2 x Anoka)	3.3**	1.4	22.1	14.3	66	MR	NS
GC 00070-110	(KS 535 x KS 482) x (UPSL-85 x PI 230971)	2.8**	1.4	16.7	11.6	65	MR	NS

[z]WF: with fungicide; WOF = without fungicide. [y]Data from fungicide-treated plot for accelerated aging test of percent germination. [x]Data from summer season for bacterial pustule, R = resistant; MR = moderately resistant. [w]No symptom for downy mildew in spring and summer seasons. [v]Yields were significantly higher than the tolerant check, AGS181 at 5% (*) and 1% (**) level, respectively.

Table 14. Genotypes selected from AYT-1 and AYT-2, summer 1987.

Entry no. or name	Yield[z] (t/ha)	Days to maturity	Downy[y] mildew	Bacterial[x] pustule
G 9947-21-9	2.8 a	87	S	R
G 82146-43-9-11	2.4 abc	91	NS	R
SRE-C-56 A	2.7 a	99	–	–
SRE-B-15C	2.6 ab	93	NS	R
GC 82200-6-12-13	2.3 abc	94	NS	R
AGS 302	2.3 bcd	98	NS	S
AGS 129	2.6 ab	93	MS	R
AGS 181	2.3 bcd	113	NS	R

[z]Values followed by the same letter are not significantly different at 5% level according to DMRT. [y]S = susceptible, NS = no symptom. [x]R = resistant, S = susceptible.

Breeding for Bacterial Pustule Resistance

Summary

During the rainy season, bacterial pustule can cause yield reduction in soybean. A higher level of bacterial pustule resistance reported in AGS 129 and G 8190 relative to the known resistant cv. CNS needs to be better understood. Results showed that bacterial pustule disease initiated at R_4 to R_5 growth stage can cause more than 60% yield reduction in susceptible cv. Shih Shih compared to 12% in AGS 129, 1% in G 8190 and no yield loss in CNS. Such results suggest that the resistance of CNS is as good or better than AGS 129 and G 8190. The inheritance studies indicate that resistance to bacterial pustule is probably governed by a recessive gene as reported earlier. However, the major dominant gene governing the susceptibility to bacterial pustule is modified by other susceptible genes. Selected resistant F_2 pedigrees will be progeny-tested in F_3 to confirm their resistance. About 2.7% to 3% of the F_2's were resistant to bacterial pustule and have other desirable agronomic characters.

Introduction

Bacterial pustule is a serious disease of soybean, especially during the rainy season. It is caused by *Xanthomonas phaseoli* var. *sojensis* (Hedges) Starr and Burkh. Hartwig and Lehman (1951)[4] found that the resistance in the cv. CNS was governed by a single recessive gene (rxp). At AVRDC the resistance to bacterial pustule observed in AGS 129 and G 8190 (PI 371611) was reported to be better than that present in CNS. Therefore, CNS was rated as moderately resistant while AGS 129 was rated as resistant.

Selected high-yielding lines were used in crosses to incorporate bacterial pustule resistance. A systematic cross between resistant, moderately resistant and susceptible genotypes were made to study the inheritance of bacterial pustule resistance as well.

Materials and Methods

Ten AGS lines, which lack bacterial pustule resistance (AGS 8, 17, 29, 66, 85, 95, 121, 144, 157 and 162) were crossed with AGS 129. The F_2 progenies were planted on 8 July 1987. For every 10 beds (20 plant rows) one set of susceptible (Shih Shih), moderately resistant (CNS) or resistant (AGS 129 or G 8190) checks were planted for comparison. One-half of the population was inoculated with bacterial suspension on 17 August 1987 while the other half was left uninoculated. At maturity six randomly chosen plots of 10 m^2 area from both inoculated and uninoculated plots were harvested from those of AGS 129, Shih Shih, CNS and G 8190. The yield data obtained were compared to estimate the loss due to bacterial pustule. Six replications were used. A split-plot design was used in analyzing the data.

The parents (Shih Shih, AGS 129 and CNS), F_1, F_2 and backcrosses of the following were also planted on 8 July 1987: 1) AGS 129 × Shih Shih; 2) AGS 129 × CNS.

The field was inoculated with bacterial suspension on 17 August 1987. Four weeks after inoculation individual plants were rated for bacterial pustule as susceptible (similar to Shin Shih), moderately resistant (similar to CNS) and resistant (similar to AGS 129 or G 8190).

Pedigree selection was practiced to select bacterial pustule resistant genotypes, which have good agronomic characteristics in all the F_2 and BC_1 populations.

Results and Discussion

The inoculated part of the F_2 population had initial bacterial pustule symptoms on 24 August 1987. The symptoms became severe and by 20 September, the susceptible genotype, Shih Shih, was almost completely defoliated by the disease. The uninoculated half of the field did not have any symptom until mid-September. By that time, the susceptible variety was already in R_7 growth stage. In the inoculated field, symptoms appeared at R_5. As a result, seed filling was drastically affected in the inoculated field compared to the uninoculated field.

The yield loss due to bacterial pustule in Shih Shih was 64% compared to 12% in AGS 129, 1% in G 8190 and no yield loss in CNS (Fig. 7). It appeared that even though the foliar symptom due to bacterial pustule in CNS was slightly more than in AGS 129 and G 8190, based on yield loss, CNS appeared to be equal to or better than AGS 129 and G 8190, in spite of slight bacterial pustule disease.

In crossing resistant with susceptible parents, the F_1 was found to be susceptible and backcrosses to susceptibles produced all susceptible progenies. However, a backcross to the resistant progenies resulted in susceptible and moderately resistant progenies, in equal proportions, while the resistant segregates comprised one-fourth of the total. In the F_2 the segregation was close to nine moderately resistant, six susceptible and one resistant. As Hartwig and Lehman (1951) pointed out for CNS, it is likely that AGS 129 probably carried genes for susceptibility, which are probably hypostatic to the homozygous recessive genes for resistance.

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[4]Hartwig, E.E. and S.G. Lehman. 1951. Inheritance of resistance to the bacterial pustule disease in soybeans. Agron. J. 43: 226-229.

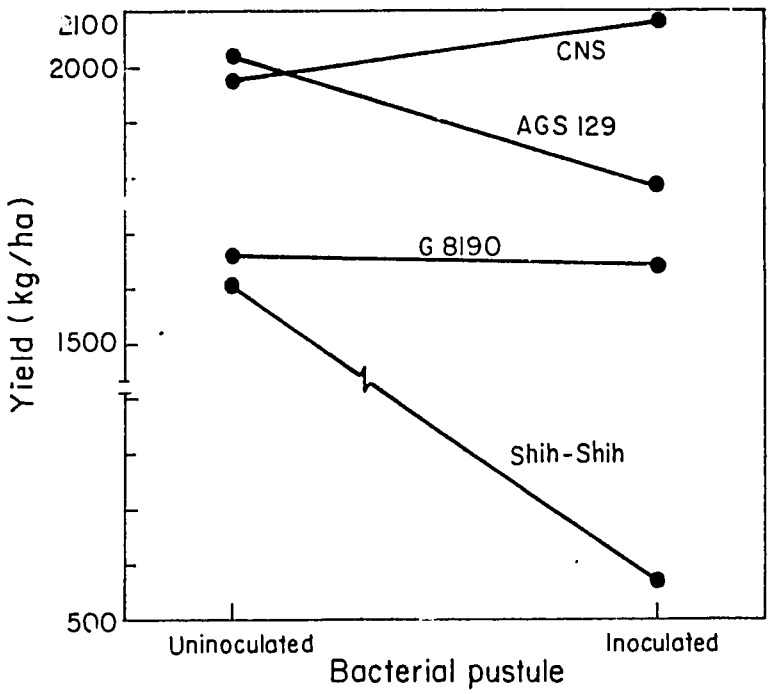

Fig. 7.
Variation in yield among genotypes resistant and susceptible to bacterial pustule inoculation.

The F_1 between AGS 129 (resistant) and CNS (moderately resistant) segregated to give 48 resistant and 27 moderately resistant progenies. When the F_1 was backcrossed to AGS 129, the segregation of BC_1 was 68 resistant to 22 moderately resistant. However, when the F_1 was backcrossed to CNS, the ratio was 62 resistant to 95 moderately resistant progenies.

The F_2 of AGS 129 and CNS segregated to give 576 resistant and 783 moderately resistant plants.

The above data show the complex nature of resistant, moderately resistant and susceptible plants. It is easy to distinguish the resistant and susceptible categories of plants. However, difficulty arises in distinguishing unequivocally the moderately resistant plants. This is because the dominant allele conferring susceptibility is modified by a few genes (Hartwig and Lehman 1951). Regulated inoculation with known bacterial concentration at a specific growth stage needs to be done and disease readings taken at a specified time after inoculation. For AVRDC conditions, such techniques need to be developed. The field screening technique used has effectively selected the resistant segregants.

From the F_2 of 10 crosses with a population of nearly 12,000 plants, a total of 362 pedigrees, roughly 3%, were selected as resistant to bacterial pustule, with good plant type and desirable agronomic traits. In another F_2 of 10 crosses with 11,000 plants, 298 pedigrees or 2.7%, were selected as bacterial pustule-resistant. These will be further evaluated to extract improved genotypes with desirable agronomic traits.

Breeding Vegetable Soybeans

Summary

Soybean as a vegetable has excellent potential in enriching the diet of people in the developing tropical and subtropical countries. From crosses made in 1983, GC 83011-35 and GC 83008-16 yielded 12.8 and 11.7 t/ha marketable pods against 8.5 t/ha for the check Ryokkoh in the spring season. In the summer, in spite of a typhoon AGS 292 and GC 83006-7 yielded 13.1 and 10.3 t/ha, respectively,

compared to 8.1 t/ha for the check Tzurunoko. To increase the percentage of two- and three-seeded pods, the narrow leaflet gene, lnln, is being introduced into the vegetable soybeans through backcrossing.

Introduction

Soybeans are used as vegetable in many tropical countries. Specific soybean varieties for vegetable use are currently unavailable in the tropics. Cultivation of vegetable soybeans provides cash income and export opportunities to earn foreign exchange, supports the processing industry and creates rural employment opportunities. Vegetable soybeans are nutritious and rich in protein. This program is expected to develop acceptable, high-yielding, good quality vegetable soybeans for developing countries in the tropics.

Materials and Methods

Fourteen selections made from five 1983 crosses have been entered in an intermediate yield trial in spring, summer and autumn seasons. The crosses were made between large-seeded genotypes with high yield potential and vegetable soybeans, Tzurunoko and Ryokkoh, that are already popular in Taiwan. Selection was based on acceptable pod types with better yield potential than the parent (vegetable soybean). Data from spring and summer seasons are presented.

Crosses were made between AGS 129 and Tzurunoko, Ryokkoh or AGS 292. In the F_2 narrow leaflet, large-seeded genotypes were selected and backcrossed to one of the vegetable soybeans to increase the seed size. Selection and backcrossing will be done for two or three generations. From the resulting progeny, selection will be made for narrow leaflet, large pod and seed size with high-yield potential.

Results and Discussion

Three selections from three crosses produced around 12 t/ha of acceptable pods (two- and three-seeded pods) in the spring season which was significantly higher than that of the check Ryokkoh (8.5 t/ha) (Table 15). GC 83011-35 was resistant to bacterial pustule. However, GC 83008-16 alone might not qualify as export to Japan, with the two selections not meeting the Japanese standard of 180 pods or lower per 500 g.

The usefulness of these selections for other countries needs to be evaluated.

In the summer season almost all the entries were damaged by typhoon. However, AGS 292 yielded 13.1 t/ha in 73 days with excellent pod size. GC 83006-7 was also as good as Tzurunoko and Ryokkoh with good pod size (Table 16).

From F_3, F_4 and F_6 generations, 424, 136 and 11 pedigrees, respectively, were evaluated for their comparative performance along with Tzurunoko and Ryokkoh. These pedigrees were derived from nine, six and two crosses in F_3, F_4 and F_6, respectively.

Table 15. High-yielding selections from IYT-vegetable soybeans in spring 1987.

Cross no.	Parents	Graded pod yield (t/ha)	Days to harvest (g)	100-seed wt. 500 g[z]	Accept. pods in	BP[y]
GC 83011-35	AGS 190 × KS 8	12.8 a[x]	90	66 cde	223 b	R
GC 83005-9	AGS 188 × KS 8	11.9 ab	90	59 de	223 b	MR
GC 83008-16	G 10134 × KS 8	11.7 ab	87	70 bcd	197 c	MR
G 9053 (check)	Tzurunoku	10.1 abc	80	71 bcd	181 cd	MR
G 10134 (check)	Ryokkoh	8.5 d	80	88 a	150 e	MR
Mean of 16 entries		4.8	83	73	187	
CV %		11.8	1.9	7.5	5.7	

[z]Acceptable number of pods per 500 g, as the Japanese market is about 180 or lower. Only two- and three-seeded pods were acceptable. [y]Bacterial pustule rated in the summer season; R = resistant, MR = moderately resistant. [x]Values followed by the same letter within the column are not significantly different at 5% level according to DMRT.

From three F_2 populations involving AGS 129 (narrow leaflet) and vegetable soybeans, narrow leaflet types with large pods had been pedigreed. Since the lnln (narrow leaflet) gene is associated with two- and three-seeded pods, these plants are expected to have a higher percentage of two- and three-seeded pods. To increase the pod size and seed size, these pedigrees will be backcrossed to vegetable soybeans. After two to three backcrosses, the vegetable soybean characteristics are expected to be fully reconstituted with narrow leaflet background.

Table 16. High-yielding selections from IYT-vegetable soybean in summer 1987.

Cross no.	Parents	Graded pod yield (t/ha)	Days to harvest	100-seed wt.(g)	Accept. pods/ 500 g	BP[y]
GC 83006-7	AGS 188 x G 10134	10.3 b[z]	73 e	74	178 i	R
AGS 292	Taishn ' roge	13.1 a	73 e	64	185 hi	R
G 10134 (check)	Ryokk ɔn	9.8 bc	74 d	65	208 efg	MR
G 9053 (check)	Tzurunoko	8.1 bcd	80 b	56	216 def	MR

[z]Values followed by the same letters within the column are not significantly different at 5% level according to DMRT. [y]Bacterial pustule noted in the summer season; R = resistant, MR = moderately resistant.

International Cooperation, Feedback and Impact

Summary

The target of all of AVRDC's research efforts is to reach out and help the farmers. Thus, the impact of its research results could be measured by the efficient transfer and adoption of AVRDC varieties and technologies by farmers in various countries to improve profitibility and increase national production.

AVRDC soybeans selected by the national program scientists in Thailand and Taiwan are increasingly adopted by the farmers. The estimated area planted to Sukothai No. 1 soybean in Thailand is about 60,000 ha, which is almost double that of 1986.

In Taiwan seeds of the newly released vegetable soybean, Kaohsiung No. 1 (AGS 292) were multiplied by the Taiwan Seed Service. An estimated 100 t would be ready for the farmers. Kaohsiung No. 10 (AGS 129) and Tainan No. 1 (AGS 66) had almost replaced Tainan No. 15, previously grown by the farmers.

Within three years Indonesia released the mutant G 2120 as Tidar, which yielded 1.0 to 2.8 t/ha in 72 to 75 days.

AVRDC vegetable soybeans are also gaining popularity in Sri Lanka. Mali would like to receive 7,000 kg of seeds of either AGS 200 or AGS 215 which have the yield potential of 2.3 t/ha while G 2261 would be distributed to farmers in Vietnam.

AVRDC distributed 19 ASETS and 407 AGS lines to 10 and 27 countries, respectively. In addition, 58 pedigrees/populations and 108 germplasm accessions were also sent out. A number of its elections appear promising; the most notable among them were AGS 129, AGS 299, AGS 217 and AGS 162.

Introduction

Research conducted at AVRDC, regardless of the crop or discipline, is aimed at solving or minimizing the problems of the small-scale farmers so that they could produce and earn more through better quality products. Therefore, genetically improved germplasm should cater to the needs of the national programs.

Distribution of Germplasm, Elite Lines and AVRDC Soybean Evaluation Trial (ASET)

Nineteen ASETs were distributed to scientists in 10 countries. A total of 407 AGS elite lines were sent to scientists in 27 countries, and 58 pedigrees/populations were also sent to seven countries

upon request of the scientists. To assist in their breeding program, 108 germplasm accessions were sent to 14 countries (Table 17).

Taiwan

On 23 April 1987, the Kaohsiung District Agricultural Improvement Station (DAIS) officially released AVRDC vegetable soybean cultivar AGS 292 as Kaohsiung No. 1. This is the first vegetable soybean variety officially released in Taiwan. In the annual frozen vegetable soybean processors, middlemen and farmers' meeting, it was proposed that all vegetable soybean farmers should plant the new variety beginning autumn 1988 season. The Taiwan Seed Service and the Kaohsiung DAIS are in charge of multiplying the needed seeds for extension. A description of the new variety is given in Table 18.

Table 17. Distribution of AVRDC soybean evaluation trial (ASET) and other enhanced germplasm to various countries, 1987.

Country	Type of seeds distributed			
	ASET	AGS lines	GC pedigrees/ populations	Accessions
Argentina		60		
Australia		7		
Bangladesh		1		13
Brazil	2			
Burma	2			
Ethiopia	3			
France		26	4	27
Ghana	1	4		
Guinea		1		1
India		34		
Indonesia		8		
Iran				
Iraq				
Japan		12	6	
Kiribati				
Korea	1	60[z]		
Liberia	1	2		2
Marshall Island		12	31	13
Mexico				6
Nepal		10		6
Niger		13		10
Nigeria	1	14	4	
Pakistan	1	9		1
Palau Island		3		
Philippines	8	30	11	12
Singapore		3		
Sri Lanka		16		
Switzerland		2		
Vietnam	2	20	1	2
Togo		5		
U.S.A.		37	212	12
Vanuatu	9	2		
West Indies	6		1	
	19 (10)	407 (27)	269 (7)	108 (14)

[z]Segregating materials and seed multiplication during off season.

In some locations, the pod wall had some spots which appeared to be physiological in nature (possibly due to pollution damage). This problem, however, needs further study.

Kaohsiung No.10 (AGS 129) and Tainan No.1 (AGS 66) were widely accepted by the farmers. However, Kaohsiung No. 10 (KS 10) in the spring season was severely damaged by downy mildew in some locations. Genotypes which are similar in yield as KS 10 but resistant to both downy mildew and bacterial pustule had been developed and are ready for yield evaluation.

Thailand

In spite of its reported moderate downy mildew and purple seed stain susceptibility problems, Sukothai No.1 is well accepted by farmers in Sukothai, Srisamrung, Kamphaengpet and Utharadit. The Department of Agricultural Extension estimated that the area planted to Sukothai No.1 would not be less than 60,000 ha during the rainy season.

New breeding lines similar to Sukothai No.1 with downy mildew resistance had been provided for evaluation in Chiang Mai. There was no opportunity to visit the trials and data are being compiled.

Indonesia

In 1984, the early-maturing mutants, G 2120 from AVRDC, along with a number of breeding lines, were provided to the Bogor Research Institute for Food Crops (BORIF) in Indonesia. After intensive yield evaluation and multilocational testing, Dr. Sumarno, Ir. Soegito and Dr. J. Siemonsma, the soybean breeders proposed it for release to the farmers. In February 1987 the Ministry of Agriculture officially named G 2120-M as Tidar. Yield data on Tidar from seven locations in different parts of Indonesia compared to other improved varieties are given in Table 19. The new variety was 8% to 182% higher yielding than the existing varieties tested (Table 19).

In 1985 and 1986, G 2120-M (Tidar) was evaluated in five different locations (two trials) in East Java. The highest yield of Tidar obtained in Bojonegoro was 2.79 t/ha in 75 days (Table 20).

Table 18. Description of vegetable soybean Kaohsiung No. 1.

Original code:	AGS 292
Pedigree:	Taishoshiroge
Origin:	AVRDC, Taiwan
Days to harvest:	68 to 78 days (average 74 days)
Plant height:	29.9 to 41.7 cm (average 35 cm)
Number of branch/plant:	2
Number of nodes of main stem:	8.9
Lodging:	All plants erect, nonlodging
Plant height at first pod:	14.5 cm suitable for mechanical harvesting
Flower color:	purple
Color of seed coat:	yellow
Skin color of pod:	white
Pod number of 500 g weight:	153
Green pod yield:	5.41 t/ha
Sugar content:	13.66% DM
Protein content:	37.85% DM
Oil content:	18.88% DM
Disease resistance:	resistant to downy mildew
Plant season:	Spring: mid-February until early March
	Summer: early June until early July
	Autumn: mid-September until early October
Release by:	Kaohsiung DAIS
Date of release:	23 April 1987
Yield:	An average of 23.5% higher than Tzurunoko.

Table 19. Grain yield of AVRDC G 2120M tested in different locations in Indonesia, 1986.

Variety name	Yield (t/ha)							Average	Days to maturity	Yield/day (kg/ha/day)
	Lampung I	Lampung II	Subang I	Subang II	Kuamang Kunning	Citayam	Muara			
G 2120-M	1.30	1.28	0.69	0.69	1.37	1.98	1.33	1.23	75	16
Wilis	0.95	1.02	0.61	0.74	0.73	2.06	1.33	1.06	84	13
Lokon	0.59	0.63	0.66	0.82	0.67	–	–	0.67	78	9
Orba	0.81	0.91	0.68	0.73	0.65	–	–	0.75	84	9
Kerinci	1.18	1.18	0.61	0.63	1.02	1.93	1.44	1.14	89	13
LSD 5%	245	240	126	126	300	220	247			
CV %	20	20	19	19	17	8	13			

Table 20. Grain yield of G 2120M in trials conducted in East Java.[z]

Varieties	Yield (t/ha)												Mean	Productivity (kg/ha/day)
	BJGR[y]	PNRG I	PNRG II	PSRN I	PSRN II	JBGD	PSRM	PNRG	SKRG	Ngale	PSRN	Genteng		
	MK86						MK 85			MK 85/86				
G 2120M (MLG 2753)	2.79	1.33	1.40	1.45	1.57	1.33	1.77	1.12	1.51	1.15	1.10	2.18	1.56	21
Wilis	2.29	–	–	–	–	1.80	1.75	1.38	–	1.33	1.15	1.91	1.66	19
Kerinci	–	1.58	1.54	1.70	1.71	1.53	1.85	1.31	1.71	1.13	1.49	2.51	1.64	18

[z]Conducted in cooperation with Malang Research Institute for Food Crops (MARIF). [y]BJGR = Bojonegoro; PNRG = Ponorogo; PSRN = Pasuruan; JBGD = Jambegede; SKRJ = Sukorejo.

In Jatiluhur area in West Java, there is almost a million hectares of land left fallow after the harvest of rice (Pasaribu and McIntosh 1986).[5] An early-maturing soybean variety is required to farm the fallow land in Jatiluhur. Tidar, which matures in 72 to 77 days, appears to meet the needs of the Jatiluhur area.

Mali

AVRDC's AGS 200 and AGS 215 had been reported to be the best performers after a number of trials using diverse materials. The yield potential of these entries had been reported as 2.3 t/ha. The Soybean Association of Mali is interested in buying 7,000 kg of seeds of either AGS 200 or AGS 215 for planting.

Vietnam

Among the number of entries received from AVRDC, G 2261 had been reported to be performing well in Vietnam (personal communication, Dr. Chi). They would like to receive more genotypes from AVRDC through the FAO pouch in Thailand.

Sri Lanka

A number of Canadians working in Sri Lanka reported that vegetable soybeans AGS 186, 188, 190 and 191 performed very well, are readily accepted by the consumers and have less beany flavor. AVRDC provided 2 kg of each of the breeder's seed for multiplication in Sri Lanka.

Korea

As in the past, 34 breeding lines for advance generation and one elite line for seed multiplication were grown from February to May 1987. From this project a total of 66 kg seeds were airfreighted in May 1987 to Korea. The actual amount of seed multiplied for Milyang No. 25 (35 kg) far exceeded the expected yield (20 kg). The seed quality was excellent. As a result of this cooperation, Korea was able to release six new soybean varieties to their farmers.

The results of elite selections evaluated in different countries are shown in Table 21. AGS 299 appeared to have high yield potential in South Africa. In Zaire, GC 82146-43-9-9 and GC 82200-6-12-10 had outyielded the local check, SJ 127. In other countries the experimental yields were quite low due to diseases, insects and drought.

Thirteen ASET (1985 and 1986) data were returned by 13 scientists in 12 countries (Table 22). The results of ASET revealed that AGS 124, AGS 129, AGS 217, AGS 299 and AGS 162 had outyielded the local checks in one or more countries (Table 23).

The updated list of varieties released by the national programs in various countries is given in Table 24.

Table 21. Summary of results of international cooperation.

Country/ location/ cooperator	Entry	Yield (t/ha)	DM	100-seed wt.(g)	SQ[w]	Remarks
Liberia						
Monrovia	AGS 58	1.06	85	28	2	Date planted: 24 July 1986
Cheng Shui-Po	AGS 66	0.44	70	13	2	Single replication –
	AGS 129	0.42	90	17	3	Observational trial –
	AGS 1038	0.96	90	31	3	No check variety.

[5]Pasaribu, D. and J. L. McIntosh. 1986. Increasing tropical soybean production with improved cropping systems and managements. Pages 1-12. In S. Shanmugasundaram, E.W. Sulzberger and B.T. Mclean, eds. Soybean in Tropical and Subtropical Cropping Systems, AVRDC, Shanhua, Tainan.

Table 21. Continued.

Country/ location/ cooperator	Entry	Yield (t/ha)	DM	100-seed wt.(g)	SQ[w]	Remarks
Andrew Saye	Check	0.58	88	16	4	Date planted: 17 May 1987
	AGS 190	0.50	92	10	3	Single replication
	AGS 292	0.49	84	14	4	
	G 10134	0.48	93	13	4	
	G 9053	0.35	94	15	4	
Philippines						
La Union Felino R.Neri	AGS 2 (G 2120)	2.10 a	–	7 b	–	Date planted: Nov. 1986 Incomplete data.
	AGS 24	1.24 b	–	16 a	–	
	AGS 7	1.21 b	–	13 a	–	
	UPLSY 2 (check)	1.87 a	–	6 b	–	
	CV.	21.5	–	22.3	–	
Pakistan						
Tandojam 25.2°N, 63.38°E, 19 m a.s.l.	Steele (check)	1.41 a	93	14	3	Date planted: 7 March 1987 [z]Resistant to thrips
	AGS 148	1.12 ab	87	12	4	
	Columbus (check)	1.10 ab	91	10	4	
		1.04 b	94	14	3	
A.H.Chaudhary N.A.Umerani M.H.Khanzada	AGS 154	1.01 b	88	11	4[z]	
South Africa						
25°24'S,	AGS 299	3.20	120	13	2	Date planted: 20 Jan. 1986
29°22'E, 1009 m a.s.l.	AGS 296	2.81	102	20	2	Irrigated: 19 times (366 mm)
	AGS 298	2.73	108	17	3	
	AGS 303	2.72	102	7	2	Single replication
(Buffelspoort) T.E.M.Odendaal						Total no. of entries evaluated: 36 Yield range: 0.2 – 3.2 t/ha
Tonga						
Donn Cobb and	AGS 129	0.64	77	–	–	Date planted: 13 March 1986
S. Malamala Vaea	AGS 66	0.89	77	–	–[y]	[y]Less charcoal rot and beanfly damage,
	KS 8	0.97	86	–	–[x]	[x]Susceptible to charcoal rot; Single replication
	H 15	0.71	66	–	–	
Zaire						
11°44'S 27°25'E Kanimeshi, Shaba 1187 m a.s.l.	AGS 66	0.86 a	105	13	–	
	AGS 200	0.85 a	102	15	–	
	AGS 222	0.82 a	113	20	–	
	AGS 215	0.82 a	114	17	–	
	SJ 127 (check)	0.49 b	126	12	–	
	GC 82146-43-9-9	1.44 a	106	18	–	
	GC 82200-6-12-10	1.43 ab	103	15	–	
	SJ 127 (check)	0.83 c-h	126	10	–	

[w]1 = Best quality, 5 = worst, badly weathered or damaged seed.

Table 22. List of cooperators who returned the data for ASET.

Country	Trial no.	Cooperators	Address
Ethiopia	85A-6	Amare Belay Gasuanin	Institute of Agri. Research Awasa Res. Center, P.O.Box 6 Sidamo, Ethiopia
Liberia	85A-9	Saye Diagor	A.V.S.P.P. Box 34, Saclesea, Nimba, Liberia
Tanzania	85A-1	J.A. Asenga E.G. Ngowi	T.A.R.O. Ilonga, Kilosa, Tanzania
Vanuatu	85A-11	Mrs. Henry Ullman	Torgil, Lolowai, Ambae, Vanautu.
Costa Rica	86-14	Ir. German Quesada H.	Ministerio de Agricultura y Ganandaria, Apt. 19094-1000 San Jose, Costa Rica
Korea	86-16	Eun-Hi Hong	Crop Experiment Station, ORD Suweon-170, Korea.
Pakistan	86-17	A.H. Chaudhary	Oilseeds section, Agril. Res. Inst., Tandojam, Sind, Pakistan
Philippines	86-2	F.F. Bongolan	Betinan Research Station, Ministry of Agric. & Food, Betinan, San Miguel
	86-31	Amy P. Yadao	Pioneer Overseas Corp., Katangawan, General Santos City, Philippines
Rep. de Guinea Bissau	86-19	Clouvel, IRHO	Proj. de Development Rural Zone II, Bafata
South Africa	86-36	T.E.M. Odendaal	Buffelspoort Res. Station, Buffelspoort, South Africa
Taiwan	86-21	Chan Kuo Lein	TARI, Wufeng, Taichung
Zimbabwe	86-41	J.R. Tattersfield	Rattray Arnold Res. Station, Box CH 142 Chisipite, Harare

Table 23. Results of ASET from cooperators.

Country location Date planted	Cross no.or name	Yield (t/ha)	Days to maturity	SQ[x]	100-SW	Remarks
Ethiopia						
7°04'N, 38°27'E	Clark 63 (ck)	2.3 a	120	2	13	[z]Highly resistant
7 July 1986	AGS 275	2.2 ab	135	2	11	to bacterial
	AGS 129	2.0 ab	138	2	12	pustule
	AGS 66	1.9 abc	123	3	11	
	AGS 242[z]	1.7 bcd	109	1	19	
	Williams (ck)[z]	1.3 def	110	2	12	
Liberia						
7°N, 9°W	AGS 242	0.8	86	–	18	[y]Resistant to
1 April 1987	AGS 66	0.7	90	–	14	rust, bacteric!
	AGS 245	0.7	90	–	16	pustule & downy
	AGS 129[y]	0.7	91	–	16	mildew
Tanzania						
6°41'S, 37°02'E	AGS 29	0.6 a	89	3	18	No disease
19 May 1986	AGS 204	0.4 b	89	3	19	
	Bossier (ck)	0.4 b	90	3	17	
Vanautu	The students of the Agricultural School liked the soybean so much (either boiled in salt water or cooked with rice), that they harvested and ate them all. No yield data was returned.					
Costa Rica						
10°00'N,84°13'W	AGS 124	1.8 a	–	–	–	Incomplete
	AGS 162	1.6 ab	–	–	–	data
	AGS 299	1.6 ab	–	–	–	
	AGS 129	1.6 ab	–	–	–	
	Siatsa 194A(ck)	1.3 bcd	–	–	–	
	Jupiter R (ck)	1.2 d	–	–	–	

Table 23. Continued.

Country location Date planted	Cross no.or name	Yield (t/ha)	Days to maturity	SQ[x]	100-SW	Remarks
Korea						
37°16'N,126°59'E	Local check[z]	2.3 a	–	–	25	[z]Highly resistant
19 June 1986	Local check[z]	2.0 ab	–	–	26	to SMV
	AGS 129[y]	1.7 bc	–	–	17	[y]Resistant to SMV
Pakistan						
25°2'N,63°38'E	AGS 129	1.7 a	96	–	14	[z]Susceptible to
4 August 1986	AGS 299	1.5 ab	91	–	13	pod blight
	AGS 124	1.5 ab	98	–	13[z]	
	Local check	1.1 abc	97	–	17	
	Local check	0.6 c	98	–	15	
Philippines						
7°54'N,123°27E	AGS 217	0.8 a	–	–	15	
3 October 1986	AGS 160	0.8 ab	–	–	13	
	Local check	0.6 bcd	–	–	11	
6°7'N, 125°11'E	AGS 299	3.1 a	80	2	16	AGS 299 is
25 Sept. 1986	AGS 129	2.8 ab	85	2	14	excellent
	AGS 208	2.8 ab	80	2	21	
	G 9961 (ck)	2.6 a-d	86	1	14	
	Manchuria (ck)	2.2 cd	86	2	15	

[x]1 = Best quality and 5 = worst, badly weathered or damaged seed.

Table 24. AVRDC soybean releases.

Local name	AVRDC ID #	Year	Country	Remarks
Darco 1	AGS 29	1981	Honduras	EM, UM, HY, CLS
KM 1	G 2120	1980	India	RF, HY
G 2120	G 2120	1980	Indonesia	HY, CC, SC, ST, G, LSV
Wilis**	G 2120	1983	Indonesia	EM, HY, (R)***
Kerinci**	G 2120	1985	Indonesia	HY, (R), BF
Tidar	G 2120-M	1987	Indonesia	HY, EM, RF, LSV, G, ST
Taiwan 30050	AGS 17	1982	Malaysia	HY, MH
BPI Sy4 (Tancosoy)	AGS 73	1985	Philippines	HY, EM, UM, LSV, BP, R, L, S, WA
Kaohsiung No. 9	AGS 12	1982	Taiwan	HY, BP, SSP
Kaohsiung No. 10	AGS 129	1985	Taiwan	HY, NL, BP, SSP
Tainan No. 1	AGS 66	1986	Taiwan	HY, S, MH, EM, SP, DP, BP, L, BS
Sukothai 1	AGS 9	1986	Thailand	NL, HY, BP, (R)
Dowling	G 58	1978	USA*	R, HY
	30229-8	1983	Zimbabwe**	NL, HY
KS # 1	AGS 292	1987	Taiwan	VS, HY, DP

* Selected at AVRDC, but not an AVRDC improved line.
** Cross between AVRDC line and local cultivar.
*** Parenthesis indicates moderate levels of resistance

BF = resistant to beanfly;
BS = suited to bean sprouting;
CLS = resistant to Cercospora leaf spot;
EM = early maturing;
HY = high yielding;
LSV = long seed viability;
NL = narrow-leafed;
RCI = suitable for intercropping with rice or corn;
S = nonshattering;
SP = suited to summer planting;
ST = preferred for making tempeh;
VS = vegetable soybean;
BP = resistant to bacterial pustule;
CC = suited to crude cultivation;
DP = resistant to downy mildew;
G = good germination;
L = nonlodging;
MH = suitable for mechanical harvesting;
R = rust tolerant;
RF = suited to cultivation in rice fallows;
SC = suited to intercropping with sugarcane;
SSP = suited to spring and summer planting;
UM = uniformly mature;
WA = wide adaptability.

Soybean Entomology

Screening of Selected Soybean Accessions for Tolerance to Beanflies

Summary

Tolerance of soybean germplasm to beanfly [mainly *Melanagromyza sojae* (Zehntner)] damage was studied in three tests. Soybean accession G 8586 showed consistently less yield loss due to beanfly infestation for three consecutive years. PI 171444, PI 229358 and G 794 also showed tolerance to beanfly damage.

Introduction

Three species of agromyzid flies, commonly called beanflies, are economically important pests of soybean in tropical to subtropical Asia, Africa, Australia and Oceania. These species: *Ophiomyia phaseoli* (Tryon), *O. centrosematis* (De Meijere) and *Melanagromyza sojae* (Zehntner) (Diptera: Agromyzidae), have a wide host range among economically important legumes. The insect larvae bore into the stems, especially those of young seedlings, and seriously weaken or at times kill the plants. Since the larvae feed inside the stem, its damage remains unnoticed. Since 1975 AVRDC has been screening soybean germplasm resistant to these insects; however, until now only a few wild soybean, *Glycine soja*, accessions have shown resistance to these pests. The resistant accessions possess very thin viny stems and this agronomically undesirable character is responsible for the resistance. All progenies bred by utilizing resistant *G. soja* parents become susceptible as soon as the plant stem diameter increases. Therefore, since 1981 AVRDC has been screening soybean germplasm tolerant to beanflies. A tolerant cultivar is one which has no or minimum yield reduction despite heavy beanfly infestation (up to 100% plants damaged). In 1985-86 the Center screened 200 accessions in a nonreplicated preliminary test and 18 additional accessions in a replicated second test, for tolerance to beanflies, mainly *M. sojae*. Four Plant Introduction (PI) accessions which had shown resistance to other insects and which are being used in the defoliator resistance breeding program, were also screened for tolerance to beanflies.

Materials and Methods

A one-hectare field was rototilled and after application of basal fertilizers worked into 1-m wide beds. These beds were partitioned into 10.25-m long plots which were divided into two adjacent 5-m long subplots separated by a distance of 0.25 m. Seeds of each entry were sown in two parallel rows 40 cm apart on the top of two adjacent 5-m long subplots separated by 0.25 m empty area. A distance of 10 cm was maintained between two adjacent hills in each row. For the preliminary test, seeds of each entry were planted in only one plot consisting of two 5-m long adjacent subplots. The second test had 18 entries and PI accession screening with the soybean seeds planted in three similar randomly selected plots, each representing one replicate. The crop was raised by customary cultural practices except that in one of the two subplots of each entry, two insecticides, monocrotophos or omethoate, were sprayed each at the rate of 0.5 kg a.i./ha. Spraying was done alternately at 3, 7, 10, 17, 24 and 31 days after germination, while the other subplot was left as untreated control.

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Four weeks after germination, the crop was sampled by uprooting 10 plants each from both subplots of each entry. Stems of each plant in the sample were cut open to observe the beanfly damage inside the pith. The number of beanfly damaged and healthy plants was recorded. Also, at this time the plants were thinned to maintain an approximately equal number in each subplot of each entry.

Starting six weeks after germination, the entire field was sprayed with contact insecticides such as deltamethrin or fenvalerate to protect the plants against other, mostly polyphagous, insect pests. At harvest the seed yield per subplot was recorded.

Results and Discussion

Preliminary screening. In this screening 200 accessions were included. In untreated subplots beanfly damage ranged from 40% to 100% with an average of 84%. In insecticide-treated subplots, plant damage ranged from 0% to 40% with an average of 8%. The yield loss ranged from 0% to 51.1% with an average of 20%. The entries that yielded at least 0.5 kg/plot in insecticide-treated subplots, in which the yield loss was 5% or less are listed in Table 1. Since the sole criterion for tolerance evaluation was the yield which, besides beanflies, could be influenced by other factors, and the fact that the experiment had only one replicate, these selected entries will be tested again in a multireplicate test in the 1987-88 season before making the final selection.

Table 1. Performance of selected soybean accessions for tolerance to beanflies in a preliminary test.[z]

Accession	No. of plants		Damaged plant (%)		Yield (kg/plot)		Yield loss
	+	−	+	−	+	−	(%)
G 2	155	160	25	50	0.95	0.90	5.3
G 8	140	149	0	70	0.85	0.90	0.0
G 38	104	86	0	85	0.86	0.82	4.7
G 92	124	129	0	90	0.70	0.85	0.0
G 97	130	141	0	65	0.75	0.77	0.0
G 100	148	159	0	55	0.72	0.75	0.0
G 110	146	147	0	95	0.68	0.75	0.0
G 141	173	170	10	55	0.63	0.60	4.8
G 278	160	162	0	85	0.70	0.67	4.3
G 336	143	138	30	90	0.73	0.73	0.0
G 516	132	112	5	80	0.75	0.74	1.3
G 669	105	116	35	85	0.50	0.48	4.0
G 725	116	115	15	95	0.56	0.61	0.0
G 750	136	138	0	85	0.65	0.69	0.0
G 292	144	135	5	90	0.90	0.46	48.9
G 448	156	148	5	85	1.25	0.70	44.0

[z]Plot size: 5 m × 1 m. Sown 30 September and 1 October 1986. Harvested 12 December 1986 to 13 January 1987. Average yield loss for 200 accessions was 20%. + = insecticide-sprayed plot, − = untreated plot.

Second screening. The accessions and breeding lines included in this screening were selected on the basis of high level of tolerance (minimum yield loss) in earlier tests. The results of the 1986-87 test are summarized in Table 2. Soybean accessions G 794 and G 8586 had no yield loss. In the 1985-86 test G 794 recorded only 1.1% yield loss while G 8586 had shown the least yield loss for the past successive three years. It was found that in some accessions and breeding lines yield loss varied from season to season. As such some entries found to be tolerant in one year were found susceptible in the next year's test. For example, in the past two years G 2320 had a yield loss of 4% and 0.9%, but this year in two tests it had a yield loss of 7% and 16%. Similar phenomenon was observed with other accessions.

Screening of PI accessions. Four PI accessions: PI 171444, PI 171451, PI 227687 and PI 229358 have shown resistance to various pests at a wide variety of locations. Their tolerance to

beanfly infestation are summarized in Table 3. There was no yield loss in PI 171444 and PI 229358 and it was minimum in PI 171444. It must be emphasized though that their yield potential is very poor. It is possible that due to low yield the differences in yield loss was not evident. Because of their resistance to several species of insect pests, further studies with these accessions will be pursued.

Table 2. Performance of selected soybean accessions and breeding lines for tolerance to beanflies in second screening.[z]

Accession	No. of plants per plot		Damaged plants (%)		Yield (kg/plot)		Yield loss
	+	–	+	–	+	–	(%)
G 652	151	152	7	83	0.76	0.66	14.5 a
G 674	144	141	5	82	1.10	0.98	10.3 ab
G 694	165	154	0	87	0.96	0.79	18.2 a
G 754	131	147	0	93	1.15	1.11	4.1 ab
G 794	136	153	5	92	0.86	0.88	0.0 b
G 848	155	157	0	83	1.24	1.02	17.3 a
G 936	172	169	8	82	0.84	0.81	4.7 ab
G 2320	166	162	7	88	1.04	0.96	7.0 ab
G 8586	139	156	0	90	0.60	0.73	0.0 b
AGS 8	158	158	2	82	1.12	1.03	8.7 ab
AGS 37	146	139	2	95	1.15	1.08	7.8 ab
AGS 50	154	163	5	97	1.13	1.06	8.8 ab
AGS 52	142	150	3	88	1.13	1.06	7.7 ab
AGS 67	148	143	5	80	1.30	1.20	8.3 ab
AGS 76	130	130	7	93	0.97	0.81	16.0 a
AGS 93	155	160	7	87	1.11	1.07	3.9 ab
AGS 106	161	154	5	77	0.90	0.88	6.7 ab
PP 18	146	144	7	93	1.02	0.96	6.0 ab

[z]Planted 1 October 1986 and harvested 24 December 1986 to 13 January 1987. + = insecticide protected, – = untreated. Plot size: 5 m x 1 m.

Table 3. Performance of selected PI accessions for beanfly infestation and yield loss.[z]

Entry	No. L + P /20 plants		Damaged plants %		Yield kg/plot		Yield loss
	+	–	+	–	+	–	(%)
PI 171444	1	6	20	53	0.20	0.22	0
PI 171451	4	11	35	58	0.40	0.39	3.0
PI 227687	2	9	23	58	0.37	0.29	20.7
PI 229358	4	10	35	58	0.23	0.26	0
AGS 199	4	9	35	77	0.72	0.66	8.6

[z]Planted 4 September 1986 and harvested 3 January 1987. Plot size: 5 m x 1 m. + = insecticide protected, – = untreated check. Mean separation in each vertical column by DMRT, P = 5%.

Beanfly Resistance in Selected PI Accessions

Summary

Four Plant Introductions, PI 171444, PI 171451, PI 227687 and PI 229358, were tested at cotyledon stage for resistance to beanfly, *Ophiomyia phaseoli* (Tryon), in the greenhouse. The number of pupae per plant was significantly less in PI 227687 than in the susceptible check and in the other three PI accessions. Plant mortality was significantly less in PI 171444 and PI 227687. PI 227687 appears to be resistant and PI 171444 tolerant to *O. phaseoli*.

Introduction

A beanfly species, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae), is the most destructive pest of soybean in Indonesia and in the southern part of Vietnam. Although this species occurs in Taiwan and is a major pest of mungbean and snapbean, so far it is not serious on soybean. Thus, AVRDC is as yet unable to screen for resistance to this species. In 1987, however, a mass-rearing technique for this insect was developed. As a result, soybean can now be screened at least in the greenhouse, for resistance to this pest. In 1987 after developing the mass-rearing technique, four soybean PI accessions, which have shown resistance to various other insect pests were screened, for resistance to *O. phaseoli*.

Materials and Methods

Seeds of the four PI accessions: PI 171444, PI 171451, PI 227687 and PI 229358, and one known susceptible entry, AGS 66, were planted in clay pots in the greenhouse. There were four pots per entry, each representing one replicate. Soon after germination when plants had only green cotyledons, the seedlings were thinned to 10/pot and the pots placed under a nylon net cage. About 1,000 freshly emerged beanfly adults were then released inside the cage. Two days after the release the number of eggs in the cotyledons was recorded. The eggs which were laid just underneath the epidermis were easily observed with the help of an ordinary magnifying lens. Two weeks after egg laying plant mortality was recorded. At this stage each plant was cut open and the number of pupae found inside each plant recorded.

Results and Discussion

The results of egg laying, number of pupae per plant and plant mortality are summarized in Table 4. There was no significant difference in the number of eggs laid by *O. phaseoli* in the cotyledons of three PI accessions and the susceptible check. In PI 171451 the number of eggs laid was significantly higher than in the susceptible check and other PI entries. However, the number of pupae per 10 plants was significantly less only in PI 227687 than in the susceptible check. Plant mortality, which is the most important mode of damage due to *O. phaseoli*, was significantly less in PI 171444 and PI 227687 than in the susceptible check and the remaining two PI accessions. In the case of PI 171444, most of the eggs became larvae and pupae but plant mortality was minimal. This PI, thus, seems to tolerate feeding by *O. phaseoli* larvae. In PI 227687 less than one-third of the eggs reached pupal stage. In this PI there seems to be antibiosis which interferes either with egg hatching, larval feeding, or the process of pupation. In any case these two entries represent an important source of at least a moderate level of resistance to *O. phaseoli*. The mechanism of resistance will be investigated in 1988.

Table 4. *O. phaseoli* infestation of selected soybean PI accessions, AVRDC 1987.[z]

Entry	No. of eggs /10 plants	No. of pupae /10 plants	% plant mortality
PI 171444	29 b	24 a	10 b
PI 171451	99 a	24 a	69 a
PI 227687	31 b	10 c	6 b
PI 229358	59 b	11 bc	52 a
AGS 66	59 b	20 ab	51 a

[z]Data are means of four replicates. Mean separation in each vertical column by DMRT, $\underline{P}$ = 5%.

A Procedure for Mass-Rearing Beanfly

Summary

A simple and inexpensive procedure that utilizes freshly emerged soybean cotyledons was developed for mass-rearing beanfly, *Ophiomyia phaseoli* (Tryon). Beanfly adults lay eggs in the soybean

cotyledons and the larvae feed and pupate in that plant part. Larvae and pupae can be taken out and used for studies at any stage or the pupae can be maintained until adult emergence. The insect raised in this manner retains its ability to infest soybean. Up to 2,000 flies/day were raised by this method with the input of one laborer.

Introduction

The beanfly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae), is one of the most destructive and widely distributed insect pests of economically important food legumes in tropical to subtropical Asia, Africa, Australia and the Pacific. The insect larva bores into the stems of young plants which results in plant mortality or severe reduction in growth and yield. In most areas of Southeast Asia and East Africa, this pest is a major limiting factor in the successful cultivation of such economically important legumes such as snap bean *Phaseolus vulgaris* L. and soybean, *Glycine max* (L.) Merrill. In many cases, infestation of beanfly is also accompanied by certain other agromyzids, such as *O. centrosematis* (De Meijere), *O. spencerella* (Greathead) (in East Africa) and *Melanagromyza sojae* (Zehntner), which cause damage similar to the beanfly.

To control beanfly economically, sources of resistance to beanfly in soybean and mungbean, and on breeding of soybean and mungbean cultivars resistant to this pest are being studied. This research requires continuous and ample supply of the insect. However, the beanfly population is not high enough to allow the conduct of resistance screening throughout the year under field condition, due to environmental factors such as rainfall and, at certain times of the year, proliferation of natural enemies. This lead to the development of a mass-rearing method which can produce large numbers of insects throughout the year to facilitate resistance breeding.

Materials and Methods

An ordinary plastic container (7 × 7 × 4 cm) with four small holes at the bottom was filled with vermiculite to a depth of about 3 cm. About 50 soybean seeds were sown on the top of this layer and additional vermiculite was added to cover the seeds completely. The container was then placed in the greenhouse and watered regularly once a day. The holes at the bottom of the container facilitated drainage of excessive water which resulted in a higher percentage of seed germination. In two to three days, the seeds germinated with thick green cotyledons above the vermiculite.

After two more days, the growing point above the cotyledons was cut off. The seedlings with cotyledons only were then placed in an oviposition cage (30 × 30 × 30 cm) containing about 200 beanfly adults. The cage had a wooden top and bottom and sides confined with nylon net, including one side that can be opened and closed. Two or three absorbant cotton plugs dipped in honey solution were placed inside the cage to serve as food for the adults. After 30 min of exposure, during which beanfly females laid eggs in the cotyledons, the seedlings were removed. The presence of oviposition holes confirmed the egg laying in the cotyledons. Within 24 hours, the cotyledons with eggs were excised with the help of a sharp knife and placed in a petri dish lined with moist filter paper. They were then maintained at 25°C for an additional 10 days to develop into pupae. Since one cotyledon can sustain the growth of a maximum of three larvae until pupation, the duration of exposure of soybean seedlings for oviposition should be carefully worked out to avoid excess laying of eggs. The presence of more than three larvae per cotyledon requires the laborious transfer of larvae to fresh cotyledons or else the larvae will die in the cotyledon before pupation.

Pupae can be collected easily by removing the papery epidermis of the cotyledon. For adult emergence, pupae were placed in an open petri dish in a cage. Adults started emerging within 10 days.

Results and Discussion

Beanfly readily lays eggs in soybean cotyledons and the larvae tunnel in that plant part (Fig. 1A). These tunnels can be opened to get larvae of desired instar (Fig. 1B) for specific studies. Pupation takes place just underneath the epidermis (Fig. 1C) on both sides of the cotyledons.

O. phaseoli had been continuously reared on soybean cotyledons in AVRDC for the past seven generations over a period of six months. The larval mortality was practically nil and pupation

rate approached 100%. The duration of various growth stages (Table 5), the entire life cycle by this procedure, and those occurring under natural condition were comparable. The growth and development of the insect was quite stable at least for the past seven generations (Table 6).

The mass rearing procedure developed at AVRDC is quite simple and inexpensive. It does not require temperature control facilities. Soybean seedlings can be raised in the open provided they are sheltered from excessive rainfall. Although the oviposited cotyledons were placed at 25°C for about 10 days from oviposition to pupal stage, the space required for this was minimum since a large number of cotyledons (up to 100), each containing two to three larvae, can be accommodated in a 9-cm diameter petri dish. It is possible to modify this stage and rear the larvae in the cotyledons maintained in the laboratory fitted with an ordinary room air-conditioner.

Excising of cotyledons after oviposition is essential because, if left intact, the second instar larvae enter the hypocotyl and kill the plant. This hinders the growth and pupation of beanfly larvae. Physical removal of pupae from the excised cotyledons is also essential since by pupation time in eight days, the excised cotyledons begin to rot and this may kill the beanfly pupae.

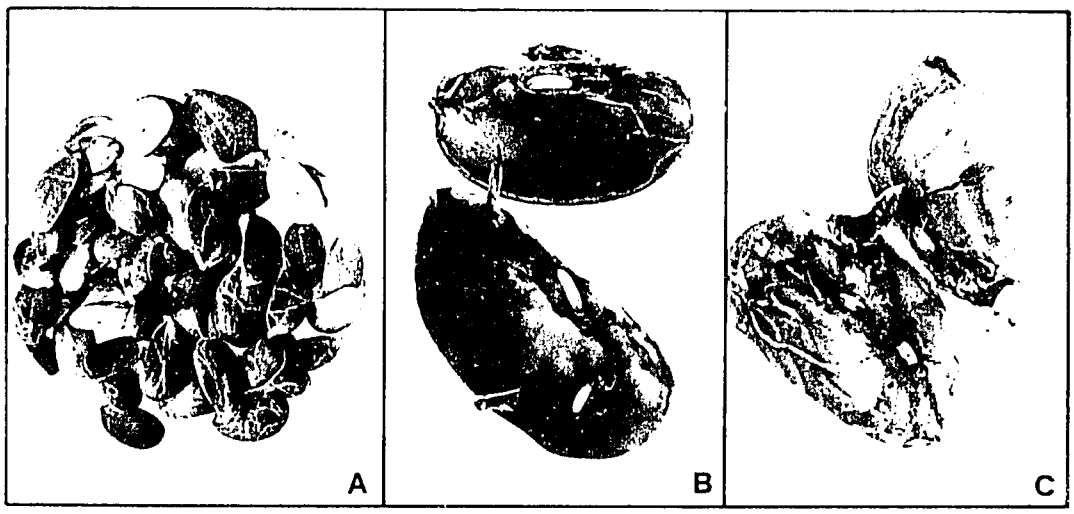

Fig. 1. *O. phaseoli* feeding tunnels (A), larvae (B), and pupae (C) in soybean cotyledons.

Table 5. Life history characteristics of *O. phaseoli* reared on soybean cotyledons.

Item	Mean[z] ± standard deviation (range)
Egg and larval stage (days)	10.0 ± 0.5 (9 to 11)
Pupal stage (days)	9.8 ± 0.6 (9 to 11)
Pupal weight (mg)	0.7 ± 0.0
Adult emergence (%)	74.5 ± 8.7
Adult longevity (days)	17.3 ± 2.3 (13 to 21)

[z]Mean of 50 insects

Table 6. Pupal weights and extent of adult emergence of *O. phaseoli* reared on soybean cotyledons over seven consecutive generations, 1987.

Generation	Pupal weight[z] (mg)	Adult emergence[z] (%)
First (February)	0.67 ± 0.05	74.5 ± 8.7
Second (March)	0.68 ± 0.06	76.2 ± 8.3
Third (March-April)	0.70 ± 0.06	77.3 ± 7.7
Fourth (April-May)	0.66 ± 0.03	75.6 ± 9.8
Fifth (May)	0.67 ± 0.05	73.8 ± 6.1
Sixth (June)	0.69 ± 0.04	77.1 ± 11.0
Seventh (June-July)	0.70 ± 0.05	74.7 ± 7.2

[z]Data are mean of 50 insects ± standard deviation.

About 2,000 beanfly adults/day with labor input of one person were produced. This can easily be increased if adequate labor input is available. The insects reared on soybean cotyledons retained their usual ability to infest soybean. There was 100% infestation of soybean plants placed in 4 × 1 × 0.5 m net cage containing 88 potted plants, with about 1,700 adults. A plant mortality of up to 90%, which is common under open field condition with ambient population at certain localities in Asia, had been achieved in soybean plants placed under cages described above.

In addition to soybean, mungbean, another easily available legume, was also utilized but it was unsuitable since beanfly did not lay eggs in mungbean cotyledons.

Recently it was also found that *M. sojae*, another agromyzid pest of soybean and several other legumes, which normally lays eggs in the foliage, can also lay eggs in soybean cotyledons. The insect is now being reared in the laboratory in the same manner as the beanfly.

Biology of *Ophiomyia centrosematis* (Diptera: Agromyzidae), a Pest of Soybean

Summary

The biology of an agromyzid pest, *Ophiomyia centrosematis* (De Meijere), was studied under laboratory conditions utilizing soybean as a host plant. The insect laid eggs just underneath the epidermis in the hypocotyl of young seedlings. Oviposition started on the third day and lasted until the 18th day after adult emergence. Most of the eggs were laid between 11 a.m. and 5 p.m. On the average, a single female laid 63.2 ± 13.7 eggs in her lifetime. Larvae which fed on cortex tissue had three instars during 10.9 ± 1.9 days of the larval period at 28°C. Pupation took place in the cortex tissue and pupal period was 11.0 ± 0.8 days at 28°C. Despite numerous eggs being laid, a maximum of only two pupae were found per plant. Adults emerged between 11 a.m. and 1 p.m. at room temperatures of 18° to 20°C and between 7 a.m. and 9 a.m. at 28° to 32°C. Most of the matings took place between 5 a.m. and 8 a.m. The longevity of the male adult was 15.4 ± 5.6 days while that of the female was 12.4 ± 4.1 days. Within the range of 20° and 35°C, the developmental stages were shorter when the temperature was higher. Under laboratory conditions, *O. centrosematis* infested 15 common legume crops. The insect completed all growth stages successfully on soybean, mungbean, snap bean, adzuki bean, cowpea, pigeon pea, horsegram and alfalfa. On black gram, rice bean and faba bean, the larvae mined into the stem but failed to pupate and on moth bean, chickpea, lentil and cluster bean, the insect oviposited but the eggs failed to hatch. *O. centrosematis* oviposition in soybean increased with increasing plant age between three and seven days after germination. It declined thereafter.

Introduction

Ophiomyia centrosematis (De meijere) (Diptera: Agromyzidae) was first found in Indonesia feeding on *Centrosema pubescens* Benth. by De Meijere in 1940. Since then this species had been reported to feed on a wide variety of economically important legumes practically throughout Asia and East Africa. In soybean, this species along with *O. phaseoli* (Tryon) and *Melanagromyza sojae* (Zehntner) form an important agromyzid pest complex that causes considerable yield loss and, at times, outright plant mortality in Southeast Asia, especially in areas closer to the equator.

The insect larva feeds on the cortex tissue just underneath the stem epidermis, especially during seedling stage. *O. centrosematis* in soybean rarely occurs alone and its damage is sometimes confused with that of the more widespread and destructive *O. phaseoli*. As a result, its damage is not quite appreciated with only scanty information on its biology and nature of damage.

The biology of this pest was studied at AVRDC under laboratory condition. The experiments were especially designed to get detailed information on its oviposition, temperature requirements and host range to enable the development of suitable control measures.

Materials and Methods

Insect source. Pupae of *O. centrosematis* were collected from soybean plants in the field. They were placed in a petri dish lined with moist filter paper and the adults that emerged were transferred

into nylon net cages (30 × 30 × 30 cm) containing several potted soybean seedlings for feeding and oviposition. The soybean plants were initially grown in pots (10 cm diameter) in a greenhouse and transferred to cages just before the introduction of *O. centrosematis* adults. The cages containing soybean plants and the insects were maintained in an incubator set at 28 ± 1°C, 75 ± 5% relative humidity (RH) and 12:12 (L:D) photoperiod. The eggs, larvae, pupae and adults from this culture were utilized for biological studies.

Oviposition. Two potted soybean seedlings were placed in a cage and one pair of 5-day old adults (one male and one female) was released inside. The cage was placed in an incubator maintained at 28 ± 1°C, 75 ± 5% RH and 12:12 (L:D) photoperiod. The host plant parts on which the adults alighted and laid eggs were recorded during frequent observations. After 24 hours each soybean plant was dissected to locate the eggs within the plant parts. This procedure was repeated several times to ascertain the oviposition sites.

In another study, a pair of newly emerged adults was confined in each of the 15 cages, each containing two potted soybean seedlings. The insects were maintained at 28°C in an incubator. The soybean plants were replaced with fresh ones everyday. The replaced plants were dissected to record the number of *O. centrosematis* eggs laid. The number of eggs laid daily per female was calculated.

In a related study, the periodicity of oviposition was investigated in the laboratory in January 1987 at room temperature of 18° to 20°C and in May 1987 at 28° to 32°C. Twenty pairs of 5-day old insects were confined with potted soybean seedlings in a cage. Fresh seedlings were replaced every two hours throughout the day, and the number of eggs laid during a given two-hour interval was computed for the following four days.

Larval stage. Immediately after egg hatching, which was observed through a window made intentionally in the stem epidermis, the progress of larval development was monitored daily by tracing the movement and development of the larvae in the mines. The number of larval instars was judged by the presence of exuviae in the individual feeding tunnel in the stem epidermis. At each larval instar, the length of the cephalopharyngeal apparatus and the larval body was measured. These measurements were subjected to a simple linear regression and correlation analysis to establish correlation between the two parameters.

Pupation. Plants infested with *O. centrosematis* were dissected and the location and number of pupae found per plant were recorded.

Adult. Pupae collected from the infested plants were placed in a petri dish and the emergence of adults was monitored by recording the number of adults that emerged for 17 consecutive days in January 1987 at room temperatures of 18° to 20°C and for 13 consecutive days in May 1987 at room temperatures of 28° to 32°C.

Several pairs of *O. centrosematis* adults were confined in net cages containing potted soybean seedlings. The mating was observed every two hours throughout the day for 14 consecutive days during May 1987 at room temperatures of 28° to 32°C.

An equal number of freshly emerged males and females were confined in net cages containing potted soybean plants. The cages were placed in an incubator at 28°C. The insects were observed daily until all of them died. The longevity of male and female was recorded separately.

Effect of temperature on the duration of various growth stages. Potted soybean seedlings were confined in a cage containing a large number of *O. centrosematis* adults. After four hours of exposure for oviposition, the plants were removed and placed in separate cages. The cages were maintained in incubators at 20° ± 1°, 25° ± 1°, 30° ± 1°, or 35° ± 1°C, which have 75 ± 2% RH and 12:12 (L:D) photoperiod. The duration of egg stage, three larval instars and pupal stage were recorded.

Host plants. Seedlings of 16 legumes, namely, soybean (*Glycine max* L. Merrill), mungbean (*Vigna radiata* L. Wilczek), snap bean (*Phaseolus vulgaris* L.), moth bean (*Vigna aconitifolia* Jacq. Marechal), adzuki bean (*Vigna angularis* Willd. Ohwi & Ohashi), black gram (*Vigna mungo* L. Hepper), rice bean (*Vigna umbellata* Thunb. Ohwi & Ohashi), cowpea (*Vigna unguiculata* L. Walp., ssp. *unguiculata* cv. gr. *unguiculata*), chickpea (*Cicer arietinum* L.), pigeon pea (*Cajanus cajan* L. Millsp.), lentil (*Lens esculenta* Moench), horsegram (*Dolichos biflorus* L.), chickling vetch (*Lathyrus sativus* L.), alfalfa (*Medicago sativa* L.), cluster bean (*Cyamopsis psoraloides* DC) and faba bean (*Vicia faba* L.) were grown in clay pots maintained in a greenhouse. Thirty seedlings of each crop were exposed to 5-day old adults of *O. centrosematis* for two days. At suitable intervals, five seedlings of each host were dissected and the location of eggs, egg hatching, larval feeding, pupation and adult emergence was observed.

In another experiment, 1- to 12-day old soybean seedlings grown in pots and initially maintained in a greenhouse were transferred to a soybean field for *O. centrosematis* oviposition. Twenty-four seedlings of each age group were dissected open after two days of exposure and the number of *O. centrosematis* eggs laid was recorded. From the data on total number of eggs laid, the percentage oviposited in the seedlings of each age group was computed.

Results and Discussion

Oviposition. *O. centrosematis* females hovered over the soybean plant and alighted on the foliage but descended to the stem and laid eggs in the stem below the cotyledon (hypocotyl). The adults did not make the characteristic feeding punctures in the foliage which is a common symptom of *O. phaseoli and M. sojae* infestation in all host legumes. *O. centrosematis* obviously made these punctures in the hypocotyl where it laid eggs. The eggs were inserted just underneath the epidermis (Fig. 2). Oviposition in the stem above the cotyledons was never found.

Oviposition started on the third day after adult emergence from pupae and peaked on the seventh day (Fig. 3) before tapering off and eventually stopped on the 18th. During the oviposition period one female, on the average, laid 63.2 ± 13.7 (range 45-85) eggs (Table 7). The periodicity of oviposition did not differ under laboratory conditions whether such phenomenon was studied in January at 18° to 20°C or in May at 28° to 32°C room temperature. Most of the eggs were laid between 11 a.m. and 5 p.m. with the peak oviposition occurring between 1 to 3 p.m. (Fig. 4).

Larval stage. Larvae fed on the cortex just underneath the epidermis of soybean stems (Fig. 5). There were three larval instars. The first instar larva was practically transparent while the second and third instars were milky white. The larval color changed to opaque before pupation. The duration of the larval stage at 28°C was 10.9 ± 1.9 days (range 9-14) (Table 7). There was a linear increase in the length of the cephalopharyngeal apparatus from the first through the third instar. The increase was by a factor of 2 from the first to the second and by a factor of 1.5 from the second through the third instar. A significant positive correlation ($r = 0.976$, $P<0.05$) was found between the length of the cephalopharyngeal apparatus and the larval body.

Table 7. Life history characteristics of *O. centrosematis* reared at 28°C.

Characteristic	Mean ± standard deviation (range)
Longevity	
male	15.4 + 5.6 days (6-24)
female	12.4 + 4.1 days (6-21)
Pre-mating period	2.5 days (2-3)
Pre-oviposition period	3.5 days (3-4)
No. of eggs per female	63.2 + 13.7 (45-85)
Oviposition period	12.2 + 3.8 days (3-18)
Larval period	10.9 + 1.9 days (9-14)
Pupal period	11.0 + 0.8 days (10-13)

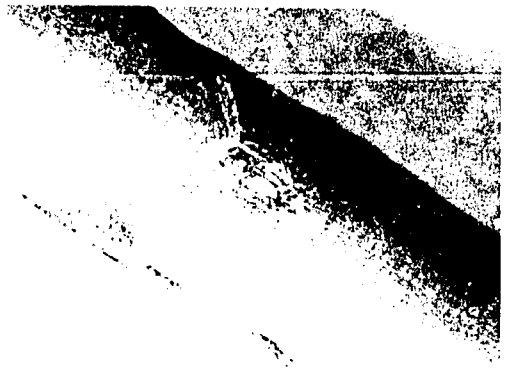

Fig. 2.
O. centrosematis egg just underneath the epidermis in the hypocotyl of soybean seedling (12 X).

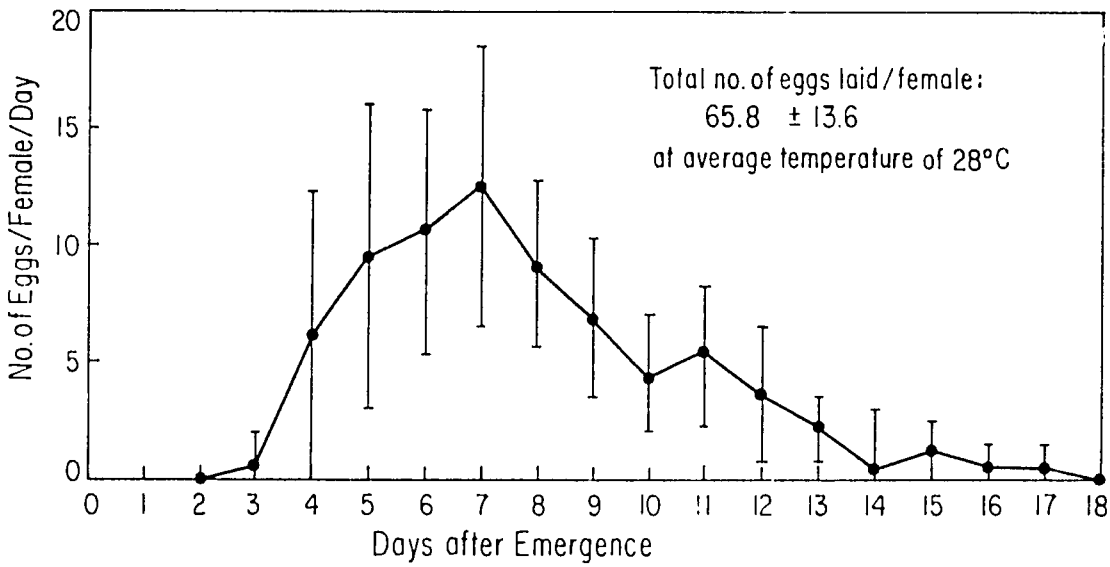

Fig. 3. Daily pattern of *O. centrosematis* oviposition in soybean.

Pupal stage. Pupation took place in the cortex tissue (Fig. 6) just underneath the epidermis at the root shoot junction. Initially the pupa was light yellow turning to golden yellow and dark yellow just before adult emergence. Pupal period at 28°C, on the average, lasted 11.0 ± 0.8 days ranging from 10 to 13 days. Although *O. centrosematis* laid up to 13 eggs/plant, there were, on the average, only two pupae per plant (Fig. 7). The higher the number of eggs per plant, the lesser was the pupation rate. The insects apparently suffered considerable mortality due to natural causes during egg and larval stages.

Adult. In January at 18° to 20°C room temperature, the peak adult emergence time was between 11 a.m. to 1 p.m., whereas in May at 28° to 32°C room temperature, the peak was between 7 and 9 a.m. (Fig. 8). In 98% cases in January and 100% cases in May, adult emergence was during the daylight hours. Temperature seems to influence the time of adult emergence from pupae; however, it is difficult to ascertain the mode in which the temperature might influence this phenomenon since the length of pupal period was dissimilar in two months. It is possible that in addition to daylight, certain minimum temperature is necessary to initiate the process of adult emergence. In cool January such temperatures are reached during noon hours, whereas in warm May it occurs much earlier.

Mating time ranged from 5 a.m. to 2 p.m. However, most of the matings occurred between 5 and 8 a.m. with the peak between 6 and 7 a.m. at room temperatures of 28° to 32°C (Fig. 9). The

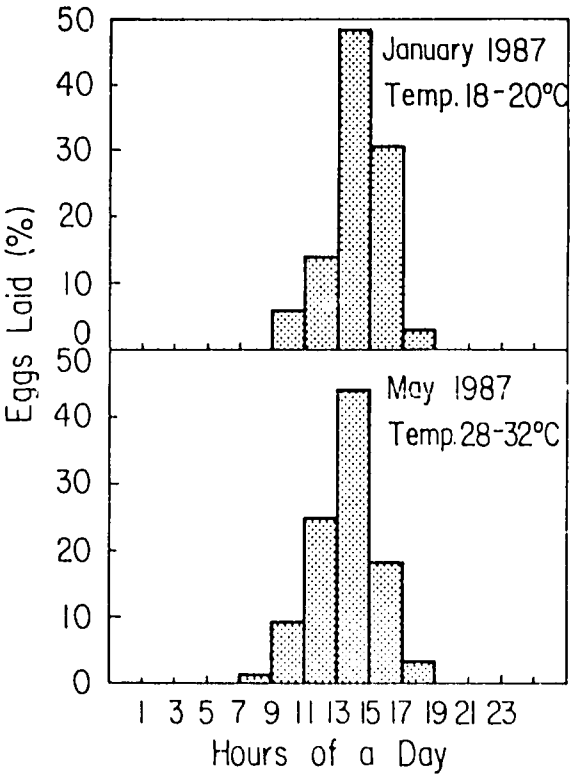

Fig. 4.
Periodicity of *O. centrosematis* oviposition in soybean under laboratory condition at two different times.

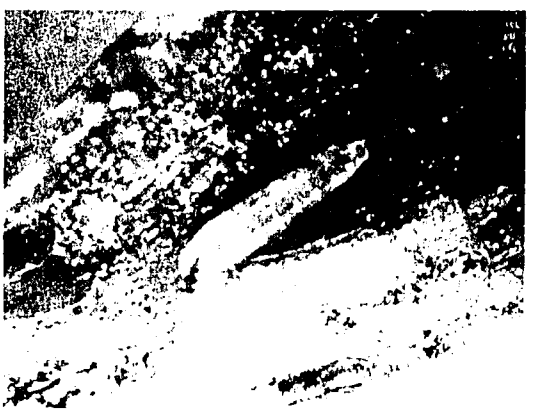

Fig. 5.
O. centrosematis third instar larva feeding underneath the epidermis in the soybean stem (6 x).

Fig. 6. *O. centrosematis* pupa in cortex tissue at the root stem junction in soybean (3 X).

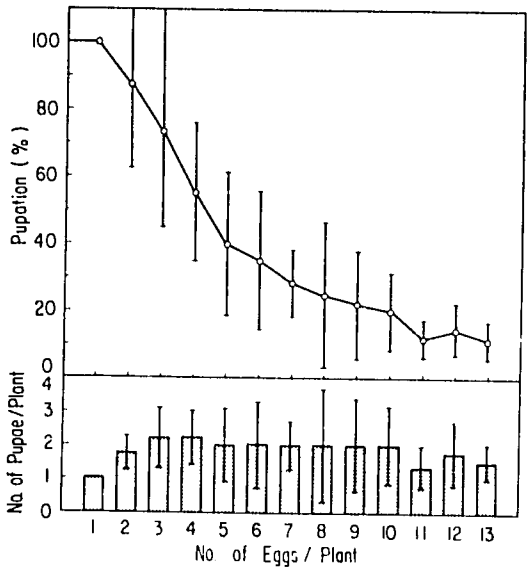

Fig. 7. Observation on the *O. centrosematis* oviposition and pupation in soybean plant.

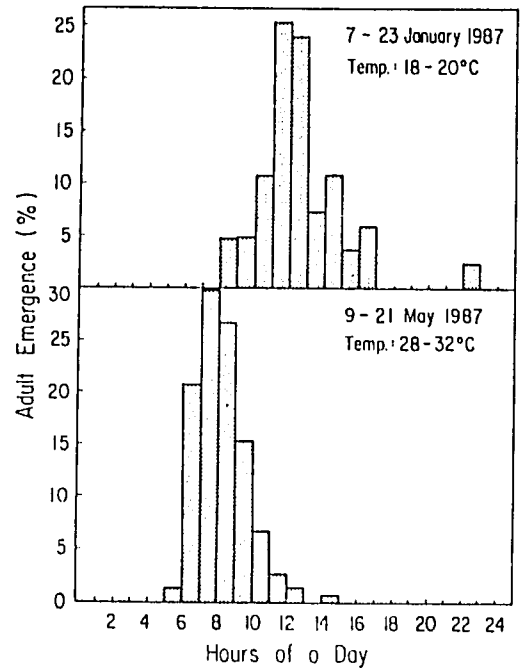

Fig. 8. Periodicity of *O. centrosematis* adult emergence from pupae at two different room temperature conditions.

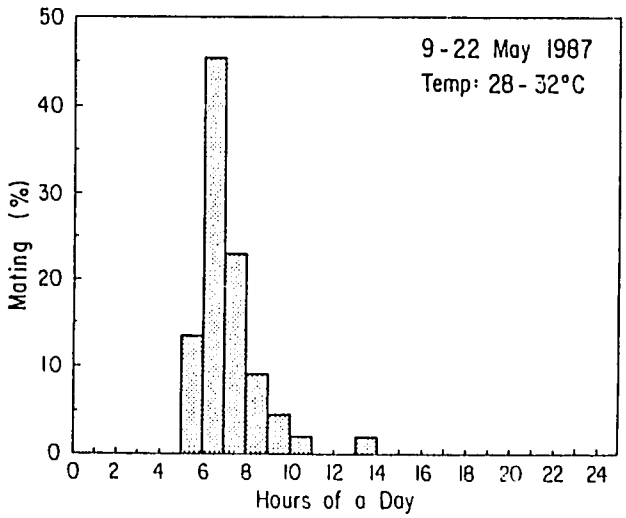

Fig. 9. Periodicity of *O. centrosematis* mating under room temperature.

longevity of adults was 15.4 ± 5.6 days ranging from 6 to 24 days for male and 12.4 ± 4.1 days ranging from 6 to 21 for female under laboratory condition (28 ± 1°C) (Table 7).

Effect of temperature on duration of various growth stages. Duration of egg, larval and pupal stages was influenced by the temperatures between 20° and 35°C (Table 8). The higher the temperature, the shorter was the growth stage. The egg stage which ranged from 7.0 ± 1.1 days at 20°C was reduced to 1.5 ± 0.3 days at 35°C. Similarly, the duration of larval and pupal stages was reduced from 20.7 ± 0.5 and 27.8 ± 2.4 to 7.9 ± 0.6 and 7.1 ± 0.7 days, respectively, at

Table 8. Influence of rearing temperature on the duration of various life stages of *O. centrosematis* on soybean seedlings.[z]

Temperature (°C)	Duration (days)					
	Eggs stage[y]	Larval stage				Pupal stage[y]
		1st instar	2nd instar	3rd instar	Total[y]	
20	7.0 ± 1.1	9.0	5	6	20.7 ± 0.5	27.8 ± 2.4
25	4.0 ± 0.3	5.0	3	4	12.5 ± 0.8	12.7 ± 0.8
30	2.5 ± 0.4	3.5	3	3	9.9 ± 0.7	8.4 ± 1.0
35	1.5 ± 0.3	2.5	2	3	7.9 ± 0.6	7.1 ± 0.7

[z]Photoperiod: 12 hours light, 12 hours dark. [y]Mean ± standard deviation.

the above temperatures. Based on these results, in Taiwan's autumn season, when soybean is traditionally grown and when temperature averages around 25°C, three to four generations of *O. centrosematis* can be expected in one growing season. It must be emphasized, however, that the infestation by this and other agromyzids cause yield loss only when the damage occurs during the first four weeks after germination. Thus, only the first two generations will be of any consequence in soybean cultivation in Taiwan.

Host plant interaction. Among the 16 common legumes offered for infestation, *O. centrosematis* laid eggs in all but chickling vetch. Moth bean, chickpea, lentil and cluster bean were not conducive to egg hatching and to the emergence of the first larval instar (Table 9). Except for moth bean, none of the remaining three legumes are known to be hosts of *O. centrosematis* or other stem-feeding agromyzids. The insect was able to feed, pupate and successfully emerge from the pupae when it infested soybean, mungbean, snap bean, adzuki bean, cowpea, pigeon pea, horsegram and alfalfa. Except for the last crop, all are important food legumes in tropical to subtropical Asia where this insect is most prevalent. Among the crops chosen only one cultivar of each was used. It is possible that other cultivars of these crops could react differently in sustaining *O. centrosematis* damage.

Among the plant species that could be infested by *O. centrosematis*, soybean is the most widely grown and economically more important in Southeast Asia. *O. centrosematis* oviposition in the hypocotyl of soybean increased with plant age from two eggs/plant in a 3-day old plant to 23 eggs/plant in a 7-day old plant. The number declined thereafter to 10 eggs/plant in 8- to 12-day old plants. This implies that one must adopt control measures within a week after germination to control this pest.

Table 9. Infestation and development of *O. centrosematis* on seedlings of various legume species.[z]

Plant species	Oviposition	Egg hatching and larval feeding	Pupation	Adult emergence
Soybean	+	+	+	+
Mungbean	+	+	+	+
Snap bean	+	+	+	+
Moth bean	+	–	–	–
Adzuki bean	+	+	+	+
Black gram	+	+	–	–
Rice bean	+	+	–	–
Cowpea	+	+	+	+
Chickpea	+	–	–	–
Pigeon pea	+	+	+	+
Lentil	+	–	–	–
Horsegram	+	+	+	+
Alfalfa	+	+	+	+
Cluster bean	+	–	–	–
Faba bean	+	+	–	–

[z] + indicates egg laying, egg hatching, successful pupation and adult emergence; – indicates absence of egg laying, egg hatching, pupation and adult emergence.

Study of Sex Pheromone Activity in Beanfly

Summary

Laboratory experiments were conducted to determine whether the classic sex pheromone activity occurs in the beanfly, *Ophiomyia phaseoli* (Tryon). Mating activity occurred mainly between 24 and 48 hours after emergence. Repeated sex pheromone bioassay utilizing Y tube and one- to two-day old virgin females and unmated males indicated that the classical sex pheromone activity common in insects belonging to Lepidoptera does not occur in either females or males of *O. phaseoli*.

Introduction

Beanfly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae), is an important pest of several economically important legumes including soybean, mungbean, snap bean and cowpea in tropical to subtropical Asia, Africa and the Pacific. The insect lays eggs in cotyledons (in soybean) or in foliage and larvae bore into the stems, especially in young plants. As a result, the infested plant dies or is severely weakened which causes yield reduction. Pupation takes place in the stem near the soil surface.

Although the sex pheromone activity is well documented in the lepidopterous insects, very little information exists on the presence of sex pheromone in dipterous insects. In the case of beanfly, no published information exists on this aspect. In the experiments described here, the existence of sex pheromone in this insect was studied.

Materials and Methods

Mating periodicity. A large number of freshly emerged beanfly adults were obtained from AVRDC's mass-rearing program. The insects were placed in a nylon net cage with one potted soybean plant and a cotton plug soaked in sugar solution to serve as food to the adults. The insects were observed continuously once every hour for 48 hours. The number of insect matings was recorded every hour.

Periodicity of adult emergence. Two hundred pupae were placed in a glass petri dish and the number of adults that emerged once every four hours until all the pupae emerged into adults were recorded.

Pre-mating and mating periods. Two hundred pairs (100 males and 100 females) of newly emerged beanfly adults were confined in a cage (30 × 30 × 30 cm) and observed once every hour until mating occurred. Subsequently, the mating occurrence was observed every hour in the morning between 5 to 8 a.m. and in the afternoon between 2 to 5 p.m. The number of insects mating every hour was recorded.

Sex pheromone bioassay. Twenty-one- to 24-day old virgin females and 20 unmated males of the same age were placed in two separate arms of a Y tube. The third arm was kept empty to serve as a check. Either male or female arm of the Y tube was then attached to a laboratory suction outlet to gently suck the air. In this manner the air passed from over either male or female and empty arm to the insects of the opposite sex. During the process the arms of the Y tube were rotated to compensate for the possible effect of light on the attraction of the insect. This test was done at a time when, based on earlier results, the mating activity was at its peak. Insect movement was observed and the number of insects attracted to the opposite sex was recorded.

Results and Discussion

Mating periodicity. The separation of insects into males and females for this and other studies was done by observing the abdominal tip of the insects. The presence of a prominent ovipositor at the abdominal tip distinguished the female from the male which possesses a blunt and rounded tip (Fig. 10).

The results of the mating periodicity of *O. phaseoli* are summarized in Figure 11. There were two peaks for mating activity. The first and more prominent peak occurred between 6 and 7 a.m. and

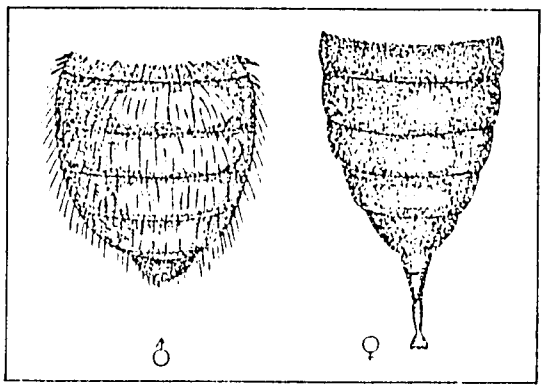

Fig. 10. Morphological features of abdominal tips of male and female *O. phaseoli*.

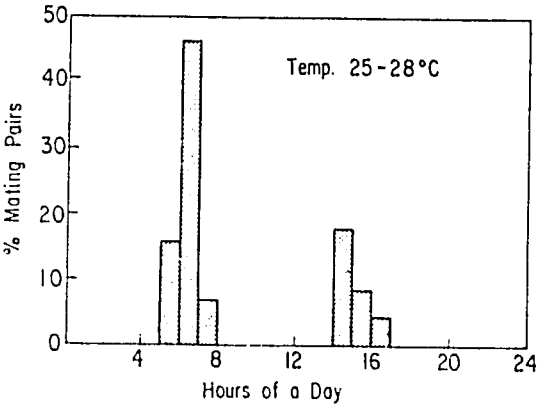

Fig. 11. Mating periodicity of beanflies.

the second less prominent between 2 and 3 p.m. Mating periodicity was obviously related to the photoperiod and possibly temperature. These results provide valuable information on the ideal time to conduct experiments on sex pheromone bioassay.

Periodicity of adult emergence. The results of the observation on the periodicity of adult emergence are depicted in Figure 12. Almost all of the insects emerged during daytime. There was no significant difference in the emergence time of male and female insects. In daytime, majority of adults emerged between 8 a.m. and 12 noon. Based on the results of the mating periodicity study, the mean time of emergence is later than the mean mating time. This implied that the beanflies mated in most cases one day after emergence.

Pre-mating period. None of the adults mated the same day of emergence. About 28.8% matings occurred the day after adult emergence (16 to 20 hours after emergence). Most of the insects mated within the first two days, with peak occurring on the second day (Fig. 13). These results indicated that the pre-mating period in *O. phaseoli* is about 20 hours and two-day old female is sexually mature for mating. These results provide valuable information in choosing the virgin female of appropriate age for the sex pheromone bioassay.

Sex pheromone bioassay. The results of the bioassay of sex pheromone activity are summarized in Table 10. When the male-containing arm was placed facing the light, the males, no matter

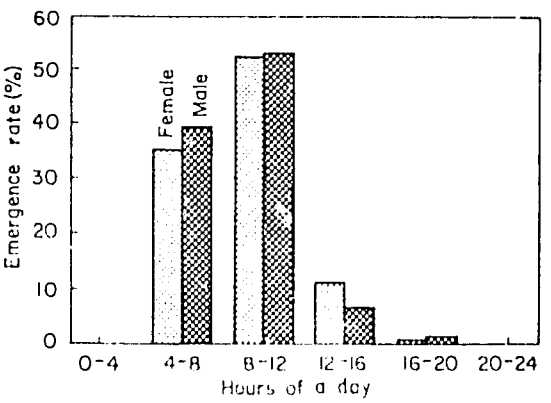

Fig. 12. Periodicity of beanfly adult emergence.

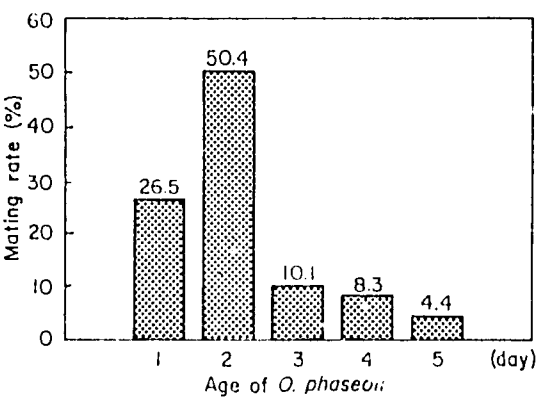

Fig. 13. Mating pattern in beanflies at various days after emergence from pupae.

what age, hardly moved to the other two arms. This indicated that the light provided a stronger stimulus than the perception of sex pheromone, assuming such chemical exists in beanfly. On the other hand, when both female and check arms were placed facing the light with the female-containing arm slightly facing the stronger light, most of the males moved towards the arms containing females. But when the check arms were placed nearer the light, more males moved towards the check arms. This indicated that sex pheromone may exist in beanflies but the stimulus of such a chemical is very weak.

Since no information exists on the sex pheromone aspect of beanfly, the possibility of sex pheromone on the male was also studied. The male and female arms in the Y tube were interchanged and the whole experiment repeated. The results summarized in Table 11 indicate that no marked number of female adults moved to the male adult-containing arm of the Y tube. This indicated that the sex pheromone does not exist in male beanflies.

Table 10. Bioassay of sex pheromone activity in beanfly females.[z]

Observation time (min)	Number of male insects attracted to					
	female arm facing light		check arm facing light		male arm facing light	
	female arm	check arm	female arm	check arm	female arm	check arm
10	1	0	1	9	0	0
20	3	0	6	11	0	0
30	5	1	4	13	0	0
40	7	1	7	12	0	0
50	7	2	6	12	0	0
60	9	3	8	10	0	0
70	14	4	6	11	0	0
Total	46	11	38	76	0	0

[z]One-day old females and males. Similar trend was observed when two-day old females and males, three-day old females and males, and four-day old females and males were used.

Table 11. Bioassay for the presence of male sex pheromone in beanflies.[z]

Observation time (min)	No. of female adults attracted to	
	male arm	check arm
10	6	6
20	5	0
30	4	4
40	3	4
50	3	4
60	1	3
70	2	4

[z]Two-day old females and males.

Insecticide Screening for Beanfly (mainly *Melanagromyza sojae*) Control in Soybean

Summary

Among nine organophosphorus, synthetic pyrethroid and insect growth regulators tested, cyromazine, an insect growth regulator, gave control of beanflies comparable to the standard organophosphorous chemical, omethoate.

Introduction

In tropical and subtropical areas of Asia, Africa, Australia and Oceania, agromyzid flies (*Ophiomyia phaseoli* [Tryon], *O. centrosematis* [De Meijere] and [*Melanagromyza sojae*] [Zehntner]) cause serious damage and yield loss in soybean. The adults, depending upon the species involved, lay eggs in hypocotyl or cotyledons or unifoliate and early trifoliate leaves of soybean in seedling stage, and the larvae mine the stems. As a result of their infestation, the plants are either killed or the yield is reduced considerably in surviving plants.

At present the use of insecticides is the most effective and practical method for controlling these pests. Due to the high soil pH at AVRDC, the use of systemic insecticides applied to soil at planting and seed dressing have limited utility in controlling these pests. Among insecticides used as foliar sprays, dimethoate, monocrotophos and omethoate were very effective in the past. However, in recent years dimethoate has lost effectiveness and monocrotophos' efficacy is slowly decreasing. Only omethoate gives effective control still. Since all three insecticides are structurally related and, dimethoate and monocrotophos already show signs that insects might have developed resistance to them after they have been used for a period of time, it is possible that omethoate will soon be rendered less effective. It is, therefore, necessary to find a substitute insecticide. In recent years a new type of chemicals, commonly called insect growth regulators or IGRs, have been developed and are selective in controlling pests while sparing the parasites. One insecticide screening was conducted during 1986-87, in which several IGRs were tested to control beanflies, mainly *M. sojae*, on soybean.

Materials and Methods

A parcel of land was rototilled and worked into 1-m wide raised beds. The beds were further divided into 3.3 m × 3 m plots. Seeds of cultivar KS 9 were sown in two parallel rows set 40 cm apart on each bed and at a distance of 10 cm between hills, at the rate of four to five seeds per hill in each plot. Fertilizer application, weeding, thinning, irrigation and other necessary cultural practices were followed.

There were 10 treatments including a control, replicated four times and arranged in a randomized complete block design. Predetermined quantities of insecticide formulations were diluted in water and sprayed on each plot with a 10-liter air-pressure sprayer charged to 2.7 kg/cm^2 (40 psi). A 0.5-liter spray volume (50% of the designated quantity of the active ingredient) was applied per plot during the first four applications and 1 liter/plot (1,000 liters/ha) at the succeeding three applications. Each sprayer was individually calibrated with a stopwatch and specific volumes of spray solution could be accurately and uniformly delivered to each plot to ensure that a specified amount of active ingredient was applied. Sprayings were done at 3, 7, 10, 14, 21, 28 and 35 days after emergence (DAE).

Insecticide effectiveness was evaluated at 21 and 35 DAE. Thirty plants at random were uprooted from each plot. Each plant was cut open and the number of larvae and pupae found within the stems was recorded. Likewise, the number of plants with visible beanfly damage, but without larvae or pupae, was also recorded.

Starting 35 days after emergence, the entire experiment was protected against other pests by occasional sprays of fenvalerate. At harvest, seed yield from each plot was recorded. All data were analyzed by ANOVA followed by Duncan's multiple range test.

Results and Discussion

The results of the insecticide screening are summarized in Table 12.

Cyromazine (N1-cyclopropyl-1, 3, 5-triazin-2, 4, 6-triyl-triamine), a new insect growth regulator, gave as good control of *M. sojae* as the standard check, omethoate. This was the first insect growth regulator that was found effective on dipterous insects, in general, and beanflies, in particular. At both observation intervals, the number of beanfly larvae and pupae found inside the treated soybean plants was the lowest among all insecticides tested. This chemical, however, is not effective against leafroller, *Hedylepta indicata*, which caused considerable damage to soybean in autumn 1986. Hence, despite excellent beanfly control seed yield was low. Since this chemical is safer to parasites, future research will concentrate on this chemical to reduce the number of sprays required and at the same time get the best beanfly control.

Table 12. Insecticide screening for agromyzid beanfly control on soybean.[z]

Chemicals	Rate (kg a.i./ha)	No. of beanfly larvae + pupae /30 plants		Damaged plants (%)		Leafroller damaged plants (%)	Yield (kg/200 plants)
		86/10/31	86/11/14	86/10/31	86/11/14		
Cyromazine 10% SL	0.15	2.5 c	1.7 d	71.7 cd	39.2 d	21.1 a	1.42 b
Fastac 3EC	0.03	21.2 b	20.5 ab	83.3 bc	85.8 a	6.3 a	1.67 ab
WL115110 5EC	0.05	21.0 bc	15.0 c	85.8 ab	90.0 a	3.7 a	1.60 ab
Applaud 25WP	0.05	24.0 b	19.5 ab	93.3 ab	87.5 a	14.2 a	1.49 ab
Karate 25EC	05	13.2 c	8.0 d	55.0 ef	45.8 cd	7.5 a	1.65 ab
BAS 166801 50EC	0.05	30.2 a	22.0 a	98.3 a	93.3 a	3.1 a	1.56 ab
BAS 178500 50EC	0.05	2.0 a	16.7 bc	91.6 ab	89.2 a	3.5 a	1.55 ab
Monocrotophos 55EC	0.50	14.2 c	13.0 cd	63.3 de	67.5 b	12.6 a	1.81 a
Omethoate 50EC	0.50	7.2 c	5.5 d	50.0 f	56.7 bc	15.8 a	1.71 ab
Control		26.2 ab	21.0 a	90.0 ab	89.2 a	23.9 a	1.46 ab

[z]Cultivar: AGS 66. Planted 3 October 1986 and harvested 13 January 1987. Insecticides applied: 13, 16, 20, 24 and 30 October, 6 and 13 November 1986. Data are means of four replicates. Means in each vertical column followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test. Plot size: 10 m^2 (1/1,000 ha).

Biology of a Stink Bug, *Riptortus clavatus*

Summary

The biology of a stink bug, *Riptortus clavatus* Thunberg, was studied in the laboratory utilizing soybean plants. Egg stage lasted from 4.2 days at 35°C to 12.6 days at 20°C and egg mortality increased from 5% at 20°C to 19.2% at 35°C. Very high nymphal mortality was observed at 20°C. There were five nymphal instars with the total nymphal period lasting from 13.9 days at 35°C to 22.8 days at 25°C. There was a highly significant positive correlation between the progression of nymphal instars and the lengths of the body and antennae. Adults survived for 22.8 days. Eggs were laid singly, mostly on the foliage. Oviposition lasted from 3 to 24 days after adult emergence. A total of 129 eggs were laid by a single female.

Introduction

The stink bug, *Riptortus clavatus* Thunberg (Hemiptera: Coreidae), is a polyphagous insect that feeds on developing seeds of soybean and several other species, particularly those belonging to family Leguminaceae. This pest is pantropical and especially serious in Southeast Asia on economically important legumes such as soybean and mungbean. Since detailed published information on this insect's biology and ecology is scanty, a rational method of controlling it has not yet been developed. The objective of this study, therefore, was to study the biology of this insect.

Materials and Methods

Insect rearing. *R. clavatus* adults were collected from soybean plants in the AVRDC campus and placed in a round acrylic cylinder containing one potted soybean plant and several excised R_4-R_5 stage soybean pods. The insects moved over the plant but fed on the pods and laid eggs on the muslin cloth which was used to cover the top of the cylinder. Eggs were collected once every 24 hours and used for various studies.

Temperature effect study. **Egg stage:** Every day for four consecutive days, 120 eggs were collected and 30 eggs each were placed in four petri dishes lined with moist filter paper. Each petri dish was regarded as one replicate. The eggs were then placed in an incubator maintained at one of the four temperatures: 20°, 25°, 30° or 35°C. The eggs were observed twice daily and their mortality and length of incubation recorded.

Nymphal stage: A large number of first instar nymphs was collected and an approximately equal number (about 25) were placed in each of the four glass jars containing R_4-R_5 stage soybean pods, each jar representing one replicate. The jars were then placed in an incubator maintained at one of the four temperatures: 20°, 25°, 30° or 35°C. The insects were observed twice daily to record their mortality, molting and emergence of next instar nymph. As soon as the insect molted, they were transferred into a new jar containing fresh soybean pods.

Body measurements. In a separate rearing experiment done at room temperature (24° ± 5°C), the lengths of body and antennae were measured during each nymphal instar. Body length was recorded between the anterior end of the head and posterior end of the abdomen. Antennal length was measured between the proximal end of the first segment to the distal end of the last antennal segment. These measurements were statistically analyzed by linear regression to determine the correlation between the two morphological characters.

Adult biology. Longevity: Freshly emerged *R. clavatus* adults were placed in several rearing jars containing one potted soybean plant and several excised soybean pods as described earlier. The insects were observed daily. The soybean pods were changed with freshly harvested ones whenever necessary. Longevity of each sex was determined separately.

Mating: One pair (one male and one female) of freshly emerged adults was placed in each of the four rearing jars containing a potted soybean plant and fresh soybean pods. The insects were observed every hour to determine the length of pre-mating period.

In a separate study, mating periodicity of *R. clavatus* was observed over a 24-hour period throughout the day. To accomplish this, a large number of adults was collected from soybean fields in the AVRDC campus. Twenty pairs were transferred into each of the four rearing jars containing one potted soybean plant and fresh pods. Each jar represented one replicate. The number of pairs in copula was recorded every hour throughout the day.

Oviposition. Pre-oviposition period: The insects used for the study of pre-mating period were held further and the period between the emergence of females from the fifth instar nymph and first egg laying was determined by observing the egg laying several times a day.

Oviposition periodicity: Adults used for mating periodicity were maintained in the cages and the number of eggs laid was recorded once every two hours.

Oviposition sites: In a separate study several mated pairs were confined in cages containing potted soybean plants of R_3 growth stage. The number of eggs laid on different plant parts such as leaves, inflorescences, stems and pods was recorded.

Oviposition duration: Immediately after adult emergence, pairs of *R. clavatus* adults were confined in rearing jars, one pair per jar. The rearing jars contained dry soybean seeds and a beaker containing water to maintain humidity. The number of eggs laid on the muslin cloth that covered each rearing jar was recorded daily until oviposition ceased.

Results and Discussion

Egg stage. Duration of egg stage decreased progressively from 12.6 days at 20°C to 4.2 days at 35°C (Table 13). This observation agrees with the principle of an inverse but linear relationship between temperature and time required to complete development. Egg mortality ranged from 5% at 20°C to 19.2% at 35°C (Table 14). Mortality increased proportionally with temperature from 20 to 35°C.

Nymphal stage. The development of the nymphs, similar to the egg stage, was prolonged considerably at 20°C than at higher temperatures (Table 13). A very high mortality was observed in first and second instar nymphs and by the end of third instar all insects at 20°C died (Table 14).

Table 13. Duration of various growth stages of *R. clavatus* reared at different temperatures.

Temperature (°C)	Duration (days)						
	Egg	Nymphal stages					Total nymphal period
		1	2	3	4	5	
20	12.6 ± 2.0	5.5 ± 0.5	10.0 ± 1.6	10.1 ± 1.6	n.a.*	n.a.	
25	5.5 ± 0.7	2.9 ± 0.3	4.3 ± 0.9	4.2 ± 0.7	5.1 ± 0.5	7.3 ± 0.6	22.8 ± 1.6
30	4.5 ± 0.7	2.3 ± 0.4	3.7 ± 0.9	3.9 ± 1.1	4.0 ± 0.6	5.3 ± 0.7	18.6 ± 2.0
35	4.2 ± 0.2	1.6 ± 0.3	2.7 ± 0.3	3.0 ± 0.7	3.2 ± 1.2	3.9 ± 0.5	13.9 ± 1.3

*n.a. = Not available.

Table 14. Mortality of *R. clavatus* eggs and nymphs reared at various temperatures.

Temperature	Mortality (%)						
	Egg	Nymphal stages					
		1	2	3	4	5	cumulative
20	5.0 ± 8.7	24.1 ± 20.2	69.2 ± 26.6	1.0 ± 2.1	n.a.*	n.a.	
25	9.2 ± 6.9	19.8 ± 18.1	4.2 ± 3.4	16.4 ± 14.7	1.1 ± 2.2	0	43.3 ± 6.4
30	17.9 ± 12.6	15.0 ± 7.5	37.9 ± 17.3	10.5 ± 7.5	8.2 ± 5.5	0	72.4 ± 8.6
35	19.2 ± 6.3	13.9 ± 5.6	25.2 ± 10.6	19.5 ± 11.3	3.4 ± 2.2	1.1 ± 2.2	65.4 ± 19.0

*n.a. = Not available.

It is possible that a low temperature of 20°C is unsuitable for the development of this insect. Indeed in AVRDC's insect pest monitoring study, this insect was found to infest soybean and mungbean only during summer. Therefore, only the nymphal stage development at 25°, 30° and 35°C was studied. Within this temperature range, the duration of each nymphal instar and the total nymphal period decreased as the temperature increased. Cumulative insect mortality was considerable but it was not related to the temperature at which the insects were reared.

Physical measurements. There was a highly significant positive correlation between the progression of nymphal instars and the length of the insect's body (r = 0.974**) and the antennae (0.911**) (Fig. 14). Similarly, a highly positive correlation was found between body length and the antennal length (r = 0.987**) (Fig. 15). These data are useful in identifying the nymphal instars in *R. clavatus*.

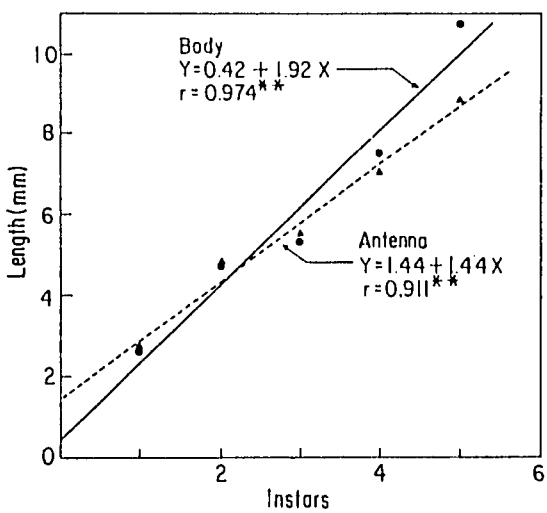

Fig. 14. The relationship between nymphal instars and lengths of body and antenna.

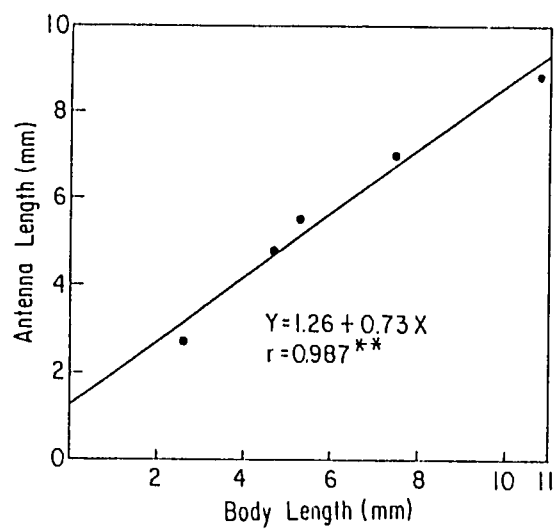

Fig. 15. The relationship between lengths of body and antenna.

Adult biology. The longevity of male and female adults did not differ significantly; both averaged around 22.8 days (Table 15). This longevity was somewhat shorter than that observed during the 1986 study. The pre-mating period was 3.7 days and pre-oviposition was 5 days.

The peak oviposition was between 2 p.m. and 6 p.m. (Fig. 16). When laying eggs, females moved up and down the plant surfaces and attached all their eggs firmly to the plant surface. The eggs could be found everywhere but were generally located in hidden places. Most eggs (67%) were located on the leaves originating from the fourth through the sixth nodes (starting from the apex) of the stem (Table 16). Between the two leaf surfaces, practically an equal number of eggs were located on the upper and lower surfaces; 44% on the upper and 39% on the lower. No eggs were found on the pods despite the fact that the insect from second instar onwards fed on developing seeds within the pods. Only 3% eggs were distributed on the stem and 14% were found on the inflorescences. All eggs were laid singly.

The oviposition pattern of *R. clavatus* is summarized in Figure 17. Starting three days after emergence from the fifth nymphal instar, the female started laying eggs. Oviposition occurred daily and peaked on the 10th day after emergence from the fifth nymphal instar. Oviposition ceased when the females were 25 days old.

The adults could mate at any time of the day but they were more active between 2 to 4 a.m. and 2 to 4 p.m. (Fig. 18). They could mate more than three times during their lifetime. Some couples were observed mating three times in one day. Each mating lasted about 30 min.

Table 15. Observations on biology of adult *R. clavatus*.

Item	Duration (days)
Female longevity	22.9 ± 4.0
Male longevity	22.8 ± 3.6
Pre-mating period	3.7 ± 0.8
Pre-oviposition period	5.0 ± 0.8

Table 16. Distribution of *R. clavatus* eggs in soybean plant.

Plant part	No. of eggs at leaf number (starting from apex)									
	1	2	3	4	5	6	7	8	Total	%
Leaf										
Upper surface	3	6	4	7	19	12	3	3	57	44
Lower surface	5	6	3	11	13	11	0	1	50	39
Inflorescence	6	0	0	3	4	3	1	1	18	14
Stems	0	0	1	2	1	0	0	0	4	3
Pods	0	0	0	0	0	0	0	0	0	0
Total	14	12	8	23	37	26	4	5	129	
%	10.8	9.3	6.2	17.8	28.7	20.2	3.1	3.9		

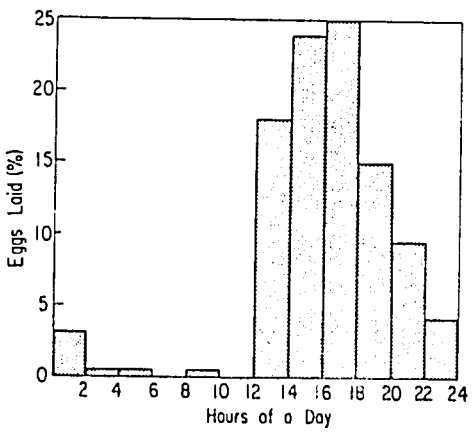

Fig. 16.
Periodicity of oviposition of *Riptortus clavatus*.

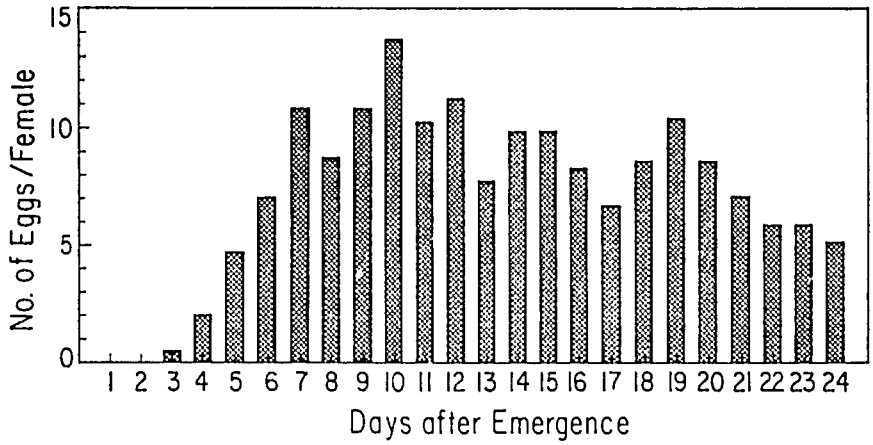

Fig. 17. Oviposition pattern of *Riptortus clavatus*.

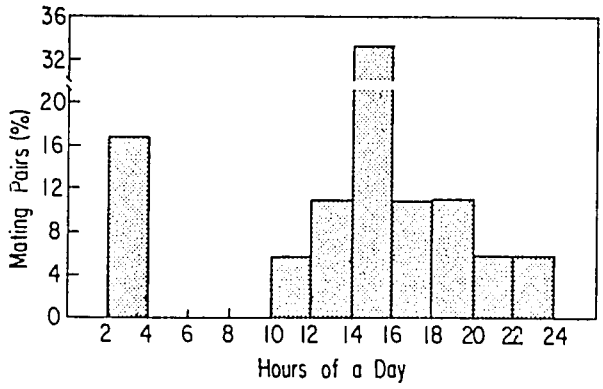

Fig. 18.
Mating periodicity in *Riptortus clavatus*.

Screening of Soybean Germplasm for Limabean Pod Borer Resistance

Summary

In a preliminary screening of 1,000 soybean accessions, planted once each in September and October 1986, for resistance to limabean pod borer (*Etiella zinckenella* Trietsche), eight entries, namely G 3515, G 3543, G 3574, G 3638, G 3681, G 3755, AGS 99 and AGS 169, were relatively less damaged than the rest in both plantings. In a second screening of selected accessions which were least damaged in 1985, accessions G 3469 and G 3472 were the least damaged in four monthly plantings between July and October 1986. These accessions have distinctly smaller pod and seed size compared to the susceptible check. Among the four defoliator-resistant plant introductions, PI 227687 and PI 229358 were significantly less damaged than the susceptible check. The resistance of these accessions will be confirmed during the 1987-88 season.

Introduction

In tropical to subtropical Southeast Asia, limabean pod borer, *Etiella zinckenella* (Trietsche) (Lepidoptera: Pyralidae), causes serious damage to soybean pods. The insect lays eggs mainly on the developing pods and the larvae bore inside and feed on developing seeds; thus yield is directly reduced. In an earlier screening, seven accessions which had significantly less pod damage have been

identified. Detailed investigation of the mechanism of resistance revealed that these accessions are late maturing, and by virtue of late pod set were escaping infestation by the pod borer which has distinct seasonality in Taiwan. In other places seasonality differs or the insect population is high throughout the year, as in Indonesia. At such places, these accessions are susceptible. To select an accession which is resistant irrespective of the seasonality, the screening procedure was modified four years ago. In the new screening procedure, the same set of soybean accessions was planted twice, once each in September and October for preliminary screening, and four times, once each in July, August, September and October, for confirmatory second screening. This arrangement minimizes the possibility of an accession escaping pod borer damage due to asynchrony in pod setting and peaks in insect population.

In 1986-87 1,000 accessions were screened in a preliminary and 35 in confirmatory screenings. In addition four PI accessions which have shown resistance to various defoliator insects were also screened.

Materials and Methods

Preliminary screening. A 0.8-ha parcel of land, located away from an area frequently using insecticide, was rototilled and after application of basal fertilizers, worked into 0.75-m wide raised beds. These beds were further divided into 5-m long plots.

Seeds of each accession were sown as a single row on the top of each bed. The first set of 1,000 accessions was planted in September 1986 and the second set of the same accessions in October 1986. The crop was raised by customary cultural practices including irrigation, weeding, fertilizer application and disease control, but no insecticide was applied.

Beginning with the flowering of the earliest maturing accession and at about 10-day intervals thereafter, a large number of pupae of laboratory-reared limabean pod borer was released at regular distances throughout the field. At harvest time, which varied for different accessions, plots with plants less than 25, or a maximum of 25 were harvested and their pods examined for limabean pod borer damage. The number of healthy and pod borer damaged pods was recorded and the percentage of damaged pods was calculated.

The percentage of damaged pod data was analyzed by a statistical procedure based on the mean of the percentage of damage and standard deviation (sd). This method enabled the classification of the germplasm into various resistance categories: accessions considered as highly resistant (HR) had percent pod damage of less than mean − 2sd; those considered as moderately resistant (MR) had percent pod damage between mean − 2sd and mean − 1sd; and those that showed low resistance (LR) had percent pod damage between mean and mean − 1sd. The susceptible (S) accessions had percent pod damage between mean and mean + 2sd and the highly susceptible (HS) accessions had greater than mean + 2sd.

Second screening. The overall crop growing, insect infestation and pod borer damage observation procedures used in this screening were identical to the preliminary screening, except that in this screening 35 accessions were planted four times, once each in July, August, September and October. At each screening each accession was planted in three randomly selected plots. The percentage of pod damage data was analyzed by analysis of variance and means were separated by Duncan's multiple range test.

Defoliator-resistant accessions. In this test four defoliator-resistant plant introduction (PI) accessions, PI 171444, PI 171451, PI 227687 and PI 229358 were screened for resistance to limabean pod borer. Each accession including one susceptible check were planted in three randomly selected 5 m × 0.75 m plots only once in September 1986. The method of crop raising, insect infestation, damage observation and statistical analysis used were similar to the second screening.

Results and Discussion

Preliminary screening. The results of pod borer damage and resistance reaction of the germplasm are summarized in Table 17. In both plantings the number of accessions falling into a

range of damage followed normal distribution. The mean damage was slightly higher in the September planting and maximum damage was 28.8%. In the October planting the range of damage was from 0 to 40.6%. As in the past tests, some accessions that were least damaged in the first test were not necessarily least damaged in the second. One of the reasons for this is the difference in the days to flowering and maturity among various accessions and pod borer seasonality. As a result, certain late-maturing accessions in the first planting and early-maturing accessions in the second produced pods set at practically the same time when pod borer population was high, while the early maturing in the first and late maturing in the second, escaped insect infestation. Examples of such variation in pod borer damage of selected accessions are shown in Table 18. Despite this variation eight entries — G 3515, G 3543, G 3574, G 3638, G 3681, G 3755, AGS 99 and AGS 169 — were relatively less damaged in both plantings (Table 19). Their resistance reaction was not influenced by maturity date or pod borer population pressure. These accessions, therefore, seem to possess true resistance. This observation needs further proof as the present evaluation was based on a single replicate experiment. In the past it was also found that in general, small pods are less preferred by the limabean pod borer. This aspect was not studied in this preliminary screening. In 1987, therefore, various morphological characters of resistant and susceptible accessions from multireplicate tests planted three to four times at monthly intervals were studied to confirm the resistance.

Table 17. Distribution of soybean germplasm, screened for pod borer resistance in various resistance categories in two screenings, AVRDC 1987.

Resistance category[z]	First screening[y]		Second screening[y]	
	Damage (%)	No. Acc.	Damage (%)	No. Acc.
HR	<2.8	1(<1%)	<0.6	2(<1%)
MR	2.8- 7.2	162(17%)	0.7- 5.1	128(13%)
LR	7.3-11.7	343(36%)	5.1- 9.6	423(43%)
S	11.7-20.5	303(31%)	9.6-18.6	291(30%)
HS	>20.5	153(16%)	>18.6	140(14%)
Total		962(100%)		984(100%)
Damage				
Range	2.3-28.8		0-40.6	
Mean	11.7		9.6	
Standard	4.4		4.5	

[z]HR = highly resistant, MR = moderately resistant, LR = low resistance, S = susceptible, HS = highly susceptible. [y]First screening planted on 16 September 1986, second screening in 15 October 1986.

Table 18. Variability in pod borer damage of certain soybean accessions in two plantings.

Accession no.	First screening[z]		Second screening[z]	
	Damage (%)	Resistance rating[y]	Damage (%)	Resistance rating[y]
G 237	2[x]	HR	11	S
G 327	29	HS	3	MR
G 667	4	MR	21	HS
G 836	21	HS	4	MR
G 3720	4	MR	26	HS
G 3750	14	S	0	HR
G 3762	23	HS	0	HR
G 4089	21	HS	4	MR
Mean	12		10	

[z]Planting dates: first screening 16 September and second screening 15 October 1986. [y]HR = highly resistant, MR = moderately resistant, S = susceptible, HS = highly susceptible. [x]Lowest damaged accession in the first screening.

Table 19. Resistance reaction of selected soybean accessions to the pod borer in two screenings, AVRDC, 1987.

Accession no.	First screening[z]		Second screening[z]	
	Damage (%)	Resistance rating	Damage (%)	Resistance rating
G 3515	5	MR	3	MR
G 3543	4	MR	4	MR
G 3574	4	MR	4	MR
G 3638	5	MR	3	MR
G 3681	5	MR	5	MR
G 3755	5	MR	4	MR
AGS 99	5	MR	3	MR
AGS 169	5	MR	3	MR
G 74	22	HS	18	S
G 298	25	HS	17	S
G 488	25	HS	24	HS
G 1269	26	HS	20	HS

[z]First screening planted 16 September 1986; second screening planted 15 October 1986. MR = moderately resistant, HS = highly susceptible, S = susceptible.

Second screening. The results of pod borer infestation of two least damaged accessions and one susceptible check in four screenings are summarized in Table 20. Accessions G 3469 and G 3472 were consistently much less damaged than the other potentially resistant entries. The susceptible check G 3266 was always the most damaged entry in each screening.

The measurement of pod diameter showed a significant positive correlation between pod diameter and pod borer damage (Fig. 19). A similar pattern was observed in past tests. In two least damaged accessions, G 3469 and G 3472, the pod diameter was 3.04 and 3.52 mm, respectively, in September planting and 3.13 and 3.03 mm, respectively, in October planting; whereas in susceptible G 3266 the diameter was 6.15 and 5.06 mm in two plantings. The resistance of these two accessions could be due to small pod size. Nonetheless, these accessions were consistently less damaged and their other morphological characters, especially trichomes will be studied in 1987-88 to confirm whether more than just the pod size is involved in less damage by *E. zinckenella*.

Defoliator-resistant accessions. The results of the pod borer infestation of selected defoliator-resistant PI accessions and the susceptible check are summarized in Table 21. PI 227687

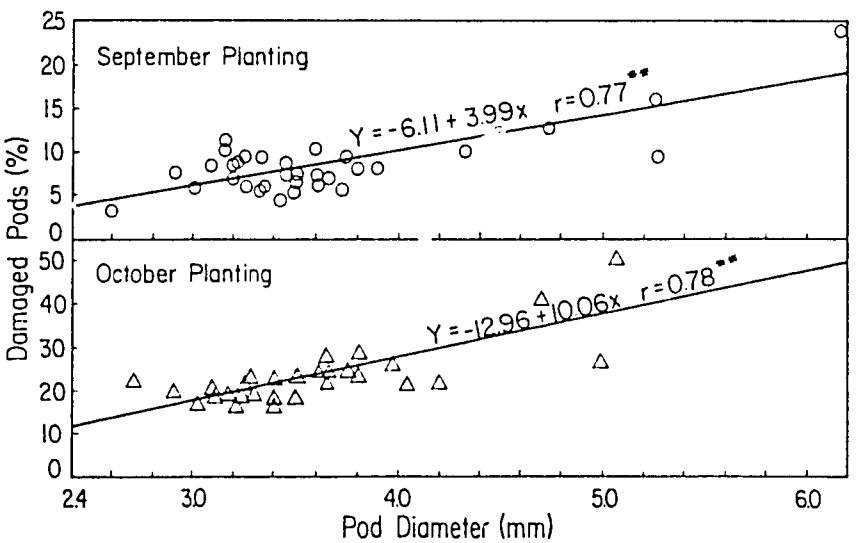

Fig. 19. Relationship of pod size and pod borer infestation.

and PI 229358 were significantly less damaged than the susceptible check TK 5. Two other PIs had similar damage as the susceptible check. All four PIs have shown varying levels of resistance to the defoliators. The resistance to defoliators is due to antibiosis. However, only two were resistant to *E. zinckenella*. Whether this is due to late maturity or small pods or possibly morphological characters such as trichomes, will be further investigated in 1988.

Table 20. Pod borer infestation of selected soybean accessions in four tests during 1986-87.

Accession	Pod damage (%)[z]			
	I screen	II screen	III screen	IV screen
G 3469	3.0 c	6.9 c	6.0 b	18.6 b
G 3472	4.8 bc	7.9 bc	6.0 b	17.2 b
G 3266	10.0 a	16.1 a	24.5 a	50.1 a

[z]Planting dates: I screening, 16 July; II screening, 13 August; III screening, 16 September; and IV screening, 15 October 1986.

Table 21. Infestation of selected defoliator-resistant soybean accessions by limabean pod borer.

Accession	Pod damage (%)
PI 171444	10.7 abc
PI 171451	15.2 ab
PI 227687	5.8 c
PI 229358	7.4 bc
TK 5	17.7 a

Planted 20 September 1986.

Study of Trichome Density on Soybean Pods

Summary

In a survey of the morphology of the pods of 1,667 soybean accessions, the trichome density on green pods (R_3-R_4) ranged from 101 to 663 trichomes per 4 mm^2 pod surface. The pod size ranged from the diameter of 1.93 to 8.28 mm. There was no statistically significant correlation between the trichome density and pod size. This data will be used for selecting soybean germplasm in screening for *Etiella zinckenella* resistance.

Introduction

Plant morphological characters such as hairiness on plant surface play an important role in oviposition of insect pest. Since oviposition is the first and the most important step in pest infestation, the hairiness or trichome density has an important bearing on insect pest infestation. Available information indicates that plant parts with both glabrous as well as high trichome density are avoided by most insect pest species. The limabean pod borer, *Etiella zinckenella* (Trietsche) (Lepidoptera:Pyralidae) lays eggs on young pods. It is possible that the trichome density on the pods will provide important information on the oviposition preference of *E. zinckenella* in soybean and, thus, help locate a reliable source of resistance to this pest. Past attempts to identify resistance sources were strongly influenced by differences in soybean maturity dates and pod size between resistant and susceptible accessions. Late-maturing and small pod sized accessions tended to be less damaged than accessions with opposite characters. In this experiment, trichome density on the pods of 1,667 soybean accessions was surveyed to select accessions with highest and lowest trichome density and study the effect of these plant characters on *E. zinckenella* infestation.

Materials and Methods

In this field experiment, 2,000 soybean accessions were planted in the field in a nonreplicated planting. Each entry was planted as a single row in 4-m long and 0.75-m-wide beds. When plants were in R_3-R_4 growth stage, 20 pods from each entry were sampled and the density of trichome on the pod surface was recorded by counting the number of trichomes in four 2 mm × 2 mm areas, two spots on each of the two surfaces. In cases where pods had only one seed, the trichome density at only two spots, one on either surface, was recorded.

At maturity when pods turned brown, 50 pods from each plot were sampled and the pod size was determined by measuring the diameter at widest point between two flat surfaces over each seed enclosed in the pod.

Results

Among the 2,000 soybean accessions, only 1,667 reached R_3-R_4 stage until the continuous heavy monsoon rains damaged the crop and the experiment was terminated. The trichome density ranged from 101 to 663 trichomes per 4-mm^2 pod surface (Table 22). The diameter of the pod size ranged from 1.93 to 8.28 mm. There was no statistically significant correlation between trichome density and pod size. Ten high and 10 low trichome density accessions having similar pod size were selected for autumn 1987 planting; the plants had been subjected to *E. zinckenella* infestation to study the possible correlation between trichome density and pod borer infestation.

Table 22. Survey of trichome density on the surface at R_3-R_4 stage soybean pods.

No. trichomes/4 mm^2	No. of accessions	Percentage
Less than 134	15	1
Between 135 to 214	326	20
Between 215 to 292	410	25
Between 293 to 450	720	43
More than 451	196	12

Soybean Pathology

Advanced Soybean Rust Tolerance Trials

Summary

Three advanced trials (ARTT-I, ARTT-II and ARTT-III) were conducted in both fall 1986 and spring 1987. A total of 42 lines were tested in the fall season and 36 in the spring season. Five entries (AGS 302, SRE-B-15C, SRE-C-56A, SRE-D-14A and SRE-D-14B) far surpassed the original selection criteria. They had superior performance with respect to yield and rust tolerance over five to six environments and showed that high levels of rust tolerance and stable, high yield can be combined in advanced lines. The yield stability of SRE-D-14B is close to the ideal of 1.0 and yield, either with or without fungicide protection, was superior to all check cultivars. In ARTT-II the two best cultivars across both seasons, SRE-D-14-0-Bkl-6e-1-3-Bk-2-2 and SRE-D-14-0-Bkl-6e-1-3-Bk-1-2, had yields similar to AGS 129, the highest-yielding check, when protected with fungicide and yielded 1.24 and 1.09 t/ha more than the best-yielding check, AGS 181, when the plants were not protected by fungicide. Nine cultivars from ARTT-II were selected and will be further evaluated.

Introduction

A series of rust tolerance trials, preliminary (PRTT), intermediate (IRTT) and advanced (ARTT) have been established to evaluate and select soybean lines with improved levels of rust tolerance and stable high yield. Selected lines from the IRTT are advanced to the ARTT, and the best lines from the ARTT will be available for testing in selected countries worldwide, where soybean rust is a serious problem.

Materials and Methods

There were three advanced trials conducted in both fall 1986 and spring 1987. In all these trials the same three check cultivars, G 38, AGS 129 and AGS 181, were used. The ARTT-I of both seasons evaluated five lines and three checks. All lines in this test were selected for their high mean yield across several trials. In addition AGS 302, SRE-B-15C and SRE-C-56A were also selected for high relative yield without fungicide protection, and SRE-D-14A and SRE-D-14B for high relative yield in both the fungicide-protected and unprotected situations.

ARTT-II (fall 1986) consisted of 20 lines previously selected for high yield potential and potential rust tolerance; 16 of these 20 lines were selected and included in the ARTT-II (spring 1987). ARTT-III consisted of 17 high-yielding AGS lines in fall 1986; and in spring 1987 it consisted of 15 AGS lines selected from the fall crop and six additional high-yielding G- and GC-lines.

The plot sizes were 4 × 5 m (3 × 4 m harvested area) for ARTT-I and 3 × 6 m (2 × 5 m harvested area) for ARTT-II and ARTT-III. The plant density was equivalent to 400,000 plants/ha. The split-plot design with four replications was used. The main plots had fungicide protection and no fungicide protection treatments, and the subplots used cultivars. ARTT-I was planted on 30 September 1986 and 24 February 1987. Unprotected plots of ARTT-I were inoculated with rust on 27 October 1986 for the fall crop and on 30 and 31 March 1987 for the spring crop. ARTT-II (fall 1986) was planted

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on 2 October and plots without fungicide were inoculated on 30 and 31 October. ARTT-II (spring 1987) was planted on 25 February and inoculated on 26 and 31 March. ARTT-III was planted on 1 October 1986 and 24 February 1987. The ARTT-III plots without fungicide were inoculated with rust on 28 October 1986 and 2, 14 and 23 April 1987. Fungicide-protected plots were sprayed with Dithan M-45, starting about the date of the first inoculation, and then sprayed at two-week intervals. AVRDC cultural practices were followed.

Data collected included grain yield, 100-seed weight and days to maturity. Yield data was converted to 13% moisture content before evaluation and yield loss was expressed as percentage of fungicide-protected yield. The criteria for cultivar selection after one or two trials is a yield similar to or better than G 38 under fungicide-protected treatment, a yield similar to or better than AGS 181 in the unprotected condition, and a yield loss similar to or less than G 38. Cultivar selection after multiple trials is based on a combined yield stability analysis.

A combined yield stability analysis was conducted on five cultivars (AGS302, SRE-B-15C, SRE-C-56A, SRE-D-14A and SRE-D-14B), as well as three check cultivars (G 38, AGS 129 and AGS 181) in ARTT-I. Regression analysis was made by using the environmental index as the independent variable and the yield of each cultivar as the dependent variable. Environmental indices for analysis were derived from the yield of cultivars included in each environment. The data from each trial were evaluated as having two different environments, one with fungicide and the other without. A total of 20 environments were evaluated with each test cultivar contained in 10 to 12 environments and the check cultivars contained in all 20 environments.

Results and Discussion

ARTT-I, ARTT-II and ARTT-III. The yield of all five test cultivars in ARTT-I was equal to or significantly higher than the yield of the check cultivar, G 38, in the fungicide-protected plots of both fall and spring trials. The yield of these test cultivars without fungicide protection was equal to or significantly higher than the yield of the check cultivar, AGS 181, in both trials. Also the yield losses of these five cultivars were less than the check cultivar, G 38, in both seasons (Table 1). Therefore, all of the five test cultivars have met or exceeded the selection criteria. A further evaluation of these cultivars across many environments appears in the next section that discusses the yield stability analysis.

Of the 20 test cultivars in the fall ARTT-II, 19 yielded at least as well as the check cultivar, G 38, in the fungicide-protected plots, with 11 cultivars yielding significantly higher. In the plots without fungicide protection in the same trial, 17 cultivars yielded similar or better than the check

Table 1. Yield and percent yield loss of cultivars in the ARTT-I grown under fungicide- and nonfungicide-protected conditions during a soybean rust epidemic, AVRDC, fall 1986 and spring 1987.

Cultivars	Fall 1986			Spring 1987		
	Yield (t/ha)[z]		%	Yield (t/ha)		%
	F[y]	NF[x]	yield loss	F	NF	yield loss
AGS 302	2.65 +	1.35	49	2.95	2.51	15
SRE-B-15C	2.52	1.55 +	38	2.97	2.55 +	14
SRE-C-56A	2.57 +	1.53 +	40	3.06	2.72 +	11
SRE-D-14A	2.71 +	1.34	51	3.95 +	2.97 +	25
SRE-D-14B	2.73 +	1.36	50	2.96	2.60 +	12
G 38[w]	2.36	1.02 –	57	2.88	2.10	27
AGS 129[w]	2.60 +	1.14 –	56	4.12 +	2.34	43
AGS 181w	2.13 –	1.35	37	2.74	2.21	20
LSD .05	0.17			0.31		

[z]Plot size was 4 × 5 m (3 × 4 m harvested area) and the plant density was equivalent at 400,000 plants/ha. [y]Fungicide-protected yield: + = significantly ($P < 0.05$) greater than yield of the check cultivar, G 38; – = significantly less than G 38. [x]Nonfungicide-protected yield: + = significantly ($P < 0.05$) greater than the tolerant check cultivar, AGS 181; – = significantly less than AGS 181. [w]Check cultivars.

cultivar, AGS 181, and the yield of the best cultivar was 122% better than AGS 129 and significantly higher than AGS 129 with fungicide protection. The yield losses of 18 cultivars were less than the check, G 38, and 10 cultivars were similar to the tolerant check, AGS 181. Of the 16 selected test cultivars in the spring ARTT-II, all yielded as well as the check, G 38, and 11 yielded significantly higher in the fungicide-protected situation. In the plots without fungicide in the same trial, 13 of the test cultivars significantly outyielded the check cultivar, AGS 181, and the yield of the best cultivar was nearly 50% higher than AGS 129 (Table 2).

The two best cultivars across both seasons, SRE-D-14-0-Bkl-6e-1-3-Bk-2-2 and SRE-D-14-0-Bkl-6e-1-3-Bk-1-2, had a yield similar to AGS 129, the highest yielding check, when protected with fungicide and yielded 1.24 and 1.09 t/ha more than the best yielding check when the plants were not protected by fungicide (Table 2). Nine cultivars from ARTT-II were selected and will be further evaluated in the future.

Fourteen of the 17 AGS lines tested in the fall ARTT-III had yields similar or significantly higher than the check cultivar, G 38, in the fungicide-protected condition. However, only six lines yielded similar or significantly higher than the check, AGS 181, when the plants were not protected by fungicide. In the spring ARTT-II, 18 of the test lines had similar or significantly higher yields than the check, G 38, with fungicide protection. Of these 18 lines, 10 had yields similar or significantly higher than the check, AGS 181, when the plants were not protected by fungicides (Table 3). Six AGS lines were selected and will be further evaluated in the future.

Table 2. Yield and percent yield loss of cultivars in the ARTT-II grown under fungicide- and nonfungicide-protected conditions during a soybean rust epidemic, AVRDC, fall 1986 and spring 1987.

Cultivars	Fall 1986			Spring 1987		
	Yield (t/ha)[z]		%	Yield (t/ha)		%
	F[y]	NF[x]	yield loss	F	NF	yield loss
C-56-1-Bk-Bke-Bkl-2e-2-3-BK-3-bK	2.36	1.02	57	3.06	2.72 +	11
C-56-1-Bk-Bke-BKl-1r-1-Bk-0-Bk	2.40 +	0.98	59	3.39	2.79 +	18
C-56-1-Bk-Bke-Bkl-lr-1-1-Bk-1-Bk	2.38 +	1.01	58	3.49 +	2.86 +	18
C-56-1-Bk-Bke-Bkl-lr-1-1-Bk-4-Bk	2.31	1.09	53	3.36	2.90 +	14
C-56-1-Bk-Bke-Bkl-lr-1-1-Bk-5-Bk	2.34	1.01	57	3.63 +	2.72 +	25
C-56-1-Bk-Bke-Bkl-1r-1-1-Bk-2-1	2.37	0.96	60	3.70 +	2.95 +	20
D-14-0-Bkl-6e-1-3-Bk-1-1	2.86 +	1.08	62			
D-14-0-Bkl-6e-1-3-Bk-1-2	2.82 +	1.15 +	59	4.19 +	3.19 +	24
D-14-0-Bkl-6e-1-3-Bk-2-1	2.81 +	1.17 +	58			
D-14-0-Bkl-6e-1-3-Bk-2-2	2.88 +	1.15 +	60	4.01 +	3.34 +	17
D-14-0-Bkl-6e-1-3-Bk-3-Bk	2.66 +	1.18 +	56	3.68 +	3.01 +	18
D-14-0-Bkl-6e-1-3-Bk-4-Bk	2.79 +	1.29 +	54	3.46 +	2.91 +	16
D-14-0-Bkl-6e-1-3-Bk-5-Bk	2.71 +	1.25 +	54	3.12	2.94 +	6
D-14-0-Bkl-6e-1-5-Bk-2-Bk	2.63 +	1.07	60			
82021-F4/1-Bk-Bk-Bk	2.09	1.07	49	3.63 +	2.47	32
82021-F4/3-Bk-Bk-Bk	2.29	0.85	63	3.99 +	2.71 +	32
82029-F5(1)-Bk-Bk	2.44 +	1.08	56	4.12 +	2.87 +	30
82031-F4/2-Bk-Bk-Bk	2.21	0.46 –	79			
Ku-81-1-038	2.27	0.64 –	72	3.87 +	1.93 –	50
H-15	1.92 –	0.79 –	59	2.87	2.21	23
G 38[w]	2.23	0.64 –	71	3.12	2.30	26
AGS 129[w]	2.43 +	0.65 –	73	4.31 +	2.25	48
AGS 181[w]	2.11	0.96	54	2.80 –	2.29	18
KS 8[w]	2.44 +	0.68 –	72	3.70 +	2.32	37
LSD .05	0.15			0.28		

[z]Plot size was 3 × 6 m (2 × 5 m harvested area), and the plant density was equivalent at 400,000 plants/ha. [y]Fungicide-protected yield: + = significantly ($P < 0.05$) greater than yield check cultivar, G 38; – = significantly less than G 38. [x]Nonfungicide-protected yield: + = significantly ($P < 0.05$) greater than the tolerant check cultivar, AGS 181; – = significantly less than AGS 181. [w]Check cultivars.

Table 3. Yield and percent yield loss of cultivars in the ARTT-III grown under fungicide- and nonfungicide-protected conditions during a soybean rust epidemic, AVRDC, fall 1986 and spring 1987.

Cultivars	Fall 1986			Spring 1987		
	Yield (t/ha)[z]		%	Yield (t/ha)		%
	F[y]	NF[x]	yield loss	F	NF	yield loss
AGS 2	2.04 –	1.08 –	47	2.97	2.03 –	32
AGS 12	2.33	1.25 –	46	3.27	1.97 –	40
AGS 29	2.33	1.10 –	53	3.32	2.32	30
AGS 58	2.58	1.12 –	57			
AGS 66	2.51	1.62	35	3.05	2 30	25
AGS 133	2.45	1.49	39	3.31	2.25	32
AGS 147	2.70 +	1.58	41	3.30	2.09 –	37
AGS 154	2.33	1.08 –	54	3.51 +	2.31	34
AGS 160	2.48	1.13 –	54	3.32	2.01 –	39
AGS 204	2.45	0.83 –	66			
AGS 216	2.66 +	1.24 –	53	4.07 +	2.32	43
AGS 217	2.50	1.37	45	3.31	2.23	33
AGS 226	2.19 –	1.44	34	3.17	2.02 –	36
AGS 227	2.34	1.22 –	48	3.12	2.30	26
AGS 242	2.54	1.97 +	22	2.85	2.73 +	4
AGS 299	2.50	1.16 –	54	3.75 +	2.19	42
AGS 304	2.02 –	0.98 –	53	2.77 –	2.04 –	26
GC 60058-12-6-6-1-18				2.90	2.06 –	29
GC 60015-6-6-6-7-64				3.14	2.06 –	35
GC 60115-6-6-6-7-18				3.20	2.09 –	35
G 9947-19-6				2.82 –	2.51	11
GC 60020-8-7-7-18				2.83 –	2.30	19
GC 60031-2-7-7-15				3.27	2.47	24
G 38[w]	2.42	1.32	45.66	3.13	2.27	27
AGS 129[w]	2.69 +	1.69 +	37.09	3.66 +	2.17	41
AGS 181[w]	2.18 –	1.49	31.45	2.82 –	2.43	14
LSD .05	0.19			0.28		

[z]Plot size was 3 × 6 m (2 × 5 m harvested area) and the plant density was equivalent to 400,000 plants/ha. [y]Fungicide-protected yield: + = significantly ($P<0.05$) greater than yield of the check cultivar, G 38; – = significantly less than G 38. [x]Nonfungicide-protected yield: + = significantly ($P<0.05$) greater than the tolerant check cultivar, AGS 181; – = significantly less than AGS 181. [w]Check cultivars.

Yield stability analysis of five test lines and three check cultivars. The results of the combined yield stability evaluation of five test cultivars and three check cultivars across five to six rust tolerance trials from fall 1984 to spring 1987 are shown in Table 4. The estimated mean yield of five test cultivars across 10 to 12 environments with or without fungicide protection ranged from 2.17 to 2.35 t/ha and were all higher than the check cultivars (1.94 to 2.12 t/ha). The five test cultivars also had higher mean yields with fungicide protection than the check, G 38, and the yield of two lines, SRE-D-14A and SRE-D-14B, was higher than AGS 129. Without fungicide protection, all of the test cultivars outyielded AGS 181, the highest yielding check in this treatment. Also the yield losses of the test lines were below the check, G 38, and four lines had yields similar or below AGS 181, the tolerant check. These five lines far surpassed the original selection criteria. They had superior performance with respect to yield and rust tolerance over five to six environments and showed that rust tolerance and high yield can be combined in advanced lines (Table 4).

The yield stability of SRE-D-14B was close to the ideal of 1.0, similar to G 38, and its yield, either with and without fungicide protection was superior to all check cultivars. The regression coefficients (slope) of two cultivars, SRE-B-15C and SRE-C-56A, were as low as AGS 181 and, therefore, had the best level of rust tolerance and yield stability. Their mean yield was higher than

that of G 38 when protected with fungicide and higher than AGS 181 when the plants were not protected with fungicide. The yield stability of AGS 302 was between G 38 and AGS 181; its yield was similar to AGS 129 with fungicide protection and higher than any check cultivar when the plants were not protected by fungicide. SRE-D-14A had the highest mean yield, yield with fungicide protection and regression coefficient, the same as AGS 129, indicating a lower than the desired yield stability.

Table 4. Yield stability analysis of five test and three check cultivars in soybean rust tolerance trials, fall 1984 to spring 1987.

Cultivars	Regression parameters				Mean yield[z] (t/ha)		Yield
	n[y]	a[x]	b[w]	r2[v]	F	NF	loss (%)
AGS 302	10	2.17	0.87	0.94	2.68	1.86	31
SRE-B-15C	12	2.19	0.75	0.96	2.48	1.98	20
SRE-C-56A	12	2.24	0.78	0.97	2.58	1.99	23
SRE-D-14A	12	2.35	1.25	0.94	3.06	1.91	38
SRE-D-14B	12	2.26	0.97	0.92	2.83	1.91	32
G 38[u]	20	2.00	1.02	0.96	2.39	1.43	40
AGS 129[u]	20	2.12	1.25	0.94	2.70	1.32	51
AGS 181[u]	20	1.94	0.78	0.93	2.22	1.51	32

[z]Mean yield for each cultivar across several environments with either fungicide or nonfungicide protection, yield loss as percentage of fungicide-protected yield. [y]Number of environments in which the line was tested. [x]Intercept of the regression equation which is the estimated mean yield of the cultivar across environments. [w]Regression coefficient, mean yield as dependent and environmental index as independent variable. [v]Square of the correlation coefficient. [u]Check cultivars.

Screening of Wild Soybeans for Soybean Rust Resistance

Summary

Soybean rust is one of the most serious diseases of soybean in Southeast Asia. No highly-resistant or highly-tolerant soybean cultivar to this disease has yet been identified. A total of 212 *Glycine* accessions was screened to identify sources of resistance. Fifty accessions were finally selected as highly resistant based on at least three test evaluations. Because of their high levels of rust resistance, these accessions will be excellent materials for interspecific hybridization.

Introduction

Soybean rust, caused by *Phakopsora pachyrhizi*, is a major constraint for growing soybeans in the tropics and subtropics in the eastern hemisphere. Soybean and over 30 other genera of cultivated and wild legumes are affected by soybean rust. Unfortunately, no highly resistant or highly tolerant soybean cultivar has been found in the past years. This study was designed to screen some wild perennial *Glycine* species for soybean rust resistance and to identify potential sources of genes for resistance that may be incorporated into soybeans in the future through interspecific crosses.

Materials and Methods

The fall 1986 test was planted on 11 September 1986 and contained 100 new accessions of perennial *Glycine* species from Dr. T. Hymowitz, University of Illinois, U.S.A., 34 of which were previously rated as highly resistant in spring 1986, and three checks, AGS 181, AGS 129 and Taita Kaohsiung No. 5 (TK5). The spring test was planted on 9 March 1987 and contained 58 accessions which were rated as highly resistant in fall 1986, 12 accessions from Dr. J.J. Burdon, CSIRO, Australia and the same three checks. The fall 1987 test, containing 67 highly resistant accessions from the previous test plus the check cultivars, was planted on 27 August 1987 for resistance confirmation.

Five seedlings of each accession/cultivar were planted in each of four 15-cm diameter clay pots containing sterilized potting soil (soil:compost:rice hull:sand at a 5:3:1:1 ratio). Two weeks later, each pot was thinned to three plants. All pots were maintained outside the greenhouse in four replications and surrounded by susceptible soybean cultivar, TK 5.

After the plants in each test reached the flowering and pod setting stages, they were artificially inoculated three times with a rust spore suspension. The disease resistance evaluation was made at least three weeks after the date of the last inoculation. The rating system was based on percentage of affected foliage as follows: highly resistant (HR) = no lesions or very few lesions; moderately resistant (MR) = less than 20% affected foliage; susceptible (S) = more than 20% affected foliage.

Results and Discussion

Although three artificial rust inoculations were made during the growth period, 59, 58 and 58 accessions failed to develop lesions or developed only a few lesions and, therefore, were rated as highly resistant in the fall 1986, and spring and fall 1987 screening tests, respectively (Table 5). In contrast, all of the soybean check varieties in this test, including the rust tolerant variety, AGS 181, were rated as susceptible. All of 12 *Glycine* accessions from Dr. J.J. Burdon were also susceptible to soybean rust in these screenings.

From 1986 to 1987, those accessions that were rated as highly resistant in one season were reevaluated in the next season. Therefore, the most resistant accessions were evaluated in three or four screening tests. Fifty accessions were finally selected as highly resistant based on at least three test evaluations (Table 6). Because of their high levels of rust resistance, these accessions will be excellent materials for interspecific soybean hybridization programs.

Effect of Storage and Seed Size on the Germination of Soybean Seeds

Summary

Soybean seeds from three different cultivars that varied in size from large (23.6 g/hundred seed weight or HDSW) to small seeds (12.4 g/HDSW) were utilized in this year-long storage experiment. The germinability of all three cultivars remained uniformly high and unchanged after a one-year storage period in the cold room in plastic jars sealed with screw-top lids. The large-seeded cultivar, PI 459025, had distinctly better longevity and germinability than the other two cultivars. Therefore, the genetic potential for seed longevity can be high in large-seeded cultivars. Apparently, seed longevity is strongly influenced by a complex interaction between genetic potential, storage temperature and seed moisture. It appears that exposure to high humidity alone may not be sufficient to cause an increase in seed moisture content. It also appears that high temperature adversely affects the actual germination process and may confound future studies on seed longevity.

Introduction

Four important factors affect seed longevity, i.e. seed moisture content, temperature, atmosphere (oxygen) and genetic potential. However, it is well established that the physiological state (degree of injury or deterioration) which plays an important role in longevity is seed response to storage. Most of the world's agriculture depends upon the simple principle that once seeds are harvested and dried, their viability must be maintained for varying periods of time until the crop is planted again. The availability of soybean seeds with high germinability in the tropics is low because soybean seeds are usually stored for eight to nine months until the next crop season. This experiment was conducted to study the effect of seed size, genetic potential and storage condition on the germination of soybean seeds

Materials and Methods

Soybean seeds from three different cultivars that varied in seed size, PI 459025 (large seed, 23.6 g/HDSW), AGS 129 (intermediate size, 16 g/HDSW) and AGS 66 (small seed, 12.4 g/HDSW)

Table 5. Disease rating and number of *Glycine* accessions tested for resistance to soybean rust, 1986 to 1987.

Disease rating[z]	No. of entries		
	Fall 1986	Spring 1987	Fall 1987
Highly resistant (HR)	59	58	58
Moderately resistant (MR)	25	2	6
Susceptible (S)	50	9	3
Total	134	69	67

[z]HR = no lesion or few lesions; MR = less than 20% foliage infected; S = more than 20% foliage infected.

Table 6. Soybean rust resistance ratings of *Glycine* accessions screened from 1986 to 1987.

IL #	Reaction to rust				IL #	Reaction to rust			
	Spring 1986	Fall 1986	Spring 1987	Fall 1987		Spring 1986	Fall 1986	Spring 1987	Fall 1987
306A	HR	HR	HR	HR	502		HR	HR	HR
312	HR	HR	HR	HR	505		HR	HR	HR
324-1	HR	HR	HR	HR	508		HR	HR	HR
324-2	HR	HR	HR	HR	520		HR	HR	HR
325	HR	HR	HR	RH	546		HR	HR	HR
326	HR	HR	HR	HR	577		HR	HR	HR
329-1	HR	HR	HR	HR	579		HR	HR	HR
329-2	HR	HR	HR	HR	580		HR	HR	HR
330	HR	HR	HR	HR	581		HR	HR	HR
331	HR	HR	HR	HR	582		HR	HR	HR
342-2	HR	HR	HR	HR	583		HR	HR	HR
346-2	HR	HR	HR	HR	584		HR	HR	HR
348	HR	HR	HR	HR	585		HR	HR	HR
358	HR	HR	HR	HR	586		HR	HR	HR
377PK-3	HR	HR	HR	HR	587		HR	HR	HR
381	HR	HR	HR	HR	588		HR	HR	HR
388	HR	HR	HR	HR	589		HR	HR	HR
418	HR	HR	HR	HR	609		HR	HR	HR
419	HR	HR	HR	HR	612		HR	HR	HR
422	HR	HR	HR	HR	614		HR	HR	HR
424	HR	HR	HR	HR	616		HR	HR	HR
449	HR	HR	HR	HR	619		HR	HR	HR
472		HR	HR	HR	624		HR	HR	HR
479-1		HR	HR	HR	637		HR	HR	HR
479-2		HR	HR	HR	AGS 181 (ck)		S	S	S
484		HR	HR	HR	TK 5		S	S	S

were utilized in this study. The seeds were harvested from the field in December 1985. After normal drying and threshing, the seeds of each cultivar were separated and placed in plastic jars sealed with screw-top lids (PJS) and in nylon net bags. The two types of container were then randomly assigned to two different storage conditions, either in the cold room (4 ± 1°C) or in the headhouse (room temperature).

The evaluation of germination and moisture content started two months after storage. Then, tests were continued at two-month intervals over a one-year period. Four hundred seeds in each seed lot were randomly collected and their moisture content measured. The seeds of each lot at each sampling time were then randomly divided into four replications and planted in plastic flats with nonsterilized potting soil (soil:compost:sand:rice hull at a ratio of 5:3:1:1) for the germination test. The flats were placed inside the greenhouse and the soil was kept moist. The final evaluation of germination was made after most of the first trifoliolate leaves were fully developed.

Results and Discussion

The germinability of the seeds of all three cultivars remained high and unchanged after one year storage in the cold room in the PJS container (Table 7). However, the germination of all three cultivars was unusually low for the 1 July and 1 September germination tests. The reduction in germination was consistent across treatments and cultivars, and did not seem to be related to storage container or storage environment (Tables 7 & 8). In previous tests, the decrease in germination from June to September had been observed and was attributed to adverse environmental conditions, principally rainfall, since the germination tests were conducted outdoors. However, these tests were conducted in the greenhouse. Therefore, it appears that high temperature adversely affects the germination process and may confound future studies on seed longevity.

In all storage container and environment treatments, except the cold room storage in PJS container, the large-seeded cultivar, PI 459025, had distinctly better longevity and germinability than the other two cultivars. The longevity and germinability of AGS 66 across these same treatments were slightly better than AGS 129 (Tables 7 & 8). Therefore, the genetic potential for seed longevity can be high in large-seeded cultivars.

Interestingly, the seed moisture content was similar for all three cultivars in any particular treatment and sampling time, yet the germinability varied considerably. Also, the treatment in which the cultivars had the shortest longevity, room temperature in net bags, was not the treatment where the seeds had the highest moisture content. The treatment where seeds had the highest moisture content — cold room storage in net bags — was, across cultivars, the treatment with the second highest longevity and germinability. These data indicate that temperature rather than seed moisture content was the more important factor influencing seed longevity. However, when the data from the two different storage container treatments in the cold room were examined, seed moisture became more important (Tables 7 & 8). Apparently, seed longevity was strongly influenced by a complex interaction between genetic potential, storage temperature and seed moisture.

It appears that exposure to high humidity alone may not be sufficient to cause an increase in seed moisture content, e.g. the seed stored at room temperature in a net bag versus the seed stored in the cold room in a net bag (Table 8). High relative humidity occurred in both storage conditions. In the

Table 7. Effect of seed size on the germination of soybean seeds stored in plastic jars sealed with a screw-top lid.[z]

Treatment	Variety[y]	Germination/moisture content (%)						
		2/28/86	5/1	7/1	9/1	10/30	12/31	3/2/87
Cold room	PI 459025	92/11	92/11	79/11	66/11	95/11	98/11	95/11
	AGS 129	89/11	79/11	56/11	68/11	94/11	96/11	94/11
	AGS 66	94/12	84/12	66/11	68/12	97/12	94/12	96/12
Headhouse	PI 459025	95/11	83/11	58/11	51/11	85/11	74/11	74/11
	AGS 129	93/11	61/11	42/11	24/11	42/11	2/11	7/11
	AGS 66	94/11	83/11	49/11	37/11	54/11	7/12	13/12

[z]The seeds were harvested in December 1985. [y]PI 459025 has large seed; AGS 129 has intermediate size seed; AGS 66 has small seed.

Table 8. Effect of seed size on the germination of soybean seeds stored in nylon net bags.[z]

Treatment	Variety[y]	Germination/moisture content (%)						
		2/28/86	5/1	7/1	9/1	10/30	12/31	3/2/87
Cold room	PI 459025	93/12	86/18	65/18	49/21	84/22	83/22	72/21
	AGS 129	90/12	67/21	23/22	26/22	75/24	44/21	41/20
	AGS 66	96/13	84/18	51/21	42/22	82/23	41/23	59/22
Headhouse	PI 459025	97/12	84/13	24/12	8/12	29/13	0/12	0/11
	AGS 129	95/12	55/13	2/12	0/12	0/13	0/12	0/12
	AGS 66	95/12	74/13	5/12	2/13	0/13	0/12	0/12

[z]The seeds were harvested in December 1985. [y]PI 459025 has large seed; AGS 129 has intermediate size seed; AGS 66 has small seed.

case of the seed stored in the cold room in a net bag, the high seed moisture content is most probably due to condensation on the seed surface allowing imbibition to occur. Condensation occurs when warm, moist air enters the cold room.

Survey of Soybean, Mungbean and Peanut Viruses in Indonesia

Summary

In a survey of soybean, mungbean and peanut in East Java, the following viruses were found: AzMV, BCMV, BlCMV, BYMV, PStV, CMV and an unknown potyvirus (isolate S-220). Peanut mottle virus, cowpea mosaic virus S, cowpea mosaic virus Y, cowpea mottle virus, peanut stunt virus, southern bean mosaic virus, black gram mottle virus and alfalfa mosaic virus were not detected. Bean yellow mosaic virus accounted for 85% of the soybean samples with various types of yellowing symptoms. This virus is considered responsible for the yellow mosaic epidemics on soybean, previously reported in this area.

Introduction

Not much information is available on the viruses which affect soybean and mungbean in certain Asian countries, such as the Philippines and Indonesia. In Taiwan, the viruses detected on soybean were soybean mosaic virus (SMV), peanut mottle virus (PMV), a soybean strain of peanut stripe virus (PStV) and another potyvirus not yet identified (isolate S-220). The viruses detected on mungbean in Taiwan were cucumber mosaic virus (CMV), blackeye cowpea mosaic virus (BlCMV) and a mungbean strain of peanut stripe virus. PStV has so far only been reported on peanut in Asia and findings on this virus on soybean and mungbean in Taiwan were somewhat surprising. This survey aimed to determine if PStV is also present on other hosts in other areas of Asia and second, determine which other viruses are present and their importance.

Materials and Methods

A total of 195 leaf samples of mungbean, soybean and peanut with typical virus symptoms were collected in 1986 by a cooperator in East Java, one of Indonesia's major legume-growing areas. The leaf samples were cut in small pieces, dried over calcium chloride and mailed to AVRDC. The samples were homogenized (1:30) in extraction buffer (PBS buffer, pH 7.4, containing 2% Polyvinylpyrolidon K-25 and 0.05% Tween 20) and tested by the standard DAS-ELISA test for the presence of 21 viruses. The antisera, their concentration of the immunoglobulines and enzyme conjugates, as well as their origin are shown in Table 9.

Results and Discussion

The results of the study are shown in Table 10. It was interesting to observe that all three crops were infected with PStV, with mungbean having the highest percentage of infection. Bean yellow mosaic virus seems to account for most of the yellow symptoms (Table 11), a serious incidence of which had been reported previously in this and other legume-growing areas of east and central Java. In this survey, BYMV was identified in about 78% of all the samples with yellow mosaic, yellowing, light green mosaic and/or chlorotic symptoms. It was, however, also present in samples with other symptoms, such as light green mosaic, green mottle, indicating that the production of typical yellow symptoms probably depends on the genotype. A high percentage of plants of all three crops were also found infected with adzuki bean mosaic virus (AzMV), blackeye cowpea mosaic virus (BlCMV) and cucumber mosaic virus (CMV). The bean common mosaic virus (BCMV) was detected only in soybean and mungbean, but not in peanut.

Several samples of the three crops reacted positively with antiserum to the potyvirus isolate S-220, so far found only in Taiwan. Other viruses: alfalfa mosaic virus, peanut mottle virus, AMV, PMV, soybean stunt virus (SSV), soybean mosaic virus (SMV), CPMV-S, CPMV-X or cowpea mottle virus,

Table 9. Antisera used for the ELISA test for the survey in Indonesia.

Antisera	Source	IgG & Conj. Conct.
Alfalfa mosaic	ATCC	1:1000 1:1000
Adzukibean mosaic	AVRDC	1:2000 1:2000
Bean common mosaic	AVRDC	1:2000 1:2000
Blackeye cowpea mosaic	AVRDC	1:1000 1:1000
Bean yellow mosaic	Bos	1:1000 1:1000
Peanut mottle	Demski & Kuhn	1:100 1:100
Soybean stunt	Manada, Japan	1:250 1:250
Soybean mosaic	AVRDC	1:1000 1:1000
Peanut stripe	KRISAT, AVRDC	1:1000 1:1000
Cowpea mosaic-S	Illinois, USA	1:1000 1:1000
Cowpea mosaic-Y	Illinois, USA	1:1000 1:1000
Cowpea mottle	ATCC	1:1000 1:1000
Peanut stunt	ATCC	1:1000 1:1000
Southern bean mosaic	Illinois, USA	1:1000 1:1000
Black gram mottle	USA	1:1000 1:1000
Bean golden mosaic	Illinois, USA	1:1000 1:1000
Isolate S-220	AVRDC	1:1000 1:1000
CMV-P	Japan	1:500 1:500

Table 10. Virus survey of soybean, mungbean and peanut in East Java, Indonesia.

	Soybean (103)[z]	Mungbean (25)[z]	Peanut (67)[z]
	% positive	% positive	% positive
Adzukibean mosaic virus	69	76	24
Bean common mosaic virus	23	44	0
Blackeye cowpea mosaic virus	1	48	18
Bean yellow mosaic virus	83	95	22
Soybean mosaic virus	0	0	0
Peanut stripe virus	6	60	15
Isolate S-220 (AVRDC)	1	36	3
CMV-P	69	12	16

[z]Total no. of samples collected.

Table 11. Occurrence of BYMV in soybean, mungbean and peanut with different types of yellowing symptoms and light green mosaic.

Symptom type	Plants infected with BYMV/total no. of samples tested with particular symptom type		
	Soybean	Mungbean	Peanut
Yellow mosaic	25/30	0/1	1/2
Chlorosis	10/12	6/6	0/1
Yellowing	3/4	1/2	6/16
Light green mosaic	20/22	5/9	1/2

peanut stunt virus, southern bean mosaic, black gram mottle virus and bean golden mosaic virus were not detected and may, therefore, be absent or of no great importance in the regions surveyed.

The survey indicated that resistance to PStV should become one of AVRDC's objective for virus resistance breeding in soybean, since surveys conducted in Taiwan and Indonesia indicated that PStV seems to occur more frequently than SMV. Furthermore, for any virus resistance breeding program in Indonesia for soybean and mungbean, incorporation of resistance to BYMV should be a priority. Resistance to AzMV, CMV and PStV should also be considered. In previous screenings of AVRDC germplasm and breeding lines for resistance, soybean and mungbean lines with resistance to the

soybean and mungbean strain of PStV have been identified. These lines should be tested again in Indonesia with the local PStV isolates to ascertain whether resistance is not strain-specific.

Inheritance of Resistance to Peanut Stripe Virus

Summary

Inheritance of resistance to a soybean isolate of peanut stripe virus (PStV-strain PN) was studied in three soybean varieties, AGS 129, Ankur and PI 230971. Genetic analysis was based on necrotic, mosaic and symptomless reactions in inoculated soybeans. A single incompletely dominant gene in AGS 129 was found to confer the resistance to PStV and was tentatively designated as *Pst*. The homozygous parent AGS 129, possessing the genotype *Pst Pst* was immune, while Ankur and PI 230971, with a genotype of *pst pst*, were susceptible, showing mosaic symptoms. The heterozygous genotype *Pst pst* resulting from the cross of either Ankur or PI 230971 with AGS 129 reacted with necrosis, distinctly different from the reactions of either of the homozygous genotypes. This genotypic effect was confirmed through the phenotypic segregation in BC, F_2 and F_3.

Introduction

An aphid-transmitted potyvirus was frequently detected in surveys of the major soybean-growing areas in Taiwan. The virus was found to be either identical to, or a soybean isolate of peanut stripe virus (PStV). Yield loss due to early infection of soybean by this virus was found to be as high as 89%. The inheritance of resistance was studied in AGS 129, a soybean line previously found to be immune to this virus.

Materials and Methods

Three soybean lines, the resistant AGS 129 (P1), and two susceptible lines, Ankur (P2) and PI 230971 (P3), were used as parents. Both susceptible parents reacted only with mosaic when inoculated with the soybean isolate of PStV (PStV-PN).

The virus was propagated on susceptible *Glycine max* Rampage. Inoculum was made from freshly harvested leaves, homogenized at a ratio of 3 ml of 0.1 M potassium phosphate buffer pH 7.0 per 1 g of tissue. Unifoliate leaves were inoculated.

Symptom appearance was observed visually 50 days after inoculation. At 16 days after inoculation, the two-side leaflets of the first trifoliolate leaves were tested for the presence of virus by ELISA (Clark and Adams 1977).[6] A second ELISA test was performed 30 days after inoculation, using two-side leaflets of the second trifoliolate leaves of BC_1F_1 and F_2 plants from the cross of Ankur × AGS 129. Symptoms were classified into three categories: symptomless, mosaic and necrotic (local lesion on the inoculated leaves and/or systemic necrosis). Plants of the symptomless category always reacted negatively in ELISA, compared with those of the mosaic category which always reacted positively. Plants of the necrotic category gave positive ELISA values.

Results and Discussion

AGS 129 showed no virus symptoms when inoculated with PStV-PN. Both Ankur and PI 230971 developed mosaic symptoms and later vein banding on all trifoliolate leaves. All F_1 plants from the crosses of Ankur × AGS 129 and PI 230971 × AGS 129 produced local lesions on the inoculate leaves and/or systemic necrosis (Table 12). These results indicate that the genotype of these three parental soybean varieties was homozygous with respect to resistance or susceptibility to PStV-PN, and that the heterozygosity with respect to the reaction of F_1 plants to PStV-PN is expressed neither as complete resistance nor as susceptibility.

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[6]Clark, M.F. and A.N. Adams. 1977. Characteristics of the microplate method of enzyme-linked immunosorbent assay for the detection of plant viruses. J. Gen. Virol. 34:475-483.

The reaction of the backcross to the resistant parent, AGS 129, was symptomless and necrotic, while the backcross to the susceptible parent, Ankur, segregated into necrosis and mosaic symptoms, with the exception of two plants that showed no symptoms. The symptomless plants might be due to the failure of infection rather than to the results of genetic interaction to the virus (Table 12). The results suggested that the gene inducing no symptom or necrosis originated from AGS 129.

The segregation ratio in the F_2 population from the crosses Ankur × AGS 129 and PI 230971 × AGS 129 was approximately 1 symptomless: 2 necrosis: 1 mosaic (Table 12). This suggests single gene involvement and the presence of a dosage effect of the resistant allele, resulting in incomplete resistance expressed as necrotic symptom at a single dose of the resistant allele, compared to mosaic (susceptible) at zero dose, and symptomless (resistant) at the double dose.

A number of plants in the F_1 and F_2 populations from the cross of Ankur × AGS 129 and PI 230971 × AGS 129, which initially had only local lesion on the inoculated leaves, also developed systemic necrosis during the later stage (Table 13). Since all the F_1 plants from the crosses of Ankur × AGS 129 and PI 230971 × AGS 129 should have identical genotypes with respect to resistance to PStV-PN, the presence of these two different symptom types had to be attributed to nongenotypic factors, such as temperature, plant age and/or inoculum dosage.

Table 14 shows the F_3 segregation pattern of F_2 groups with different symptoms. As expected from the hypothesis above, F_3 plants derived from necrotic F_2 plants, segregated in the ratio of 1 symptomless: 2 necrosis: 1 mosaic, whether the seeds were from F_2 plants showing systemic necrosis or only local lesions without systemic necrosis. Every F_2 plant showing mosaic symptoms again produced only mosaic but no other symptom types in the F_3 offspring of both crosses. Progenies of symptomless F_2 plants were also studied for their reaction to the soybean isolate of PStV. A small number of these F_3 plants did show necrotic or mosaic symptoms, contrary to what had been expected probably due to escape in their parental F_2 generation.

Table 12. Reaction of parents, F_1, backcross and F_2 populations to soybean isolate of peanut stripe virus.

Population		No. of plants				Expected ratio	X^2	
		Total tested	Symptom-less	Necrotic[z]	Mosaic		Value	P
AGS 129	(P1)	71	71	0	0	-	-	-
Ankur	(P2)	20	0	0	20	-	-	-
PI 230971	(P3)	36	0	0	36	-	-	-
(P2 × P1)	F1	13	0	13(3)	0	-	-	-
(P3 × P1)	F1	17	0	17(12)	0	-	-	-
P1 × (P2 × P1F1)	BC	28	18	10(0)	0	1:1:0	2.286	.05-.10
P2 × (P2 × P1F1)	BC	32	2	15(10)	15	0:1:1	-	-
(P2 × P1) selfed	F2	300	73	139(81)	88	1:2:1	3.113	.10-.25
(P3 × P1) selfed	F2	58	12	32(14)	14	1:2:1	0.758	.50-.75
(P2 × P3) selfed	F2	160	0	0	160	-	-	-

[z]Number of plants showing local lesions on the inoculated leaves, figures in parentheses refer to the number of plants showing systemic necrosis

Table 13. Development at different times of systemic necrosis in plants initially with local lesions only.

Cross	Generation	Plants w/ local lesions[z]	Plants with systemic necrosis		
			16[y]	34[y]	50[y]
			%	%	%
Ankur × AGS 129	F_1	13	8	23	23
Ankur × AGS 129	F_2	80	35	46	56
PI 230971 × AGS 129	F_1	17	53	71	71
PI 230971 × AGS 129	F_2	32	34	38	44
Total		142	35	45	52

[z]Observed 16 days after inoculation. [y]Days after inoculation.

Table 14. Reaction to PStV-PN of F_3 plants originating from necrotic and mosaic F_2 plants from the crosses of Ankur × AGS 129 and PI 230971 × AGS 129.

Cross	Symptom class in F^2	F_3 Frequency			Expected ratio	X^2	
		Symptomless	Necrosis[z]	Mosaic		value	p
Ankur × AGS 129	Necrosis[y]						
	pooled	67	177(165)	80	1:2:1	3.857	.10-.25
	SN	24	61(57)	26	1:2:1	1.166	.50-.75
	LL	43	116(108)	54	1:2:1	2.831	.10-.25
	Mosaic	0	0	36	0:0:1	-	-
PI 230971 × AGS 129	Necrosis						
	pooled	56	140(137)	77	1:2:1	3.412	.10-.25
	SN	16	50(47)	26	1:2:1	2.869	.10-.25
	LL	40	90(90)	51	1:2:1	1.343	.50-.75
	Mosaic	0	0	51	0:0:1	-	-

[z]Plants showing local lesions on the inoculated leaves. Nos. in parenthesis are plants showing systemic necrosis. [y]SN = systemic necrosis; LL = local lesion or vein necrosis on the inoculated leaves only.

Since this is the first report on inheritance of soybean to peanut stripe virus (soybean isolate), the gene symbols *Pst* and *pst*, respectively, for resistant and susceptible checks, were tentatively assigned as the PStV resistance gene in *G. max* AGS 129.

Sweet Potato Breeding

Hybridization Program

Summary

A total of 108,639 seeds were produced from three open crosses and a series of hand crosses. The objectives were to obtain higher dry matter content, higher level of scab resistance and to backcross 5x-hybrids (progenies *Ipomoea batatas* × 4x *I. trifida*) with sweet potato.

Objectives

In the 1985-86 hybridization program, three groups of open crosses and a series of hand crosses were conducted. For dessert type sweet potato with orange flesh, improvement of dry matter content/yield was emphasized. The prior objective for the staple type was to combine sweet potato scab resistance and higher dry matter yield. To explore the possibility of utilizing wild species for the second straight year, the progenies (5x hybrids) obtained from the crosses between sweet potato cultivars and 4x *Ipomoea trifida* were backcrossed to sweet potato parents for the second straight year.

The results of the program are summarized in Table 1.

Table 1. Objectives and number of seeds produced in the AVRDC sweet potato hybridization program, fall 1986 to spring 1987.

Crossing method	Objectives	No. of cultivars/lines entered	No. of seeds harvested
Open cross			
	To improve dry matter content/yield of orange-fleshed type	5	63,053
	To combine scab resistance and high dry matter	8	42,290
	To backcross 5x-hybrids to sweet potato	12	2,316
Hand cross			
	To backcross 5x-hybrids (reciprocal cross) to sweet potato	8	980
		Total:	108,639

Seedling Screening and Observational Yield Trials

Summary

A total of 65,435 seeds were sown in the 1987 seedling screening, and from there 2,196 clones were selected and entered into observational yield trials (OYT). Different selection criteria for OYT

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selections, such as high dry matter of orange and staple types and utilization of wild relatives depending on the objectives of each population were applied.

Introduction

As a first step in identifying elite clones, a large number of entries are usually screened at the seedling stage and then entered into observational yield trials (OYT). In 1987 a total of 65,435 seeds were sown for seedling screening and, from there 2,196 clones were selected and entered into OYT.

Materials and Methods

Seedling screening. The seeds were sown on 10 to 13 and 19 March and screened on 29 June to 17 July. Detailed information about the populations and selection criteria are shown in Table 2.

Table 2. Selection status of seedling screening, AVRDC, 1987.[z]

Group	Seed source	Objectives	No. of seeds sown	No. of seeds germinated (A)	No. of selections (B)	Selection rate (B/A) (%)	Selection criteria
Group 1	1986-87 Open cross	To improve dry matter of dessert type	46,369	38,257 (82.5)[y]	1,200	3.1	Root formation Flesh color SG[x]: 1.04, 1.05
Group 2	1986-87 Open cross	To integrate scab resistance & high dry matter of staple type	8,072	6,869 (85.1)	370	5.3	Root formation Flesh color SG: 1.05, 1.06
Group 3	1985-86 Open cross	To improve dry matter yield of staple type	8,154	6,502 (79.7)	370	5.7	Root formation Flesh color SG: 1.06
		Subtotal:	62,595	51,628 (82.5)	1,940	3.8	
Group 4	1986-87 Open cross	To backcross sweet potato to 5x hybrids	1,860	516 (27.7)	129	25.0	Root formation
Group 5	1986-87 Hand cross	To backcross sweet potato to 5x hybrids	980	346 (35.3)	127	36.7	Root formation
		Subtotal:	2,840	862 (30.4)	256	29.7	
Total number of selected clones: 2,196							

[z]Date of planting = 10 – 13 and 19 March 1987; Date of selections = 29 June to 17 July 1987. The seeds were sown directly in the field with a spacing of 15 cm[2] cm. [y]Germination rate (%). [x]Specific gravity.

Observational yield trials (OYT). Selected clones from the 1987 seedling screening were planted on 1 to 16 July and screened on 28 October to 3 December. After screening, five cuttings of each selected plant were transplanted immediately into the field for OYT with a spacing of 1 m between rows and 25 cm between hills, without replication. The preselection in the field was based on the general root characters and specific gravity. The root samples of the selected clones were sent to the chemists for the analysis of dry matter content for final selection.

Results and Discussion

The results of the seedling screening and the OYT are summarized in Tables 2 and 3, respectively. A total of 221 entries were preselected in the field, and after getting the results of the analysis for dry matter content, 132 entries were finally selected.

For progenies obtained from the backcross of 5x hybrids (Groups 4 & 5), only root formation was used as a criterion for selection at seedling stage; moreover, less drastic selection pressure was applied at OYT than usual. Details are reported in the other section of this report.

Table 3. Selection status of observational yield trials, AVRDC, 1987.

Groups[z]	No. of entries	Preselection		Final selection	
		No.	%	No.	%
Group 1	1,200	97	8.1	38	3.1
Group 2	370	31	8.4	18	4.9
Group 3	370	29	7.8	12	3.2
Subtotal:	1,940	157	8.1	68	3.5
Group 4	129	–	–	23	17.8
Group 5	127	–	–	41	32.3
Subtotal:	256			64	25.0
Total no. of clones selected: 132					

[z]Objectives and sources of the groups are shown in Table 1.

Preliminary and Advanced Yield Trials

Summary

To select clones which adapt well to humid tropical conditions, preliminary yield trials (PYT) and advanced yield trials (AYT) were conducted in two different seasons (spring and summer) in the hot-wet season in Taiwan. Out of 21 entries in AYT, three breeding lines with high dry matter yield (CN 1510-25, CN 1489-89 and CN 1688-116) showed relatively good tolerance to the hot-wet conditions.

Introduction

From a large number of new genotypes which underwent rigorous screening at the early selection stages, only the promising breeding lines, or less than 10% of the original seedling populations, were evaluated in the preliminary yield trials (PYT). Subsequently, outstanding clones were entered into the advanced yield trials (AYT) and evaluated based on their combined performance over a few years. To distinguish the clones which adapt well to the humid tropics, the trials were conducted during spring and summer, hot-wet seasons in Taiwan.

Materials and Methods

A series of yield trials, PYT and AYT, were conducted in 1987 in two different seasons, spring and summer. The spring trials were planted in late March to early April and harvested in late July to early August to coincide with the wet season at the late stage of tuberization. The summer trials were conducted from early June to early October to encounter wet conditions at the initial stage of tuberization. The air temperature and rainfall during the trials are shown in Figure 1.

All the trials were set up to be harvested at 120 days after planting. However, the harvesting of the spring trials had to be postponed for 10 days because of heavy rainfall and the subsequent bad field conditions.

Because of the large number of entries, the total was divided in 18 groups for PYT and two groups for AYT. The common check cultivar for all groups was Tainung 66 (TN 66), a stable high-yielding local variety with good general acceptability. Besides TN 66, at least two other checks were also included in each group, such as CN 1108-13, CN 1232-9, CN 1489-43 and AIS 0122-2.

The experimental details of the trials are given in Table 4.

Results and Discussion

Preliminary yield trials (PYT). A total of 158 entries were evaluated in the 1987 PYT.

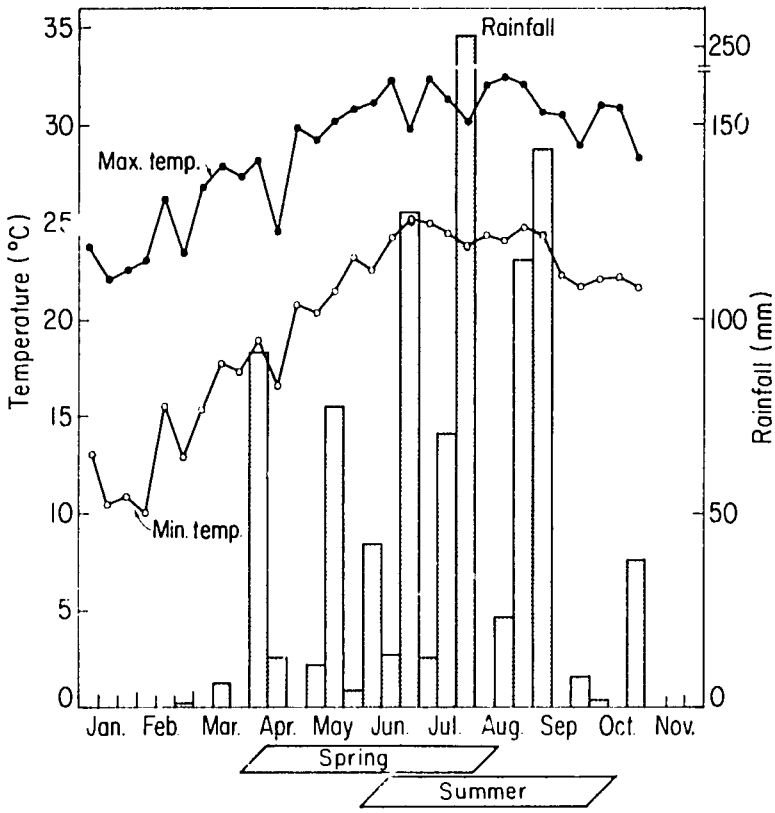


Fig. 1. Temperature and rainfall during the spring and summer trials of sweet potato, AVRDC, 1987.

Table 4. Sweet potato yield trials conducted during 1986, AVRDC.

Trial	Group number	No. of entries	Spring[z]		Summer		Remarks
			DP[y]	DH[x]	DP	DH	
PYT[w]	1-8	64	Apr. 2	Aug. 10-12	Jun. 3	Oct. 1-2	
	9-10	16	Apr. 8	Aug. 18	Jun. 10	Oct. 8	Experimental design:RCBD (2 reps)
	11-13	36	Apr. 8	Aug. 18	Jun. 9	Oct. 5	Unit plot: 2 rows, 5 m long
	14-17	32	Apr. 1	Aug. 13	Jun. 9	Oct. 12	Spacing: 100 cm × 25 cm
	18	11	Mar. 24	Jul. 29	Jun. 2	Oct. 1	
Total:	18	159					
AYT[v]	1	10	Mar. 24	Aug. 3	Jun. 16	Oct. 14	Experimental design: RCBD (4 reps)
	2	11	Mar. 24	Aug. 3	Jun. 16	Oct. 14	Unit plot: 4 rows, 5 m long[u] Spacing: 100 cm × 25 cm
Total:	2	21					

[z]The harvesting of all spring trials was postponed for about 10 days because of heavy rainfall and subsequent bad field conditions. [y]Date of planting. [x]Date of harvesting. [w]Preliminary yield trial. [v]Advanced yield trial. [u]Yield data were taken only from the middle two rows.

The performance of the high-yielding clones is shown in Table 5. The yield data were adjusted to remove the effect of trial locations of groups and then combined over groups within each season.

Yield of the summer trials were heavily depressed compared with the spring trials. Among the check cultivars, TN 66 was the most depressed showing only 9% of the spring season yield. CN 1108-13 gave the best yield during the summer season, even though the yield was only 9.8 t/ha, which was 26% of the spring season yield.

Considering the difference in the performances between spring and summer seasons, the high-yielding entries can be divided into two groups. The first group had yields higher or comparable

Table 5. Adjusted yield and other characteristics of sweet potato selections from preliminary yield trials, AVRDC, 1987.

Clone no.	Adjusted yield (t/ha)[z]		Dry matter[y] (%)	Flesh[x] color
	1987 Spring	1987 Summer		
CN 1831-55	75.6*	7.9	34.0	Y3O3
CN 1831-66	64.3*	6.1	34.9	Y3
CN 1831-42	52.6*	4.3	36.9	Y3
CN 1828-37	50.7*	8.0	35.4	Y7
CN 1831-14	47.8	6.4	35.7	Y3
CN 1831-33	47.8	2.3	36.0	Y1
CN 1821-39	41.8	12.0	29.2	Y3
CN 1821-8	41.2	26.0*	30.8	Y5
CN 1756-163	40.5	28.1*	26.9	Y1
CN 1795-268	40.2	6.6	35.3	Y7
CN 1732-4	39.2	7.0	36.1	Y3
CN 1836-163	39.0	11.4	29.7	Y3
CN 1821-130	38.7	22.0*	21.8	O3Y1
CN 1836-188	38.5	11.2	32.4	Y1
CN 1790-42	38.4	7.7	29.9	O3Y3
CN 1826-45	34.5	18.9*	33.0	O3
CN 1831-57	33.7	16.7*	30.2	O3Y7
CN 1822-101	29.0	16.6*	27.5	O5
CN 1108-13 (ck)	36.5	9.8	24.1	O3Y3
TN 66 (ck)	35.2	3.2	24.5	O5
CN 1232-9 (ck)	32.1	3.2	25.2	Y1
CN 1489-43 (ck)	29.1	4.6	33.9	Y3
AIS 0122-2 (ck)	28.0	2.8	19.7	O5
AIS 0125-2 (ck)	16.1	3.6	25.1	O5
TN New 31 (ck)	1.1	0.4	23.7	Y1
Mean of 165 entries	28.9	6.3		
LSD (0.01)	12.2	6.6		
CV (%)	16.5	40.8		

[z]Value given is the mean of the adjusted value (Y) where: Y = observed value × [mean of checks (TN 66)/mean of check (TN 66) at a given group]. [y]Value given is the average of two seasons. [x]Y = yellow, O = orange. Increasing color intensity is indicated by the number prefix (1 = pale to 7 = very intense). *Significantly higher than the superior check cultivars.

to the superior check in the spring season, but the summer group were low yielders with only 4% to 29.2% of the spring season's yield. Cultivars CN 1831-55, CN 1831-66, CN 1831-42, CN 1828-37 and the other seven entries listed in Table 5 were classified in the first group.

The entries belonging to the second group were more tolerant to excess moisture conditions. Six entries in the trials, CN 1756-163, CN 1795-268, CN 1821-130, CN 1826-45, CN 1831-57 and CN 1822-101, were classified in the second group. The yield of the summer entries ranged from 16.6 to 28.1 t/ha, which was 49.6% – 69.3% of the spring's yield.

In the spring trials, all the checks showed good performance and the yield seemed not affected by the wet condition at the late stage of tuberization. However, it was that several of the breeding lines showed frequent field sprouting and contained rotten roots. Field sprouting was observed less in the summer than in the spring trials.

Spring and summer planting seasons provide a good basis for analyzing the adaptability of sweet potato clones to the humid tropics. In spring trials, sweet potato yield was equivalent to those under more favorable conditions, such as the fall planting season in Taiwan. Clones with field sprouting and root rotting can be eliminated in this trial. In summer trials, the effect of excess moisture on storage root performance can be evaluated.

Advanced yield trials (AYT). A total of 21 entries were entered into the AYT in 1987. Since there was no difference in the yield of TN 66, the common check cultivar, over two groups, the yield data were combined and analyzed over groups within each season.

As in the PYTs, the summer yield was heavily reduced compared with the spring yield. Among the check cultivars, TN 66 was also the most sensitive to wet conditions.

The distribution of the yield and dry matter content of all entries and check cultivars of the AYT in spring is shown in Figure 2. All the entries exceeded the check cultivars in dry matter content. For dry matter yield among the checks, TN 66 showed the highest dry matter yield at 8.9 t/ha; 18 of the entries showed higher or comparable dry matter yield to TN 66. More specifically six entries, CN 1510-25, CN 1656-97, CN 1489-89, CN 1656-101, CN 1661-62 and CN 1688-116 showed significantly higher dry matter yield at 10.7 to 12.4 t/ha than TN 66.

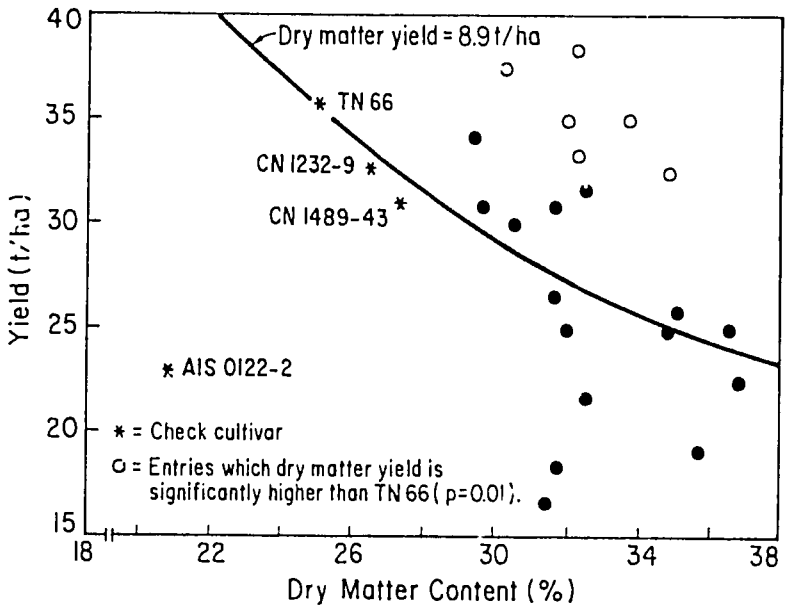


Fig. 2.
Yield and dry matter content of 21 entries of the advanced yield trial in spring 1987 at AVRDC.

The yield and other characteristics of the best selections from AYT are given in Table 6. In the spring, all the selections performed comparably to TN 66. In the summer, the yield of these selections decreased from 30.6% to 59.3% of the yield in the spring trials. CN 1656-97 and CN 1618-461 were considered more sensitive to the hot-wet conditions than the other six selections, which showed comparable yield to CN 1108-13, the superior check cultivar in the season. Therefore, CN 1510-25, CN 1489-89 and CN 1688-116 were considered as promising lines for humid tropical conditions. These entries will be evaluated further.

Utilization of Related Species in Sweet Potato Breeding — Preliminary Evaluation of the First Backcross Generation Between 5x Interspecific Hybrids and Sweet Potato

Summary

Some 5x hybrids, obtained from crosses between sweet potato cultivars and 4x *I. trifida*, showed weevil resistance or high dry matter content in the previous evaluations. To improve the yielding ability of the 5x hybrids, backcrosses were made and BCF_1 progenies evaluated in OYT trials. There were clear differences in crossing direction between sweet potatoes and the 5x hybrids for capsule set, seed germination and root performance.

Table 6. Yield and other agronomic traits of selections from advanced yield trial, AVRDC, 1987.

Clone	Marketable yield (t/ha)		Dry matter content (%)		Dry matter yield (t/ha)		Root characters* (spring)[z]				
							Unif.	Size	Shape	Skin color	Flesh color
	87 sp	87 su	87 sp	87 su	87 sp	87 su					
CN 1510-25	38.3	16.4 (42.8)[x]	32.4	29.9	12.4*	4.9	F	M-L	LS	R3	Y3
CN 1656-97	37.3	11.4[y] (30.6)	30.2	30.7	11.3*	3.5	P	M	S	Y3R3	Y1
CN 1489-89	34.9	20.7 (59.3)	33.8	33.6	11.8*	7.0*	F	M-L	LS	Y3	Y3
CN 1525-11	34.3	13.8 (40.2)	29.5	28.8	10.1	4.0	F	M-L	LS	Y3	Y5
CN 1656-101	33.3	13.1 (39.3)	32.2	30.2	10.7*	4.0	F	M-L	S	Y3R3	Y1
CN 1688-116	32.4	15.6 (48.1)	34.7	33.1	11.2*	5.2	F	M-L	LS	R5	Y1
CN 1656-37	31.5	16.1 (51.1)	32.6	32.9	10.3	5.3	F	M	S	R7	Y3
CN 1618-461	31.0	11.1[y] (35.8)	29.8	29.0	9.2	3.2	F	M	LS	Y5	Y3
TN 66	35.6	4.6[y] (12.9)	25.1	25.4	8.9	1.2[y]	G	M-L	LS	R5	O5
CN 1108-13	32.9	17.2 (51.7)	26.6	24.7	8.8	4.3	F	M-L	M	O3Y3	O3Y3
CN 1232-9	30.6	10.9[y] (35.6)	27.5	25.0	8.4	2.7[y]	F	M-L	R-S	Y3	Y3
Mean of 26 entries	28.0	10.7			8.7	3.3					
LSD (0.01)	5.2	4.8			1.7	1.5					
CV (%)	9.8	23.9			10.4	24.9					

[z](Unif.) G = good, F = fair, (Size) M = medium, L = large; (Shape) M = massive, R = rounds, S = spindle, SS = short spindle, LS = long spindle; (Skin and flesh color) R = red, Y = yellow, O = orange, increasing color intensity indicated by number prefix (1 = light to 6 = very intense). [y]Significantly lower than the superior check cultivar. [x]Summer/spring (%). *Significantly higher than the superior check cultivar.

Introduction

Genetic introgression from wild relatives has been utilized as an effective breeding method to introduce specific characters in many crops. The use of wild relatives in sweet potato breeding has been tried also since the 1930s. However, much more information is needed to utilize wild relatives in practical breeding procedures, especially for the breeding value of 2x or 4x *Ipomoea trifida* which are more common in nature and with wider variation than 6x *I. trifida*.

Crosses between sweet potato cultivars and 4x *I. trifida* were made by Dr. Masaru Iwanaga of the International Potato Centre (CIP). The progenies, which were supposed to be 5x, were evaluated at AVRDC for agronomic traits, nutritional value and weevil resistance in 1985-86. Although the 5x hybrids showed potential for weevil resistance and high dry matter content, they were still not of immediate use as cultivars.

The first backcross of the 5x hybrids was conducted using open cross and hand cross. The feasibility of transferring the desirable traits of the 5x hybrids to the backcross progenies without reduction of intensity was monitored. The progenies from the first backcross (BCF_1) were evaluated in the preliminary trial mainly for their root performance.

Materials and Methods

Open cross. Based on the weevil screening trial and the preliminary evaluation trial in 1985, six of the 5x hybrids (Table 7) with the following characteristics were selected to enter the open cross nursery for backcross: 1) none or low weevil infestation, 2) high dry matter, and 3) relatively good yield.

Together with the six 5x hybrids, two leading Taiwanese cultivars, TN 66 and TN 57, and four AVRDC advanced clones, CN 1108-13, CN 1345-8, CN 1405-14 and AIS 0122-2, were set into the crossing field as shown in Figure 3. A beehive was placed in the nursery to promote pollination. Seeds were collected only from the 5x hybrids.

Hand cross. Reciprocal crosses were made between two sweet potatoes, CN 1345-8 and CN 1405-14, and five clones of 5x hybrids (Table 7). The 5x hybrids were selected based on results of the weevil-screening trial, the preliminary evaluation trial in 1985 and the secondary evaluation

Table 7. 5x interspecific hybrid clones used in the backcrosses.

Clones (5x hybrids)	Pedigree (Female) *I. batatas*	×	(Male) 4x *I. trifida*
Open cross			
WT 81	Kyukei 7210-34		CCP 9-17
WT 129	Kyukei 7210-34		CCP 9-2
WT 298	Kyukei 42		CCP 6-4
WT 532	Koganesengan		CCP 9-2
WT 629	Kyukei 7210-34		CCP 9-17
WT 700	Kyushu 90		CCP 9-2
Hand cross			
WT 81	Kyukei 7210-34		CCP 9-17
WT 260	Kyukei 42		CCP 6-4
WT 298	Kyukei 7210-34		CCP 6-4
WT 352	Kyushu 90		CCP 6-4
WT 459	Kyukei 42		CCP 6-4

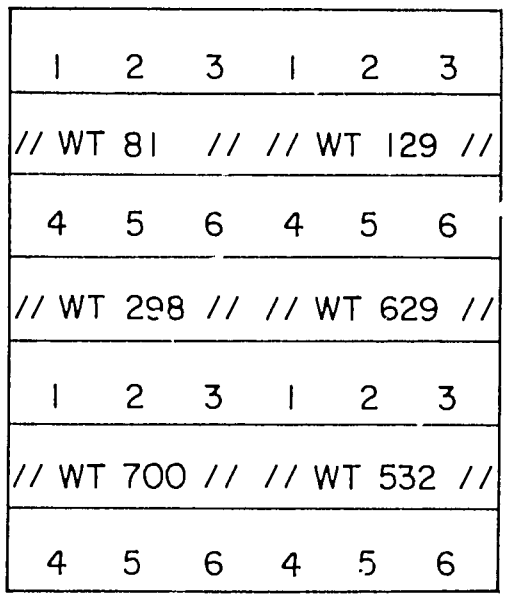


Fig. 3.
Field layout of the open-crossing nursery for backcross; 1 = TN 57, 2 = TN 66, 3 = CN 1345-8, 4 = CN 1405-14, 5 = CN 1108-13, 6 = AIS 0122-2. Seven plants were planted for each plot.

trial in 1986 for none or low weevil infestation, high dry matter and relatively stable yield over the three trials.

Seedling screening and observational yield trial. The seeds obtained from both the open cross and the hand cross were sown on 13 March and harvested on 6 July 1987. The plants which produced storage roots, regardless of size, were selected and five cuttings from each were transplanted immediately into the OYT field and harvested on 2 November. Yield, number of roots and root flesh color were recorded. Based on general appearance, 66 clones were selected, and root samples were sent to the chemist for analysis of nutritional value.

Results and Discussion

All the 5x hybrid entries were self-pollinated and pollen germination on stigma was observed by using aniline blue stain method. The results showed that all of the 5x hybrid entries of the trial were self-incompatible.

A total of 2,316 seeds from the open cross and 980 seeds from the hand crosses were obtained.

The results of the evaluation of the progenies obtained from the open cross are summarized in Table 8. The general crossing abilities of the six 5x hybrids with sweet potatoes were quite different in each clone. No seed was obtained from WT 700 and only 60 seeds from WT 81, whereas 1,819 seeds were obtained from WT 532. In the seedling screening, progenies from WT 81 showed lower germination rate than those from the other four clones, and none of them produced storage roots while about half of that of the progenies from the others produced storage roots. In the OYT, some of the entries showed yields comparable to that of sweet potato cultivars, but generally, the number of roots and root weight of BCF_1 progenies were almost half of that of the check cultivars. No special influence was shown by the female parental lines.

Table 8. Germination rate and root performance of the progenies (BCF_1 progenies) obtained from the outcross.

Clones (Female parents)	Seeds harvested	Seedling screening		Observational yield trials			
		Germination rate (%)	Seedlings with tuberous root (%)	No. of root/plot		Root wt.(kg)/plot	
				Range	Mean	Range	Mean
WT 81	60	19.0	0	-	-	-	-
WT 129	176	37.5	43.2	0-28	12	0-2.2	0.8
WT 298	126	26.3	52.6	1-23	11	0.1-2.1	1.0
WT 532	1819	26.7	42.3	0-30	11	0-3.0	0.8
WT 629	135	30.3	47.4	0-25	13	0-1.7	1.0
WT 700	0	-	-	-	-	-	-
			Mean of BCF_1 progenies:		12		0.9
			Check cultivars:				
			TN 66	15-28	21	1.2-2.2	1.7
			CN 1108-13	17-32	24	1.6-3.7	2.3
			CN 1232-9	11-24	18	1.1-3.0	2.4
			CN 1345-8	13-24	20	2.0-2.8	2.5
			CN 1489-43	12-21	18	1.0-1.9	1.4
			Mean of check cultivars:		20		2.1

Differences between crossing direction or parents were evaluated for crossing ability, seed germination and storage root performance for the progenies obtained from the hand crosses. No significant differences were observed among the parents. However, clear differences by crossing direction between sweet potatoes and 5x hybrids were observed. For all the characters shown in Figure 4, except the number of roots, higher figures were obtained when the 5x hybrids were used as male parents.

The frequency distribution of the yield in OYT by crossing direction is shown in Figure 5. In terms of yield, there was a higher possibility to obtain better-yielding progenies when 5x hybrids were used as male parents.

From the 256 OYT entries, 66 clones were selected and the root samples analyzed by the chemists (Table 9). For all the components analyzed, no special tendency was recognized in comparison with the distribution of the variation of ordinary sweet potatoes.

The evaluation reported here is preliminary. The selected BCF_1 progenies will be evaluated for weevil resistance, yielding ability in bigger scale and other agronomic traits in the next step.

Preliminary Evaluation of Sweet Potato for Reduced Sweetness

Summary

The sweetness of sweet potato depends on the concentration of both nonreducing and reducing sugars. The development of nonsweet sweet potato is one possibility of promoting the utilization of this crop in wider areas. A total of 70 advanced clones and germplasm accessions were analyzed for

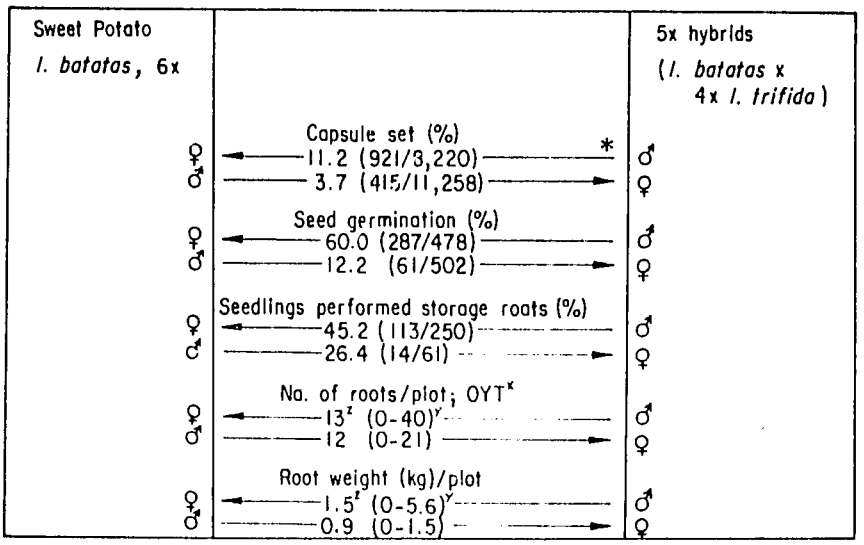


Fig. 4. Difference of the performance of BCF_1 progenies by crossing direction. *Crossing direction; [z]Mean of the entries; [y]Range; and [x]Observational yield trial.

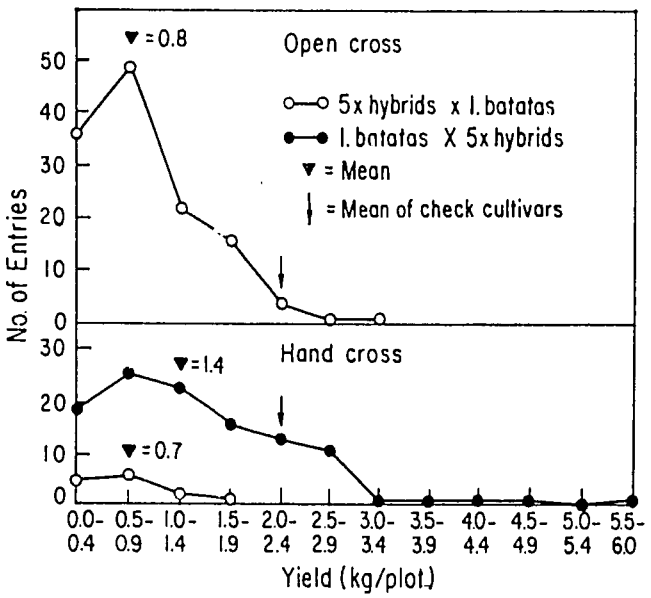


Fig. 5. Frequency distribution of yield among BCF_1 progenies by crossing direction.

Table 9. Nutritional components of BCF_1 clones compared with check cultivars.

Early	Dry matter (%)	Protein	Sugar	Starch	Fiber	Carotene (mg/100 g)	Amylase (unit*/ml)
		% DWB[z]					
BCF_1	19.1-38.6	2.5-7.6	5.7-18.2	52.2-78.0	2.5-5.7	1.5-9.5	8.5-245.9
n = 66	27.0	4.6	11.9	68.5	3.7	3.3	104.5
TN 66	25.5	4.8	15.3	62.0	4.0	7.7	212.7
CN 1108-13	22.4	3.2	16.5	65.2	3.7	5.0	29.3
CN 1232-9	24.9	4.6	12.6	64.3	4.2	2.5	27.1
CN 1345-8	29.5	3.9	11.0	69.3	3.5	2.7	107.6
CN 1489-43	31.2	3.9	11.9	71.3	3.4	3.3	60.8

*Unit = 1 mg Maltose/min. [z]DWB = Dry weight basis.

nonreducing sugar content and the activity of β-amylase which converts starch into reducing sugar during cooking. A total of 13 clones showed low β-amylase activity and also low sugar content and were identified as promising breeding materials.

Introduction

According to AVRDC's sweet potato survey in 1983, 76% of the respondents from the Asian and Pacific regions felt that sweet and moderately sweet sweet potatoes were preferable to the nonsweet type. Even in a country like Papua New Guinea, where sweet potato is an important staple food, the people prefer the sweet or moderately sweet type.

However, despite its high energy productivity and relative tolerance to biotic or abiotic stresses, sweet potato is not well accepted as a substitute staple food by people who are used to having other crops, such as yam or cassava, because of its sweetness. The development of nonsweet or less sweet potatoes has been considered to promote its utilization in a wider area.

The sweetness of sweet potato depends on the concentration of both nonreducing and reducing sugars. Nonreducing sugar, such as sucrose, is not affected by cooking; however, reducing sugar, such as maltose, increases during cooking because of the presence of β-amylase. To develop the nonsweet type, concentrations of both nonreducing and reducing sugars should be considered.

Recently Martin and Ruberté (1983)[1] reported a sweet potato cultivar, "Ninety-nine" developed at the Tropical Agriculture Research Station in Puerto Rico in which the starch was not converted to maltose by cooking. Likewise in Japan, cultivar "Satsuma Hikari" with low β-amylase activity had been officially released in 1987 (Kakimura et al. 1987)[2]. Japanese scientists also reported that sweet potato with low β-amylase activity is suitable not only for staple use but also as materials for the food processing industry, such as for dried flakes, granule powder, fried chips and French fries.

The development of these cultivars caught the interest of some national breeding programs; thus, promising breeding materials for this purpose are required. The AVRDC sweet potato germplasm were evaluated for less sweetness considering these requirements.

Materials and Methods

A total of 52 advanced lines and 41 germplasm accessions considered as good breeding materials for specific characteristics, i.e. high yield, scab and vineborer resistance and wide adaptability, were entered into the evaluational trials.

Ten cuttings for each clone were planted on 28 April and harvested on 26 August 1987. A plot consisted of a single 2.5-m long row. Rows were spaced 1 m apart and plants within the row 25 cm apart, without replication. Three check cultivars, CN 1108-13, CN 1232-9 and Tainung 66, were planted every 25 entries.

At harvest, yield and other agronomic characters were recorded and root samples were sent to the chemists for analysis.

Results and Discussion

Out of 96 entries, including the check cultivars, 26 had low yield and insufficient storage roots for sampling to obtain reliable chemical data for analysis. Therefore, only 70 entries were analyzed.

The frequency distribution of β-amylase activity and nonreducing sugar content of the entries are shown in Figure 6. The β-amylase activity of the entries varied from 1.4 to 455.7 unit/min (Unit = 1 mg maltose) and range of the sugar content was 4.5 to 20.3 (% dry weight base).

[1]Martin, F.W. and R.M. Ruberte. 1983. Sugars in staple type sweet potatoes as influenced by cooking technique. Proc. Amer. Soc. Hort. Sci. Trop. Reg. 27(8):136-138.

[2]Kukimura, H., T. Yoshida and K. Komaki. 1987. A new sweet potato variety 'Satsumahikari'. J. Agr. Sci. 42,30. (In Japanese.)

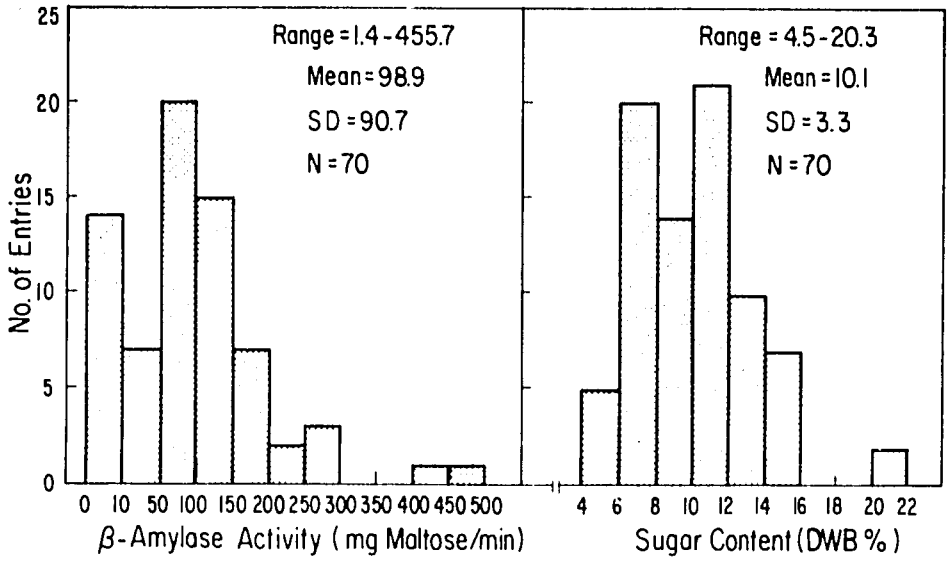


Fig. 6. Frequency distribution of β-amylase activity and nonreducing sugar content among 70 sweet potatoes.

Entries with β-amylase activities less than 10 unit/min, and their sugar and dry matter contents, are listed in Table 10. Of these 14 entries, 12 are new introductions from Japan. The clones were F_1's from the cross between the cultivars with low β-amylase activity, Kanto 92 and Satsuma Hikari. AVRDC advanced clone, CN 1229-14, appeared as the second lowest and the Taiwanese local cultivar, Kinmen, also showed relatively low activity. It was also found that sugar contents of all the clones except Kinmen were quite low.

Since Ninety-nine (I 1192) from Puerto Rico did not perform well in this trial, the root sample from the propagation field was analyzed. The β-amylase activity was 24.7 unit/min.

There was no significant correlation between β-amylase activities and sugar contents of the 70 entries (Fig. 7). This suggests the possibility of developing sweet potato low in both β-amylase activity and sugar content.

International Cooperation

Summary

The first batch of 22 improved AVRDC breeding materials had gone through the virus-indexing scheme and became available for international distribution in November, 1987.

The performance of 11 AVRDC advanced lines in China was reported. CN 1108-13 performed well in the preliminary yield trials at several locations and was selected to be further tested for adaption to broader growing areas.

International Distribution

International exchange of wide-scale tested improved sweet potato breeding materials has always been restricted by strict quarantine regulations. Thus, a virus-indexing scheme was instituted by AVRDC virologists as a self-imposed requirement to ensure that only 'clean' stocks are provided to AVRDC's international cooperators. Twenty-two improved sweet potato breeding materials had been through the scheme as the first batch and became available for international distribution since November, 1987.

Table 10. Sugar and dry matter contents of low β-amylase clones.

Name or No. of Entries	β-amylase activity (unit[z]/min.)	Sugar (% DWB)	Dry Matter (%)
71-4	1.4	7.9	34.9
CN 1229-14	2.1	8.6	32.7
71-1	2.3	6.8	36.5
71-5	3.1	7.1	39.6
71-10	3.5	9.3	32.4
71-2	4.1	5.8	39.1
71-3	4.5	8.1	34.0
71-6	5.4	7.3	35.6
71-7	9.9	15.4	23.4

[z]Unit = 1 mg maltose.

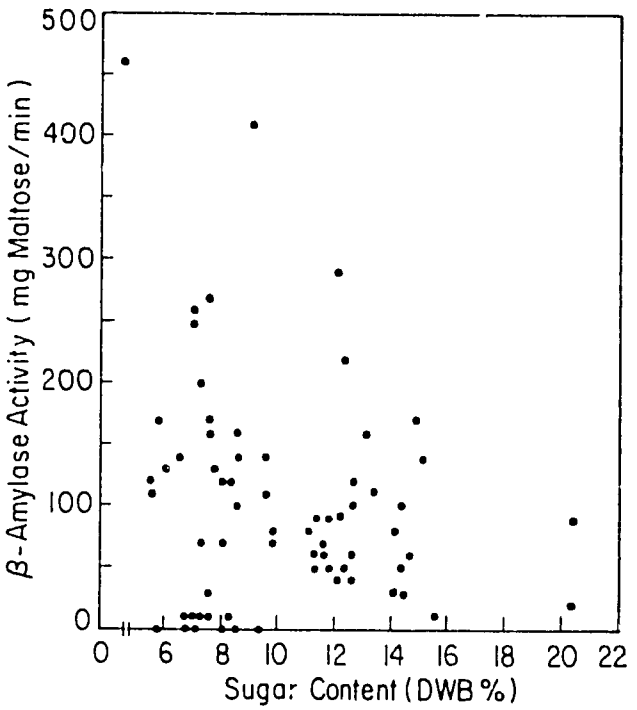


Fig. 7.
Relationship between β-amylase activity and sugar content of 70 sweet potatoes.

Feedback from International Cooperators

Except for the result from China, no other feedback from the international cooperators on advanced lines distributed was received.

The performance of AVRDC advanced lines in China was provided by Dr. Kenneth T. MacKay of the International Development Research Centre (IDRC).

Eleven advanced sweet potato lines of AVRDC were included in yield trials conducted in 1985. The participating institutions were: the Chinese Sweet Potato Research Laboratory in Xuzhou, the Sweet Potato Laboratory of the Jiangsu Academy of Agricultural Science in Nanjing, the Crop Research Institute of the Sichuan Academy of Agricultural Science in Chengdu, and the Upland Crop Research Institute of the Guangdong Academy of Agricultural Science in Guangzhou.

From the data provided, only the result from the Chinese sweet potato research laboratory in Xuzhou is included in this report (Table 11). In total, leaves of CN 1108-13, CN 1232-9, CN 1367-2 and I 423 outyielded the best check variety, Xushu 18, which was a newly released award-winning Chinese national sweet potato variety. CN 1108-13 and AIS 0122-2 produced more roots than Xushu 18. CN 1108-13 also outyielded Xushu 18 in total chip production.

Based on the results of these preliminary trials, CN1108-13 was selected to be further tested for adaption to other growing areas in China.

Table 11. The performance of AVRDC sweet potato lines in Xuzhou, China, 1985.[z]

Entries	Leaves (t/ha)	Roots (t/ha)	Chips (t/ha)
AIS 35-2	19.39	26.73	6.58
AIS 0122-2	25.50	30.52	4.46
CN 941-32	21.63	21.73	5.02
CN 1038-16	17.00	26.78	7.47
CN 1108-13	30.74	38.80	8.96
CN 1219-1	20.83	19.70	5.10
CN 1232-9	38.89	24.33	5.38
CN 1280-3	21.91	25.71	6.17
CN 1367-2	29.48	–	–
I 423	38.76	21.17	4.50
I 981	22.50	23.67	5.68
Beijing 284 (cK 1)	18.67	27.81	6.34
Xushi 18 (cK 2)	26.07	30.28	8.30

[z]The data was provided by Dr. K.T. MacKay, International Development Research Centre.

Sweet Potato Entomology

Search for Sweetpotato Weevil-Resistant Germplasm Sources

Summary

Three sets of trials were conducted to screen sweet potato germplasm for resistance to sweetpotato weevil, *Cylas formicarius*. Certain accessions showed significantly less infestation than the standard susceptible checks. Since wide variation in weevil infestation of any particular sweet potato accession for each season and each location is common, the least damaged accessions will be screened next year to confirm the resistance.

Introduction

Sweetpotato weevil, *Cylas formicarius formicarius* F. (Coleoptera:Curculionidae), is the most destructive pest of sweet potato in the tropics and subtropics. The larvae and adults feed on sweet potato roots and crowns. Weevil feeding either on the roots or crowns does not reduce yield, but even slight pest damage impairs the quality of the infested roots, making them unfit for human consumption. To control this pest inexpensively and effectively, sweet potato germplasm have been screened since 1975 to find an accession resistant to this pest. In 1986-87 three such screenings were conducted.

Materials and Methods

The land used for the screening was rototilled and worked into 1-m wide beds after the application of basal fertilizers. Eight weeks prior to the planting of test materials, every third row was planted to a weevil-susceptible cultivar, I 57. A week before planting the test materials, laboratory-reared weevil adults were released uniformly over the planted rows. These weevil-infested rows later served as source of weevil for infestation of test materials. Sweet potato accessions to be screened were planted between weevil-source rows in 1 m × 5 m plots. The crop was raised using customary cultural practices, except that no insecticide was applied. At harvest the roots were evaluated for weevil infestation by cutting open each root and counting the number of larvae, pupae and adults found inside. The insect count (larvae + pupa + adults) data were converted to the number of total insects per kilogram of roots and subjected to statistical procedure specific to each screening.

Preliminary screening. In this screening, 31 accessions which were never screened before were included. Each accession was planted in a single nonreplicated plot. The insect count data were statistically analyzed based on the mean and standard deviation (sd) of the population included in the test. The accessions were classified into various resistance categories as follows:

Highly resistant (HR) = No. of insects/kg roots
less than mean − 2 sd
Moderately resistant (MR) = No. of insects/kg roots
between mean − 2 sd and mean − 1 sd
Low resistance (LR) = No. of insects/kg roots
between mean − 1 sd and mean

Susceptible (S) = No. of insects/kg roots
between mean and mean + 2 sd
Highly susceptible (HS) = No. of insects/kg roots
more than mean + 2 sd

Intermediate screening. In this screening, six accessions which showed least damage in one previous screening were included in a three-replicate screening test. The insect count data were subjected to analysis of variance and means were compared by Duncan's multiple range test.

Advanced screening. In this screening one accession, I 943, which was least damaged in two previous tests was compared for weevil infestation with two susceptible checks in a six-replicate test. The insect count data were analyzed by analysis of variance and means were compared by Duncan's multiple range test.

Results and Discussion

Preliminary screening. The number of weevils per kilogram of roots ranged from 0 to 172. Among 31 accessions 5 were highly susceptible, 4 were susceptible and 22 showed low levels of resistance. Among the low resistance accessions, the insect number ranged from 0 to 30.4/kg roots. Seven accessions, namely, I 967, I 986, I 990, I 991, I 998, I 999 and I 1000 had no insect infestation. These accessions will be included in next season's screening to confirm the resistance.

Intermediate screening. The results of the second screening are summarized in Table 1. Two accessions, I 600 and I 783, were free of weevil infestation. The remaining three entries were at par with the susceptible check, I 57. Accessions I 600 and I 783 were also least damaged in the preliminary test in 1985-86. These two accessions will be screened in an advanced screening test in 1987-88 to confirm the resistance.

Advanced screening. In this test accession I 943, which had shown least damage in two previous tests, was as susceptible to weevil as the two known susceptible checks, I 57 and I 207.

As in previous years, a considerable variation in weevil infestation of sweet potato roots was observed among replicates of the same accession in the same experiment. Despite continuous efforts over the past 12 years, a resistant sweet potato accession has not yet been found.

Table 1. Infestation of selected sweet potato accessions by sweet-potato weevil, AVRDC, autumn 1986 and 1987.[z]

Accession	No of weevils/kg roots
I 600	0.00 b
I 783	0.00 b
I 712	0.67 ab
I 810	1.10 ab
I 626	2.77 ab
I 57[y]	5.40 a

[z]Planted 1 September 1986 and harvested 10 February 1987. Plot size 1 m × 5 m. Design: RCBD with three replicates. Mean separation by DMRT. [y]Susceptible check.

Screening of Progenies from Interspecific Cross for Sweetpotato Weevil Resistance

Summary

Forty-nine progenies of a cross between *Ipomoea batatas* and *Ipomoea trifida* that were least damaged in 1985-86 season were screened for resistance to sweetpotato weevil, *Cylas formicarius*.

There was a wide variation among replicates of each entry and among entries which vitiated selection of least damaged clones based on statistical test. Nonetheless, 13 entries were free of weevil infestation and five entries had less than one weevil/kg roots. These entries will be screened next year to confirm the stability of resistance.

Introduction

Since getting a reliable source of resistance to sweetpotato weevil, *Cylas formicarius formicarius* F. (Coleoptera:Curculionidae) has proven to be an extremely difficult task, in 1985 crosses were made by a CIP plant breeder between *Ipomoea batatas* and *I. trifida*, with the objective of developing a weevil-resistant sweet potato cultivar. In a preliminary single replicate trial in the 1985-86 season, 1,131 progenies were screened and 49 entries with satisfactory yield and low weevil infestation were selected for second screening. In the 1986-87 season, these entries were evaluated for weevil resistance.

Materials and Methods

Each entry, including two susceptible checks, was planted in three randomly selected 1 m × 5 m plots in a sweetpotato weevil nursery. Each plot was bordered on one side by a weevil-infested row of sweet potato which was planted two months earlier and inoculated with laboratory-reared weevil. The crop was grown using customary cultural practices except that no insecticide was applied. At harvest yield was recorded and the roots evaluated for weevil infestation by cutting them open and counting the number of larvae, pupae and adults found inside. The insect count data were converted to the number of total insects (larvae + pupae + adults) per kilogram of roots. The data were studied by analysis of variance and means were separated by Duncan's multiple range test.

Results and Discussion

The results of weevil infestation are summarized in Table 2. The number of insects found per kilogram of roots ranged from 0 to 45. There was considerable variation between replicates of entries which had weevil infestation. As a result there was no statistically significant difference among these entries and the susceptible checks, and in fact some test entries were more susceptible than the susceptible checks, I 444 and I 57. However, 13 test entries were free from weevil damage and five entries had less than one weevil/kg roots. The entries with less damage during the previous year will be tested in 1987-88 season to confirm the stability of resistance.

Correlation between Root Characters and Sweetpotato Weevil Infestation

Summary

In a three-year (1984-86) correlation study between easily quantifiable sweet potato root characters and sweetpotato weevil (*Cylas formicarius*) infestation, no significant and consistent correlation was observed between root characters, such as dry matter, sugar, β-carotene, protein content and weevil infestation.

Introduction

Sweetpotato weevil, *Cylas formicarius formicarius* F. (Coleoptera:Curculionidae), infests sweet potato roots and makes even slightly damaged roots unfit for human consumption. AVRDC has been screening sweet potato germplasm to identify sources of resistance to this pest and breed an agronomic cultivar with weevil resistance. However, despite 12 years of continuous research not a single accession that is consistently resistant to the weevil has been found. Other research groups had similar difficulties. Starting 1984-85 season, therefore, basic research to understand the host-plant relationship of this insect was initiated. In 1986-87, the study on the relationship between various quantifiable root

Table 2. Infestation of interspecific cross progeny by sweetpotato weevil, AVRDC, autumn 1986.[z]

Entry	Weevils/ kg roots	Entry	Weevils/ kg roots	Entry	Weevils/ kg roots
WT3	45.07 a	WT66	6.25 de	WT460	0.80 e
WT7	38.17 ab	WT143	5.97 de	WT230	0.50 e
WT146	32.15 abc	WT241	5.00 de	WT314	0.35 e
WT629	2[illegible].00 abcd	WT346	4.35 e	WT325	0.23 e
WT786	24.40 abcde	WT335	4.27 e	WT125	0.00 e
WT675	22.50 abcde	WT478	4.16 e	WT237	0.00 e
I 444[y]	21.53 abcde	WT129	3.63 e	WT60	0.00 e
WT128	15.53 bcde	WT194	3.23 e	WT399	0.00 e
WT603	13.15 cde	WT10	2.50 e	WT452	0.00 e
WT298	12.97 cde	WT306	2.40 e	WT578	0.00 e
I 57[y]	10.73 cde	WT278	1.97 e	WT108	0.00 e
WT164	10.47 cde	WT203	1.90 e	WT532	0.00 e
WT248	9.15 cde	WT555	1.77 e	WT213	0.00 e
WT700	8.33 cde	WT279	1.67 e	WT57	0.00 e
WT250	8.23 cde	WT81	1.50 e	WT320	0.00 e
WT260	7.50 cde	WT571	1.37 e	WT843	0.00 e
WT62	6.53 de	WT262	0.97 e	WT59	0.00 e

[z]Planted 3 September 1986 and harvested: 8 February 1987. Plot size: 1 m × 5 m. Design: RCBD with three replicates. Mean separation by DMRT. [y]Susceptible checks.

characters (dry matter, sugars, β-carotene and protein content) and weevil infestation was continued. The root characters were analyzed by the AVRDC chemist before initiation of this experiment.

Materials and Methods

Twenty-two accessions or breeding lines were selected for this study. There were four entries each with white and orange flesh and dry matter contents ranging from 17.1% to 37.1% and 19.4% to 33.7% (fresh weight basis), respectively. Five entries had total sugar content ranging from 10.6% to 31.4% (dry weight basis). Five entries contained β-carotene ranging from 1.4 to 10.5 mg/100 g root (fresh weight basis), and four entries had protein content from 2.0% to 9.7% (dry weight basis).

Stem cuttings from each entry were dipped in 0.05% carbofuran solution for 20 min before planting to rid the planting material of weevils. Each entry was planted as a single row on the top of randomly selected eight 1 m × 5 m plots. Each plot was bordered on one side by weevil-infested sweet potato which served as a source of weevil. The crop was raised using customary cultural practices except that no insecticide was applied. At harvest the roots were cut open and the number of larvae, pupae and adults found inside recorded. The insect count (larvae + pupae + adults) and root constituent data were subjected to simple linear regression and correlation analysis to study the influence of various root constituents on sweetpotato weevil infestation.

Results and Discussion

Results of the correlation between various root constituents and sweetpotato weevil infestation are summarized in Figures 1 to 5.

Two sets of four accessions each, one set with white flesh and the other with orange, were selected to study the influence of dry matter on weevil infestation. In both sets there was no statistically significant correlation between dry matter content and the number of weevils in the roots (Figs. 1 and 2). In orange-fleshed entries, there were less weevils with increased dry matter content in 1984 tests, but no such trend was observed in the 1985 or 1986 tests. There was no definitive trend observed in white-fleshed sweet potato in any of the three seasons. Published reports indicate negative correlation

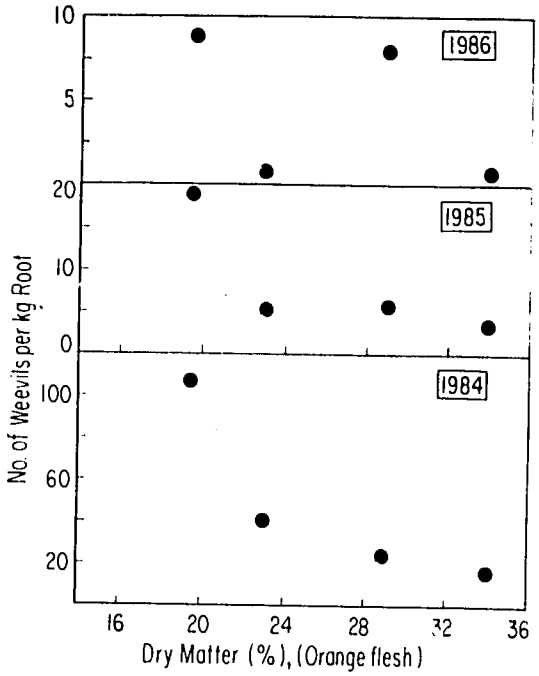


Fig. 1. Relationship of dry matter content of orange-fleshed roots and sweetpotato weevil infestation.

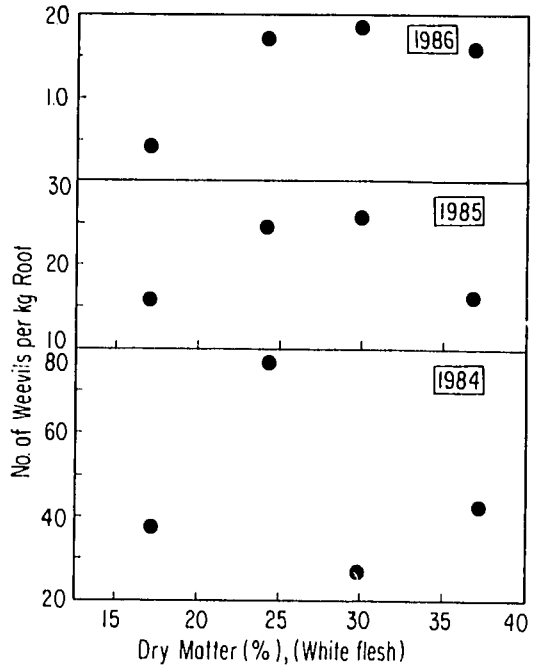


Fig. 2. Relationship of dry matter content of white-fleshed roots and sweetpotato weevil infestation.

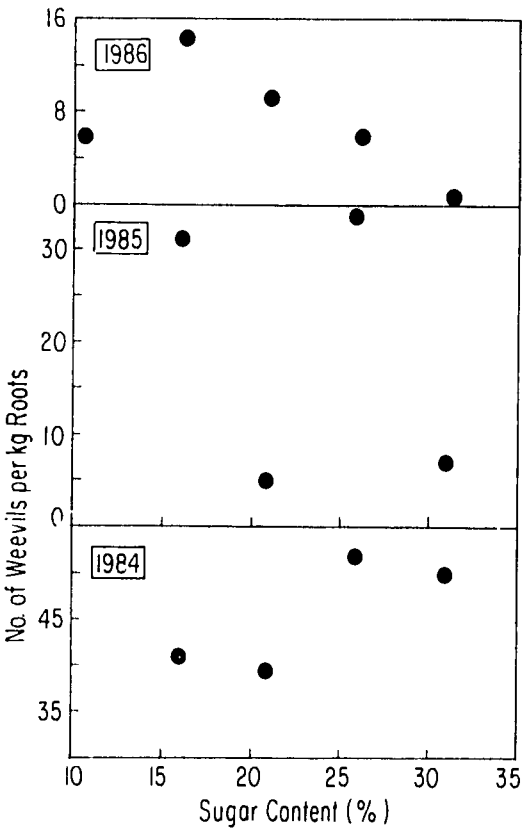


Fig. 3. Relationship of sugar content of sweet potato roots and sweetpotato weevil infestation.

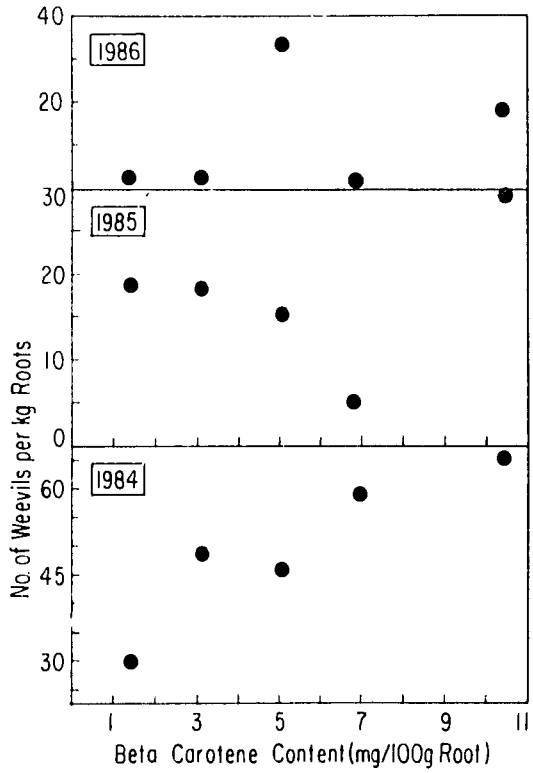


Fig. 4. Relationship of β-carotene content of roots and sweetpotato weevil infestation.

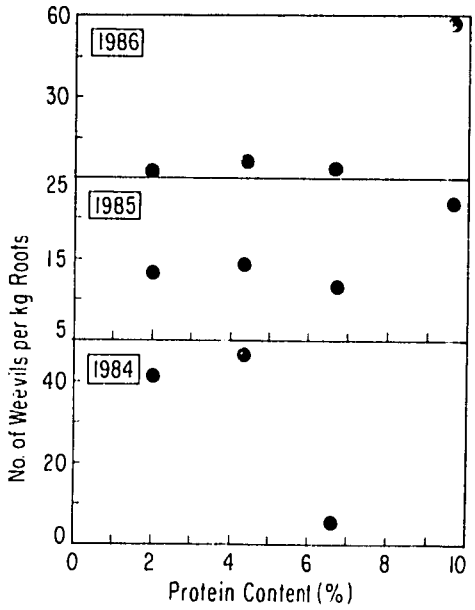


Fig. 5.
Relationship of protein content of the roots and sweetpotato weevil infestation.

between root dry matter content and weevil infestation, but such reports seem to be based on one season tests, which are not reliable in the case of sweetpotato weevil infestation.

In general, more weevils were found in roots with increased concentration of total sugar during the 1984 season but this was conversely true in the 1986 season (Fig. 3). No such trend was observed in the 1985 tests.

As the concentration of β-carotene in the roots increased, so did the number of weevils in the 1984 test (Fig. 4). In fact, there was a significant positive correlation ($r = 0.91^*$) between this plant constituent and weevil infestation. However, no such significant trend was observed in the 1985 and 1986 tests.

No definitive tendency was observed between protein content of the roots and weevil infestation in any of the three seasons (Fig. 5). Entries with high-protein content sometimes gave very poor yield and weevil infestation assessment, at times, was impossible.

Influence of Irrigation on Sweetpotato Weevil Infestation

Summary

The influence of irrigation on sweetpotato weevil (*Cylas formicarius*) was investigated once each in the 1985-86 and 1986-87 seasons. Increasing the frequency of irrigation during the season not only tended to reduce weevil infestation but also reduced root yields. A proper balance between frequency of irrigation to reduce soil cracking to prevent access of the weevil to roots and allow the roots to develop adequately to get optimum yield should be established for each soil type and crop cultivar.

Introduction

Soil cracks around sweet potato plants expose the roots. Such cracks and exposed roots are the major route by which the sweetpotato weevil, *Cylas formicarius* F. (Coleoptera:Curculionidae), initiates infestation. The cracks can be caused either by enlarging of roots or by drought stress. Large roots, which contribute to high yield, cause cracks. However, cracks can be prevented by maintaining adequate moisture in the soil which reduces weevil damage. This was tested in one field experiment conducted twice, once in 1984-85 and repeated in the 1986-87 season.

Materials and Methods

Land was rototilled and after application of basal fertilizers, worked into 1-m wide beds. Every fourth bed was planted to sweet potato eight weeks before the start of the experiment. Laboratory-reared adult weevils were released in this planting to ensure a source of infestation for sweet potato crops. Sweet potato was then planted in three empty rows between two adjacent weevil-infested lines. The plot size was 3 m × 12 m in 1985-86 and 3 m × 10 m in the 1986-87 seasons. There were three irrigation interval treatments. Starting two weeks after sweet potato planting, four randomly selected plots were flood irrigated at 10-, 20-, or 30-day intervals. All other cultural practices, such as fertilizer application, weeding and vine turning, were kept identical in each plot. At harvest only the central row was harvested and after determining the yield, each root was cut open and the number of weevils (larvae + pupae + adults) and percentage of damaged roots were recorded. The insect infestation and root yield data were subjected to analysis of variance and means were separated by Duncan's multiple range test.

Results and Discussion

The results of both the 1985-86 and 1986-87 tests are summarized in Table 3.

There was no significant difference in weevil infestation in three irrigation interval treatments in both seasons. There was, however, a tendency for the number of weevils per unit root weight to increase, with increasing interval between two consecutive irrigations. Root yield also tended to be higher with longer intervals between two consecutive irrigations. There was no significant rainfall except once in each season at three and two months after planting in 1985-86 and 1986-87 seasons, respectively. More frequent irrigation obviously kept the soil moist and prevented the soil from cracking, thus reducing the weevils' access to the roots. The same treatment obviously adversely affected the root yield possibly due to reduced aeration. However, neither the cracks nor the aeration status in the plots was recorded. Frequent irrigation reduced the soil cracks but it conceivably affected the root yield due to reduced aeration. However, this is expected to vary for each soil type. A proper balance between frequency of irrigation to reduce soil cracking and yield response should, therefore, be worked out for each soil type and crop cultivar.

Table 3. Effect of irrigation frequency on sweetpotato weevil infestation and root yield, AVRDC, 1987.[z]

Irrigation frequency	No. of weevils/kg roots	Damaged roots (%)	Yield (t/ha)
	1985-86		
Every 10 days	0.93 a	3.25 a	5.75 a
Every 20 days	1.55 a	3.10 a	6.10 a
Every 30 days	1.70 a	1.66 a	6.43 a
	1986-87		
Every 10 days	0.00 a	0.00 a	8.60 ab
Every 20 days	0.00 a	0.00 a	7.02 b
Every 30 days	1.40 a	1.40 a	10.10 a

[z]Planted 12 September 1985 and harvested 20 February 1986 for the 1985-86 season. Planted 10 September 1986 and harvested 4 February 1987 for the 1986-87 season. Plot size. 3 m × 12 m in 1985-86 and 3 m × 10 m in 1987. Design: RCBD with four replicates. Mean separation by DMRT.

Studies on Sex Pheromone

Summary

The utilization of synthetic sex pheromone of the sweetpotato weevil, *Cylas formicarius formicarius* F., was studied in the field. A dose of 0.1 μg sex pheromone was more effective than five virgin females

in attracting male weevils. Within a range of 0.001 to 1 mg, a proportionately greater number of males were captured in traps baited with increasing concentrations of the sex pheromone. Among the five different traps tested, a water trough trap with an opening near the top in all directions was more effective, easier to use and relatively less expensive. The capture of male weevils decreased with increasing distance from 5 to 100 m of the insects from the pheromone source. Within a distance of 10 m, over 90% males were captured in the pheromone-baited trap. Preliminary studies indicated the possibility of utilizing sex pheromone for sexual communication disruption so that the insects will not mate, thereby reducing their population.

Introduction

In early 1986 scientists at the United States Department of Agriculture synthesized a potent female sex pheromone of the sweetpotato weevil, *Cylas formicarius* F. (Coleoptera: Curculionidae), and demonstrated the potential of this chemical in trapping male weevils and thus controlling the pest. Based on their findings a locally synthesized chemical was obtained and various studies were conducted to suit local conditions to trap the male weevils efficiently.

Materials and Methods

Comparison of synthetic pheromone and virgin females. A total of 12 traps, of which four each were baited with 1,000 μg pheromone, 0.1 μg and four one- to two-day old virgin females, were placed randomly in a sweet potato field infested with sweetpotato weevil. After 24 hours the number of male weevils caught in each trap was recorded. The number of weevils trapped was analyzed by ANOVA and means were compared by Duncan's multiple range test and t test.

Pheromone concentration study. Twenty traps, four of each baited with 0, 0.001, 0.01, 0.1 or 1.0 mg of synthetic pheromone, were placed randomly in a sweetpotato weevil-infested field for four successive weeks. A distance of at least 20 m was maintained between two traps and the traps' position was changed randomly everyday. The number of weevils trapped was recorded every week. The number of weevils captured per week was analyzed by ANOVA and means were compared by Duncan's multiple range test.

Trap design study. Five traps of different designs (Fig. 6), each baited with 10 μg synthetic sex pheromone were placed in weevil-infested fields at least 20 m away from each other.

In the first experiment, all five traps were tested for three consecutive weeks and the number of insects trapped in each per week was recorded. Insects captured each week was considered as one replicate. In the second experiment in a separate field, only three traps — a water trough with an opening on all directions, a plastic bottle and stainless steel funnel — were utilized. The number of insects captured in each trap for four consecutive days was recorded and considered as one replicate. The third experiment, in yet another field, was conducted in a similar fashion as the second, except that insect count was recorded over three consecutive days with each day's data representing one replicate. Insect count data were analyzed by ANOVA and the means were compared by Duncan's multiple range test.

Insect capture efficiency. Every day for five consecutive days, one water trough, one plastic bottle and one stainless steel funnel were placed wide apart in an open field. A total of 100 sweetpotato male weevils, marked with color paints on their elytra, was released along the circumference 1 m away from each trap. The number of marked insects captured the following day was recorded everyday and each day's insect count was considered as one replicate. The insect capture efficiency in percentage was calculated by dividing the number of insects trapped by 100. The insect count data were analyzed by ANOVA and means were compared by Duncan's multiple range test.

Effective distance study. A water trough baited with 1 mg synthetic pheromone was placed in an open field, and at a distance of 5, 10, 20, 40, 50, 60, 80, or 100 m from the trap, along the wind direction, marked males were released. The number of marked insects captured the following day

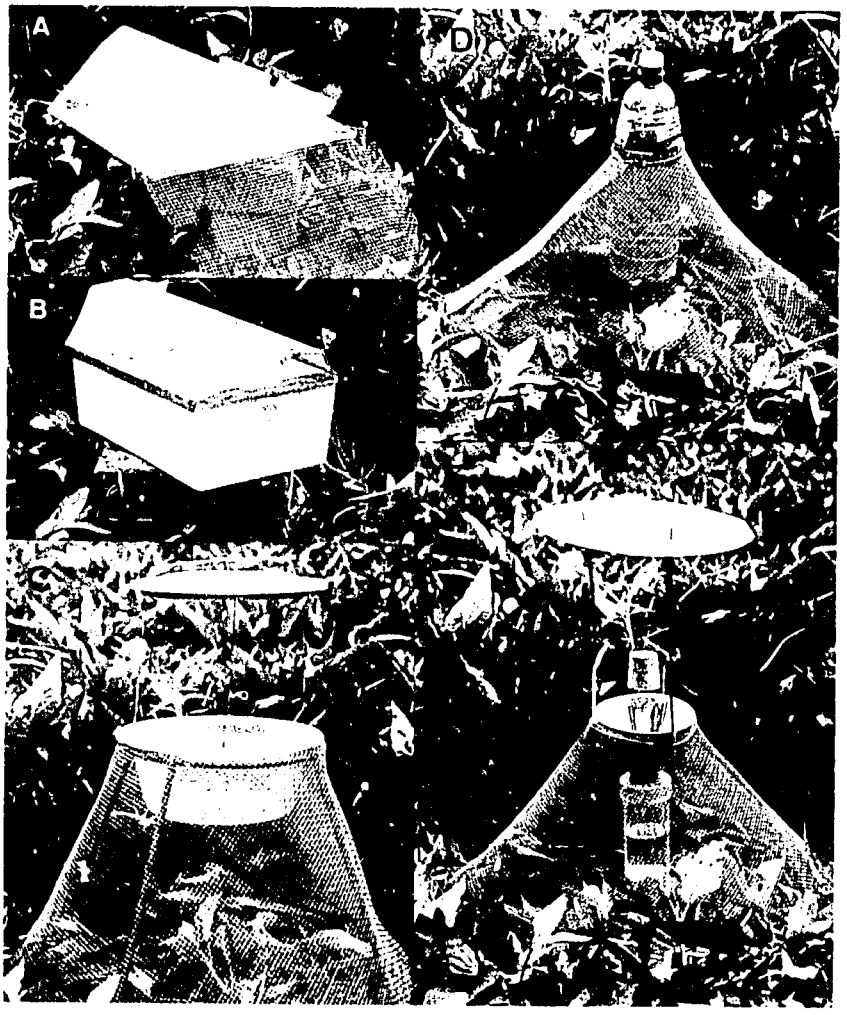


Fig. 6. Various traps tested for trapping of sweetpotato male weevils in synthetic pheromone-baited traps. A) Sticky paper trap; B) Water trough with lid opening in two directions; C) Water trough with lid opening in all directions; D) plastic bottle; and E) Stainless steel funnel.

was recorded. This experiment was repeated for 10 days and the mean number of insects captured from each distance per day was computed. The data were analyzed by simple linear regression to determine the correlation between the location of insects from the trap and the number of insects captured.

Communication disruption study. In a sweetpotato weevil-infested field, rubber septa coated with 1 mg synthetic sex pheromone were placed at a height just above the plant canopy. The septa were placed at the junction of a 2 m grid in one location, 5 m grid in the next and 10 m grid in the third. A trap baited with 0.1 μg pheromone was placed in the center of each grid and the number of insects trapped was recorded three times. The insect count data were analyzed by ANOVA and means were separated by Duncan's multiple range test.

Results and Discussion

Comparison of synthetic pheromone and virgin females. The results of the comparison of male weevils captured in pheromone-baited and virgin female-baited traps are summarized in

Table 4. Both pheromone-baited traps attracted considerably more insects than the virgin female-baited traps. The number of males trapped in 0.1 μg synthetic pheromone trap was six times greater than in the virgin female-baited trap while the 1-mg baited trap attracted 182 times more males than the virgin female-baited traps. The results indicated that even very low concentrations of synthetic pheromone was more effective than virgin females.

Table 4. Effectiveness of synthetic sex pheromone and virgin females in capturing male weevils.

Sex pheromone concentration or virgin females (VF)	No. of male weevils caught/trap/day	
	Means compared by	
	ANOVA-DMRT[z]	t test[y]
1000 μg	2087.0 a	
0.1 μg	69.8 b	69.8**
5 VF	11.5 b	11.5**

[z]Data analyzed by AVRDC and means compared by DMRT. [y]Means of 1,000 μg and 0.1 μg and 0.1 μg and five virgin females were compared by student's t test. Observations are means of four replicates.

Pheromone concentration study. As the synthetic pheromone concentration in each trap increased from 0.001 to 1.0 mg/trap, the number of males captured increased proportionately during each of the four successive weeks (Table 5). For mass trapping, therefore, at least up to 1 mg concentration per trap appears to be suitable.

Table 5. Influence of synthetic pheromone concentrations on male weevil capture.

Concentration (mg/trap)	No. of male weevils caught/trap/week[z]			
	1st wk	2nd wk	3rd wk	4th wk
1.000	17029 a	7580 a	6559 a	5859.0 a
0.100	5953 b	2365 b	2774 b	2007.0 b
0.010	1467 b	802 bc	968 c	606.0 c
0.001	1644 b	307 c	218 c	190.0 d
Control	283 b	2 c	0 c	0.0 d

[z]Data are means of four replicates. Mean separation by DMRT.

Trap design study. In the first experiment wherein five types of traps were included, a sticky paper trap and water trough trap with openings on all directions attracted the greatest number of weevils (Table 6). Since sticky paper traps need to be replaced frequently and the water trough with openings on only two directions captured less insects than the one with more openings, they were dropped in subsequent tests. No significant difference in insect capture was observed among the three remaining traps in subsequent tests. Generally, however, more weevils were trapped in the water trough. This trap was also cheaper than the stainless steel funnel trap and more convenient and durable than the plastic bottle trap. The water trough will be used in all future tests

Insect capture efficiency. No significant difference was observed among the three traps placed 1 m away from the pheromone source in capturing male weevils. The water trough captured 92.2% of the insects, plastic bottle, 92.3% and stainless steel funnel trap, 96.7%. The capture efficiency of all traps was quite high, which is satisfactory for their practical use in the field.

Effective distance study. The percentage of marked males recaptured varied from 94.7% at 5 m to 11.4% at 100 m from the pheromone source. There was a gradual and proportional reduction in the percentage of insects recaptured from a distance of 5 m up to 100 m from the pheromone trap (Fig. 7). At a distance of 10 m, over 90% of the marked males were recaptured in less than 24 hours.

Table 6. Effectiveness of various trap designs in capturing male weevils in pheromone-baited traps.

Trap types	No. of males captured[z]		
	Expt. 1[y]	Expt. 2[x]	Expt. 3[w]
Sticky paper	4138 a	–	–
Water trough (opening on two directions)	3685 abc	–	–
Water trough (opening on all directions)	4023 ab	1901 a	873 a
plastic bottle	2000 bc	2081 a	303 a
Stainless steel funnel	1713 c	1436 a	797 a

[z]Mean separation in vertical columns by DMRT. [y]Number of insects trapped/week, mean of three replicates. [x]Number of insects trapped/day, mean of four replicates. [w]Number of insects trapped/day, mean of three replicates.

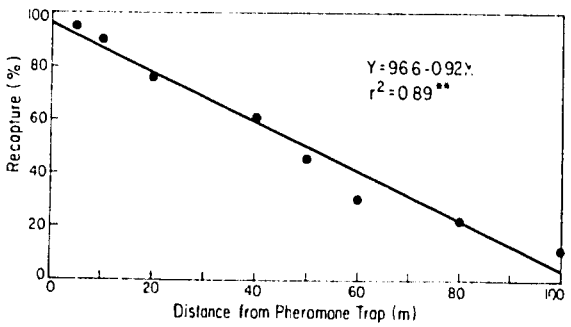


Fig. 7.
Correlation between the distance of male weevil location from the pheromone-baited traps and the percentage of males captured.

A distance of 20 m between two adjacent traps will, therefore, be adequate to continuously trap males from the field. This amounts to 25 traps/ha, assuming that the traps are kept stationary throughout the season.

Communication disruption study. Results of a preliminary communication disruption study are summarized in Table 7. The communication disruption effect was judged by the number of males attracted to the trap baited with 0.1 μg pheromone placed in the center of a quadrangle, the four angles of which had 1 mg pheromone. The greater the confusion caused by the high concentration of pheromone in the surroundings the lesser the insects trapped. A significantly low number of males captured in the pheromone-baited traps was observed in the treated area compared to the control in two out of three observation intervals. There was no statistically significant difference in communication disruption percentage between the 2 m and 5 m or 5 m and 10 m grids. The slightly greater percentage of communication disruption obtained at the 5 m grid compared to the 2 m grid may be due to the fact that males group at a point of high pheromone concentration. Since the pheromone points are farther at the 5 m grid than at the 2 m grid, less male adults are available for attraction in the trap placed in the center of the 5 m grid. Results indicate the potential for use of high concentrations of the weevil sex pheromone for communication disruption. Further studies on the utility of this method as well as mass trapping of the weevil are in progress at AVRDC.

Integrated Control of Sweetpotato Weevil on Farmers' Fields

Summary

Attempts were made to introduce integrated pest management (IPM) technology to control sweetpotato weevil (*Cylas formicarius*) in farmers' fields on Penghu Island, Taiwan. IPM consisted of

Table 7. Influence of exposure to high concentration of sex pheromone on trapping of weevil males in pheromone-baited traps.

Distance between pheromone points[z]	No. of males captured (% CD efficiency)[y]		
	87/9/18 to 9/21	9/21-9/24	9/25-9/30
2	54.0 (82.3) b	28.0 (58.5) a	–
5	12.5 (95.4) b	6.3 (90.7) a	6.3 (86.3) b
10	–		7.8 (83.0) b
Control	305.5 (0.0) a	67.5 (0.0) a	46.0 (0.0) a

[z]1 mg pheromone was placed at the junction of 2, 5 or 10 m grids. [y]Data are means of four replicates. Mean separation in vertical column by DMRT.

$$\% \text{ CD efficiency} = \frac{\text{No. insects in control} - \text{No. insects in treatment}}{\text{No. insects in control}} \times 100$$

the use of weevil-free cuttings for planting, use of sex pheromone to trap male weevils and the removal of *Ipomoea* sp. plants from the surroundings. A total of 69,315 male weevils were captured in sex pheromone traps in 62 fields. The number of weevils per kilogram root at harvest ranged from 0 to 98 with a mean of 14.5. The percentage of weevil-damaged roots ranged from 0% to 58% with a mean of 11.64%. Generally, root damage was less than 10% and in nine fields there was no weevil infestation. If all farmers in a community rigorously follow the IPM control measures, there is a possibility of eradicating the weevil over a period of time.

Introduction

Sweetpotato weevil, *Cylas formicarius formicarius* F. (Coleoptera:Curculionidae) and other related species are the most destructive pests of sweet potato in the tropics and subtropics and wherever it is cultivated. Despite intensive research at AVRDC and elsewhere, no sweet potato cultivar that is consistently resistant to the weevil has been developed. Past research indicated the potential of using cultural and sanitation methods to reduce weevil damage to a negligible level if all farmers in a community follow the control measures. In 1986 AVRDC successfully reduced weevil damage in farmers' fields in one island on the Penghu Island chain. During late 1986 a sex pheromone developed by USDA, which showed outstanding ability to attract male sweetpotato weevil and long persistence under field condition was obtained. In 1987, therefore, in addition to cultural and sanitation practices, sex pheromone was used to trap sweetpotato male weevils to reduce insect population in farmers' fields on Penghu Island.

Materials and Methods

This experiment was carried out on Jungtwun Island in Baisha prefecture on the Penghu Island chain. Forty farmers cultivated 5 ha of sweet potato in 62 small fields, each averaging 0.08 ha. Prior to planting sweet potato, a meeting was held with the farmers to explain the principles and procedures involved in weevil control and the importance of everyone's participation, since failure of even one farmer to participate will reduce the effectiveness of the whole program. During the planting of sweet potato, three large containers holding 100 liters each of 0.04% a.i. carbofuran solution was provided to the farmers. Each farmer dipped sweet potato cuttings in the insecticide solution for 20 min, drained them of excess liquid and planted them in the field. The farmers were advised on safety precautions to use while handling the insecticide-contaminated cuttings and everyone used hand gloves. They were also requested to clean their respective fields and surroundings of *Ipomoea* weeds, most of which harbored the sweetpotato weevil and also advised to hill up the plants whenever possible, especially when roots start enlarging. Hilling reduces land cracking which exposes roots to weevil infestation. Depending upon the size of the cultivated area, each farmer was given 1 to 5 traps baited with sweetpotato weevil sex pheromone (Fig. 8). The farmers were advised to rotate the traps in the field as often as possible to cover the entire field so that the existing as well as migrating male weevils can be trapped. The number of weevils trapped in each field during the entire season was then recorded.

At harvest about 5 kg of sweet potato roots were sampled from each field and cut open to record the number of weevil larvae, pupae and adults in each sample. The weevil-damaged portion of the roots was weighed and the percentage of damage was calculated.

Results and Discussion

During the entire season 69,315 male weevils were captured in 62 fields. The number of weevils per kilogram of roots ranged from 0 to 98 (Fig. 9) with a mean of 14.5, and weevil-damaged roots from 0% to 58% (Fig. 10), with a mean of 11.64%. In majority of cases, root damage was less than 10% and in nine farmers' fields there was no weevil infestation at all. In 1985 root damage averaged 50% while in 1986 it was 30% (AVRDC Progress Report 1986).

Fig. 8. A sweetpotato weevil sex pheromone-baited trap to capture male weevils.

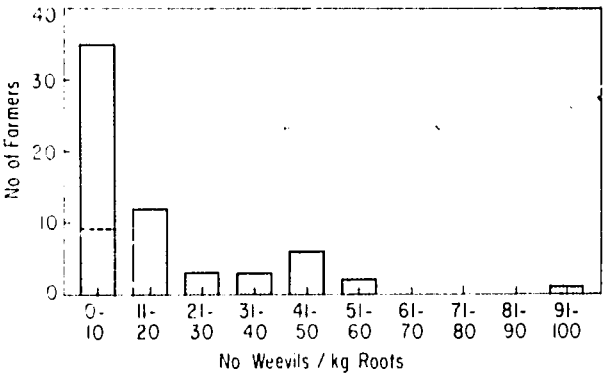


Fig. 9. Number of weevils/kg root in samples taken from farmers' fields practicing integrated control of sweetpotato weevil. Nine fields had no weevil infestation.

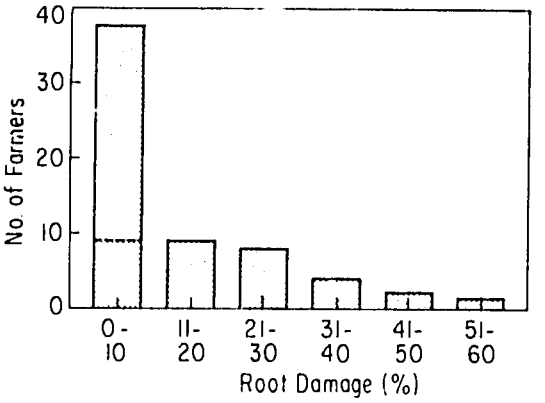


Fig. 10.
Range of sweetpotato weevil damage in root samples taken from farmers' fields practicing integrated control of sweetpotato weevil.

The farmers who dipped the cuttings in carbofuran solution, controlled the *Ipomoea* weeds, and frequently rotated the pheromone traps within their fields were highly successful in controlling the weevil. The few farmers whose fields had substantial weevil infestation were those who did not dip the planting materials in insecticide solution and ignored the presence of *Ipomoea* weeds on the border and empty areas around the field. Although sex pheromone was effective in trapping males, the mated females from the *Ipomoea* weeds migrated from the surrounding areas. For effective weevil control, therefore, control of these weeds is as important as the use of weevil-free cuttings or sex pheromone.

Screening of Breeding Materials for Sweetpotato Vine Borer Resistance

Summary

Progenies of crosses between sweetpotato vine borer (SPVB), *Omphisa anastomosalis* (Guenée), resistant accession and agronomic cultivars were screened for SPVB resistance on Penghu Island, Taiwan. The average damage among 122 breeding materials was 33.2%. The damage was 34.4% for a susceptible check and 7.1% for three resistant checks. In some progenies, root yield was high despite heavy SPVB damage. This raised the possibility of developing SPVB-tolerant sweet potato cultivars. Eight entries with less than 20% damaged plants were selected for further improvement.

Introduction

Sweetpotato vine borer (SPVB), *Omphisa anastomosalis* (Gn) (Lepidoptera:Pyralidae) is a serious pest of sweet potato in Southeast Asia, China and the Pacific, including Hawaii. The insect lays eggs on stems and leaves and the freshly emerged larvae bore into the vines, especially in crown position and pupate inside. This weakens the plant and considerably reduces the yield, up to 50% in some areas.

Screening of AVRDC's sweet potato germplasm resulted in identification of two accessions, I 55 and I 92, which showed a consistently moderate level of resistance to SPVB. I 55 was used for breeding SPVB resistance in a high yielding, agronomic sweet potato cultivar. In 1986 all breeding materials were tested in a single replicate screening and 125 materials which were relatively less damaged by SPVB were selected. In 1987 these materials were again tested along with three resistant and one susceptible check for resistance to SPVB in a multireplicate test.

Materials and Methods

This experiment was done on Penghu Island where SPVB is especially serious. After application of basal fertilizer, the land was rototilled and worked into 1-m wide beds. Entries, including 125 breeding materials and three resistant and one susceptible check, were planted in single rows on 5-m long beds. There were three replicates and the plots were arranged in a randomized complete block design. The crop was raised using routine cultural practices such as postplanting fertilization, banking, weeding and others but no insecticide was applied. At harvest each plant in every plot was observed and the number of SPVB-damaged and healthy ones was recorded.

Results and Discussion

Among the 125 breeding materials, three were severely affected by witches' broom or died due to the combination of witches' broom and other diseases. One susceptible check AIS 35-2, was also severely damaged by witches' broom. These entries were not evaluated. Among the 122 breeding materials left, the percentage of plants damaged ranged from 3.7 to 86.9 with a mean of 33.2. The average plants damaged in three resistant checks was 7.1 and the susceptible check had 34.4. Eight breeding materials with less than 20% plant damage in each of the three replicates were selected for further screening, evaluation of yield traits, and further crosses to improve their agronomic characters. The SPVB damage in these entries along with that in resistant and susceptible checks is summarized in Table 8.

In certain entries, such as CN 1757-40, plant growth was normal and they had good-sized storage roots despite SPVB damage. Since major SPVB damage is confined to the vines and rarely does the insect feed on the storage roots, it is possible to develop an SPVB-tolerant cultivar. In such a cultivar, there is no significant yield reduction despite severe SPVB damage to the vines. This will be studied in the 1988 cropping season.

Table 8. SPVB damage in selected breeding materials and checks.[z]

Entry	Plant damage	Yield (kg/plot)	Entry	Plant damage	Yield (kg/plot)
CN 1759-47	5.0 ± 5.0	6.2	CN 1759-635	3.7 ± 6.4	3.7
CN 1759-296	11.1 ± 9.7	1.7	CN 1757-40	86.9 ± 13.5	10.7
CN 1759-316	8.4 ± 10.4	6.1	CN 1759-282	78.5 ± 5.7	6.3
CN 1759-330	11.9 ± 10.4	5.5	I 57(S)[y]	34.4 ± 5.1	8.4
CN 1759-465	8.7 ± 10.4	3.0	I 55(R)[x]	13.9 ± 10.2	1.5
CN 1759-487	10.2 ± 5.0	6.3	I 92(R)[x]	7.4 ± 3.2	0.7
CN 1759-491	7.6 ± 3.7	0.9	I 789(R)[x]	0.0	0.0

[z]Data are means of three replicates. Plot size 5 m × 1 m [y](S) = Susceptible check. [x](R) = Resistant check.

Characterization of Sweetpotato Vine Borer Resistance in Sweet Potato Accessions

Summary

Studies on plant morphology, oviposition preference and larval feeding of the sweetpotato vine borer (SPVB), *Omphisa anastomosalis*, were conducted to understand the mechanism of SPVB resistance in three sweet potato accessions I 55, I 92 and I 789. No clear-cut difference was found in plant morphology and oviposition but feeding of larvae in intact plants indicated that certain active principles in stems reduce larval feeding and cause significantly greater larval mortality in resistant than in susceptible sweet potato accessions.

Introduction

Sweetpotato vine borer (SPVB), *Omphisa anastomosalis* (Guenée) (Lepidoptera:Pyralidae), is one of the most destructive pests of sweet potato in Asia and the Pacific. The insect larva bores into the vines and main stems. At times the insect also bores into tuberous roots and pupates in them. Seriously infested plants appear stunted and wilted during hot and sunny days. In Taiwan yield reduction of up to 50% is common, especially on Penghu Island.

Since the insect bores into the stems and spends the entire larval and pupal periods concealed inside the plant, it is difficult to control by conventional insecticide application techniques. Using insecticide to control this pest is not economical at present. Therefore, AVRDC initiated a host-plant resistance screening program on Penghu Island and identified two sweet potato accessions, I 55 and I 92, which were moderately resistant to this pest. In a later screening, another accession, I 789, proved to be moderately resistant to this pest. The resistance breeding program to develop a sweet potato cultivar resistant to SPVB is already ongoing at AVRDC. In this experiment plant morphological and insect pest host-plant interaction characters were studied to understand the mechanism of resistance to SPVB in these resistant accessions.

Materials and Methods

Plant morphology study. Twenty fully opened leaves from the top portion of the plant were plucked and the leaf area of each measured by a Licor area meter. The length and diameter of the petioles were also measured. After measuring the leaf area the leaf lamina and petiole were weighed and dried at 110°C for 48 hours. The weight of the dried plant parts was recorded and the moisture content determined. At this stage, in the case of leaf lamina, the specific dry weight, i.e. dry weight per cm^2 of the leaf area was also calculated.

In another study the number of trichomes on lamina, petiole and stems was recorded. The number of trichomes on both sides of the lamina was counted and the number per 100 mm^2 was computed. The total number of trichomes on each petiole was recorded and based on the length and the diameter

of the petiole the number per 100 mm^2 was computed. The main veins, after recording the number of trichomes, were stripped of lamina and their area determined on a leaf area meter.

Oviposition preference. **Free choice:** Three tender branches, each with three top leaves from the three resistant accessions, I 55, I 92 and I 789, and two susceptible accessions, I 444 and AIS 35-2 were obtained. Each individual branch was immediately placed in an Erlenmeyer flask containing water to maintain its freshness. One branch each of the five entries was placed in three cages lined with smooth plastic. Five male and five female SPVB moths were then introduced in each cage to study their oviposition preference for each entry. The number of eggs laid on each branch was recorded one week after the start of the experiment.

No choice: The plant material was prepared in the same way mentioned above. But instead of putting five accessions in one cage, three branches of each accession was placed in individual plastic cylinders. One pair of SPVB moth was then released inside each cylinder and the number of eggs laid after one week recorded.

Larval feeding: Two tests were done in larval feeding. In the first test three tender stem cuttings of each accession were placed in each of the three 150 ml Erlenmeyer flasks containing water to sustain freshness for one week. Then, six freshly emerged SPVB larvae were released on the three cuttings and the number of insects making entry holes in the vines and location of larval entry hole recorded. At the end of the week, the number of surviving larvae was also recorded.

In the second test 15 cuttings of each entry were planted in clay pots with one cutting per pot. The pots were placed in the greenhouse six weeks before the test was started. Ten freshly emerged SPVB larvae were then released on each plant and allowed to feed on them for several days. Two weeks after the insect release, each plant was cut open and the number of larvae surviving inside was recorded.

Results and Discussion

Plant morphology study. The results of the estimates of leaf area, leaf moisture and specific dry weight are summarized in Table 9. Two resistant accessions, I 55 and I 92, had significantly smaller leaves and less moisture content than the two susceptible accessions, I 444 and AIS 35-2. Specific dry weights in I 55 and I 92 were greater than in susceptible accessions, although in I 55 such difference was not statistically significant. On the other hand, I 789 has shown resistance to SPVB in several AVRDC tests on Penghu Island.

Leaves of all accessions except I 789 were practically glabrous (Table 10). Accession I 789 had a high density of trichomes. Very high and very low trichome densities on plant parts adversely affect insect pest infestation of such plants. In the case of sweet potato infestation by SPVB, this plant character did not seem to play any role since two of the three resistant and both susceptible accessions were glabrous. Although I 789 had a relatively high trichome density, especially on the petiole and main vein where insects prefer to lay eggs, this did not seem to be high enough to deter insect oviposition, since SPVB laid practically a similar number of eggs on the foliage of resistant and susceptible entries. It must be emphasized that the role of trichomes, specifically in the interaction of SPVP and sweet potato, is not yet known.

Table 9. Leaf area, moisture content and specific dry weight of selected sweet potato accessions.[z]

Accession	Leaf area cm^2/leaf	Moisture content (%)	Specific dry weight (g/cm^2)
I 444	30.48 c	85.87 b	0.42 c
AIS 35-2	57.40 a	88.27 a	0.54 b
I 789	47.20 b	84.27 bc	0.54 b
I 92	21.42 d	82.54 d	0.62 a
I 55	14.51 e	83.49 cd	0.56 b

[z]Data are means of 20 replicates. Mean (in vertical column) separation by DMRT.

Table 10. Trichome density on various plant parts.[z]

Accession	Number of trichomes/100 mm^2		
	Petiole	Main vein	Lamina
I 444	0.00 b	0.00 b	0.00 b
AIS 35-2	0.77 b	0.00 b	0.00 b
I 789	37.70 a	143.70 a	3.15 a
I 92	0.00 b	0.00 b	0.00 b
I 55	0.00 b	16.05 b	0.00 b

[z]Data are means of four replicates each with five leaves. Mean (in vertical column) separation by DMRT.

Oviposition preference. Most of the eggs were laid on the main veins in the leaf lamina and very few elsewhere (Table 11). Few eggs were laid on the petioles or stems — the plant parts often tunneled by SPVB. Among the three plant parts though, significantly more eggs were laid on the leaf lamina than in the petiole and stem. Most of the eggs found on the lamina, as surmised earlier, were on the main veins.

No clear-cut difference in the oviposition pattern was found among various plant parts between resistant and susceptible accessions. On the main vein the resistant accession, I 55, had the lowest and I 92 had the highest number of eggs.

In a free choice test where resistant and susceptible accessions were planted together, SPVB laid significantly fewer eggs on I 55 and I 92 than on the susceptible accession AIS 35-2. However, this was not significantly different from the number of eggs laid on I 444, which is another susceptible accession (Table 12). Similarly the number of eggs laid on resistant I 789 was not significantly different from those of the two susceptible checks. In the no choice test, however, there was no significant difference in oviposition among the accessions (Table 13).

Although there were differences among certain resistant and susceptible accessions based on the results of these tests, oviposition preference did not seem to play any definitive role in the resistance of these sweet potato accessions to SPVB.

Larval feeding. When first instar SPVB larvae were placed on the cuttings of resistant and susceptible accessions for one week, no difference in their boring activity and survival was found. However, when the first instar larvae were allowed to feed on intact plants for three weeks, significantly less larvae survived on the resistant than on the susceptible accessions (Table 14). It seemed that certain principles in the vines of resistant accessions caused larval mortality. These principles were

Table 11. Distribution of SPVB eggs among various plant parts.[z]

Plant part	Eggs laid (%)
Stems	21 b
Petioles	16 b
Leaf lamina	63 a

[z]Data are means of three replicates. Mean separation by DMRT.

Table 12. Oviposition preference of SPVB on various sweet sweet potato accessions in the free choice test.

Accessions	Eggs laid (%)[z]
I 444	14 b
AIS 35-2	48 a
I 789	29 ab
I 92	3 b
I 55	5 b

[z]Data are means of three replicates. Mean separation by DMRT.

Table 13. Oviposition of SPVB on various sweet potato accessions in the no-choice test.[z]

Accession	No. eggs/cutting[z]
I 444	33 a
AIS 35-2	15 a
I 789	32 a
I 92	54 a
I 55	26 a

[z]Data are means of three replicates. Mean separation by DMRT.

Table 14. Survival of SPVB larvae which fed on various sweet potato accessions.

Accession	Survival (%)[z]
I 444	33 b
AIS 35-2	50 a
I 789	17 c
I 92	18 c
I 55	23 c

[z]Data are means of three replicates. Mean separation by DMRT.

inactivated when the plant's integrity was destroyed. This important aspect needs to be investigated further to understand the mode of resistance.

Two of the three resistant accessions, I 55 and I 92, have dark purple vines. The purple stem is reported to confer resistance in soybean to an agromyzid fly. It is possible that the anthocyanin pigment in the stems of I 55 and I 92 are involved in their resistance to SPVB. Vines of another resistant accession, I 789, are green and an independent resistant factor may be responsible for its resistance to SPVB.

Sex Pheromone Activity in Sweetpotato Vine Borer

Summary

Laboratory and field studies were conducted to characterize sex pheromone activity in sweetpotato vine borer (SPVB), *Omphisa anastomosalis*. In female moths, there was a distinct calling behavior which started when it got dark in the evening. Mating started 6.5 hours after the initiation of darkness. Peak matings occurred between 7 and 7.5 hours after the onset of darkness. Most adults emerged from pupae one hour after initiation of darkness and few mated later during the same night but most mated the following night. Three- to four-day old virgin females attracted a greater number of males than the younger or older ones. Virgin females of six days and older failed to attract males. These data can be utilized for isolating the SPVB sex pheromone in future studies.

Introduction

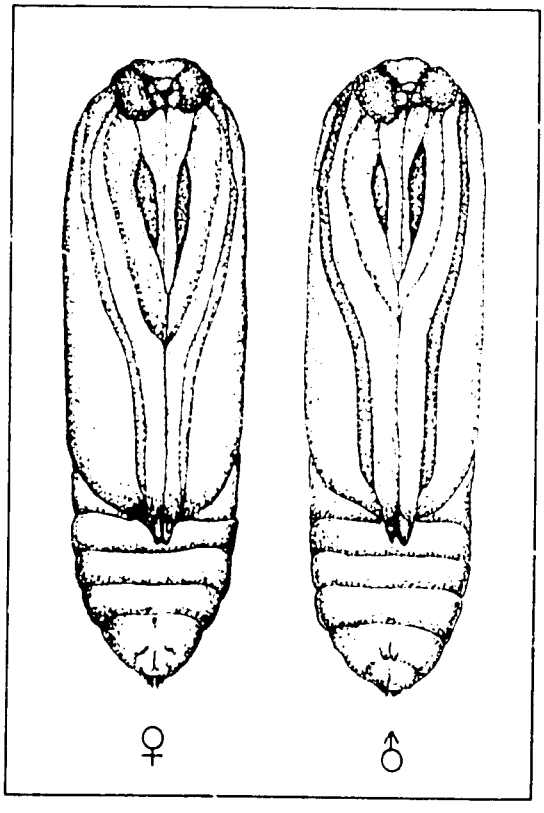
The sweetpotato vine borer (SPVB), *Omphisa anastomosalis* (Guenée) (Lepidoptera:Pyralidae) lays eggs on foliage and tender stems and its larva bores into the main stem leading to the roots and sometimes feeds and pupates inside the roots. Severely tunneled vines show weak growth, poor foliage which appears yellow and wilted during sunny days, and poor root growth. In Taiwan, mainly on Penghu Island, over 89% of the plants sustain damage and yield reduction is about 50%.

Because of the severity of damage, suitable control measures are necessary. Any control measure must take into consideration the fact that sweet potato is a low value crop and, hence, frequent

insecticide applications are not economical. The utilization of sex pheromone to monitor, trap or confuse the male insects is a good alternative to the use of chemicals. This method is also widely used in the control of several other insect pests. Since no information exists on the sex pheromone of SPVB and a preliminary test in 1986 indicated the presence of the female sex pheromone, various aspects of sex pheromone activity in this insect were studied in this experiment.

Materials and Methods

Insect rearing. SPVB larvae were collected from sweet potato plants on the AVRDC farm. The larvae were reared in the laboratory on sweet potato roots, which were replaced once every three to four days until the larvae pupated. The pupae were collected by cutting open the roots and separating the males from females based on their morphological characters (Fig. 11). Newly emerged unmated adults (Fig. 12) were either used for the sex pheromone study or the males and females were placed in a cage (30 cm^3) containing a branch of sweet potato plant for two-day mating. The insects were then transferred to an acrylic jar lined with paper for oviposition and the larvae reared on pieces of sweet potato roots.



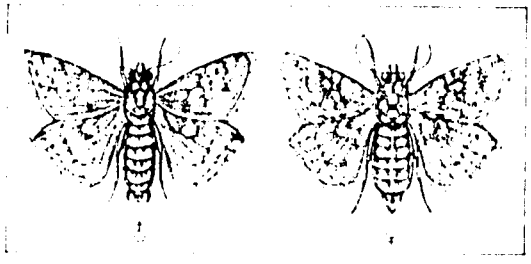


Fig. 12. Male and female adults of *Omphisa anastomosalis*.

Fig. 11.
External morphological characters of female and male pupae of *O. anastomosalis*.

Mating periodicity. A large number of pupae were collected and placed individually in small plastic cups. Their sex was determined by the morphological characters of the pupae. Immediately after emergence, the adults were also examined to confirm their sex. Males and females were maintained separately and one-day old adults were used for the mating periodicity study. One male and female each were confined in an acrylic jar (15 cm diameter, 30 cm height) the top of which was enclosed with muslin cloth. An absorbant cotton plug dipped in sugar solution was placed inside the jar to serve as food source. Insects were observed once every 30 min during a 24-hour period and the number of matings were recorded. To facilitate observation during the dark, a weak red light lamp was used.

Adult emergence periodicity. A large number of SPVB pupae were collected from laboratory rearing and separated into males and females. They were then placed individually in small plastic containers. Adult emergence was observed every hour during a 24-hour period and the number of adults that emerged during each hour was recorded.

Female age study. This experiment was conducted both in the laboratory and in the field. Virgin females, ranging from 0 to 7 days old were used in the experiment. One female of each age group was placed in each of the five sticky paper traps. The traps were placed 60 cm above the soil surface in the field at 5 P.M. and the number of males captured in each trap was recorded at 7 A.M. the following day.

In the laboratory test, virgin females with ages ranging from 0 to 5 days were confined individually in acrylic jars (15 cm diameter, 30 cm height). One unmated zero to two-day old male was then introduced in each jar containing the female. The jars were covered with muslin cloth and an absorbant cotton plug dipped in sugar solution was placed inside to serve as food. After 24 hours the females were dissected open to observe the presence of spermatophores to judge the mating.

Results and Discussion

Mating periodicity. During the day the SPVB adult remained motionless. Adult activity began at the onset of darkness at around 7 P.M. The moth started to move its antennae backward and forward and took short flights around the cage or container. The female initiated the calling behavior to attract the male about three hours after the onset of darkness. The calling behavior of SPVB female is illustrated in Figure 13. The tip of the abdomen was raised slightly during the night (Fig. 13A). A glandular section flexed from the tip of the abdomen and remained exposed for a period of time (Fig. 13B). The female then curved its abdominal tip with the flexed glandular section still exposed (Fig. 13C) and wiggled it right and left (Fig. 13D). This behavior could be associated with the release of sex pheromone in search for the mate or searching of a suitable site for oviposition. There is, however, no proof yet to this effect.

The mating periodicity of SPVB is illustrated in Figure 14. In the first test, the mating began 6.5 hours after initiation of darkness, with peak activity occurring at 7 to 7.5 hours after the beginning of darkness. In the second test, mating started slightly earlier, four hours after the beginning of darkness, but it still peaked at about the same time as in the first test, seven hours after dark, 1:30 to 2:30 A.M. It is possible that due to the larger number of insects used in the second test, the mating period was slightly widely distributed than in the first test. It is safe to conclude that the mating period of *O. anastomosalis* is between four and seven hours after the initiation of darkness.

Adult emergence periodicity. The results of the emergence periodicity of SPVB adults over a seven-day period are summarized in Figure 15. There were two peaks per 24-hour cycle; the major peak occurred one hour after the initiation of darkness and the minor one eight hours later. Most of the insects emerged between 7:00 A.M. and midnight; a small portion emerged between 4:00 and 6:00 A.M. Mating period which was confined between 11:00 P.M. and 3:00 A.M. was related to the emergence periodicity. It is likely that some insects that came out at the beginning of the emergence

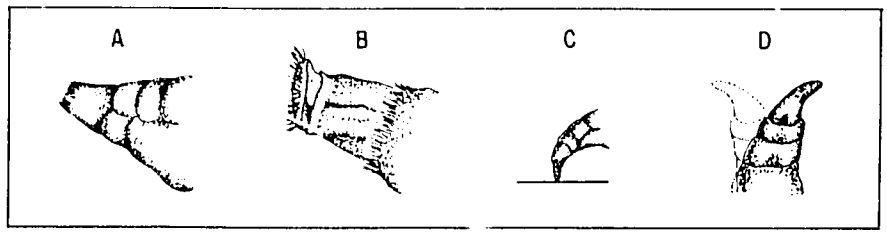


Fig. 13. Calling behavior of *O. anastomosalis*. A) Tip of the abdomen is raised slightly; B) Abdominal tip remains exposed for a period of time; C) Abdominal tip is bent downwards with tip still exposed; and D) Abdominal tip is then wiggled right and left.

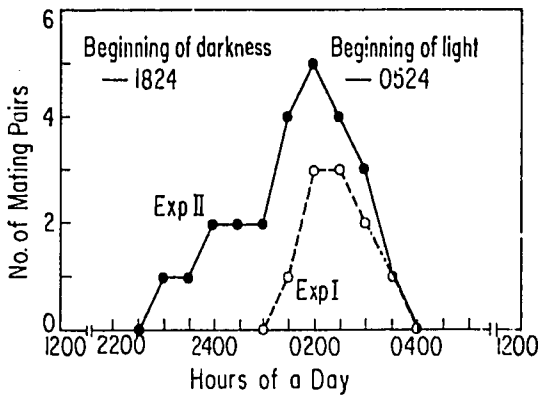


Fig. 14.
Mating periodicity of *O. anastomosalis* in two experiments.

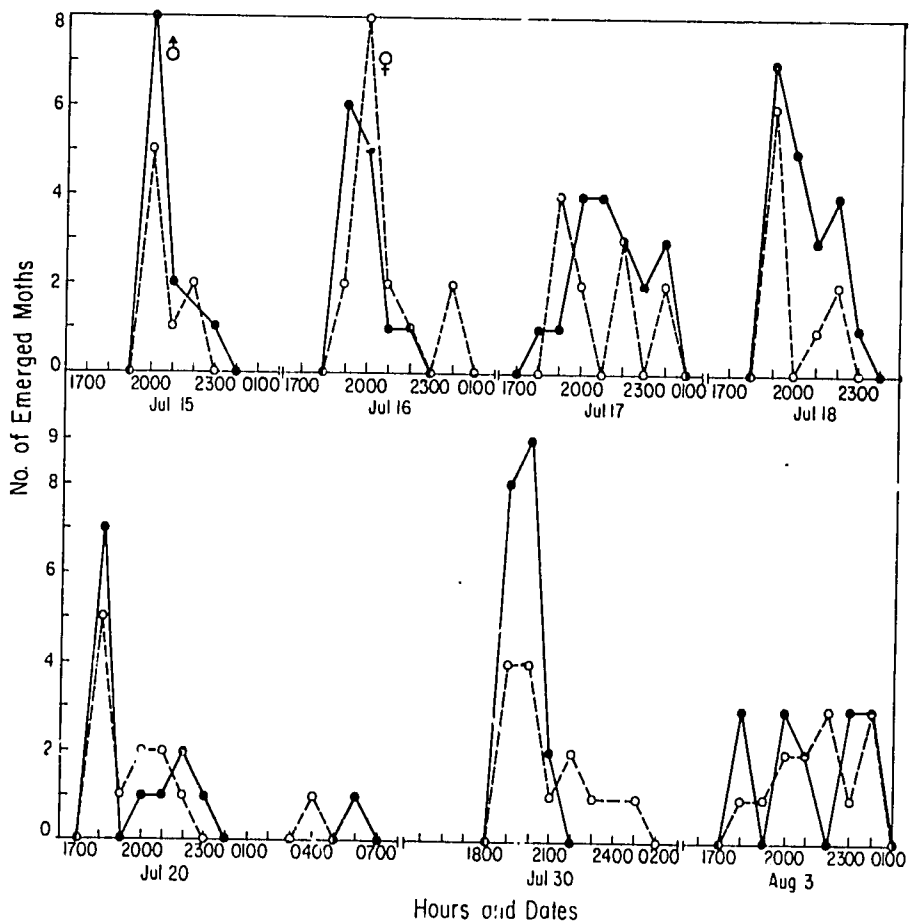


Fig. 15. Adult emergence periodicity in *Omphisa anastomosalis*.

period were sexually mature and they mated during the same night. This was also evident from the female age study, wherein some insects were found mating the same night they emerged. Most, however, seemed to mate the following night. There is, however, no definitive proof of the proportion of mating in each occasion.

Female age study. The results of the study on the virgin female's age in the release of sex pheromone are summarized in Table 15. Males were attracted to virgin females with ages ranging

from immediately after emergence to five days after emergence. Six- and seven-day old females failed to attract any males. These results, obtained from the field study, were also corroborated by observation in the laboratory where it was found that only zero to five-day old females mated successfully. In general, three- to four-day old females attracted more males. It is likely that three- to four-day old females produce a maximum amount of sex pheromone. This age group in females is, therefore, ideal for extraction of pheromone or comparison of the effectiveness of synthetic pheromones.

The results of matings of various aged females are summarized in Table 16. One-day old females mated far less frequently than the older ones. Most of the virgin females seemed to initiate releasing pheromone one day after emergence and mated during this period. Only a small portion mated four hours after emergence.

Table 15. Influence of virgin female age on the capture of males in female-baited traps.[z]

Days	Number of males captured/trap baited with females of various ages (days)							
	0	1	2	3	4	5	6	7 (days)
87/7/21	4.4	1.6	1.4	4.6	6.4	2.2	0	0
87/7/22	0	1.0	1.5	4.0	1.7	0	0	0
87/7/23	0	0	0	0.3	1.5	1.7	0	0

[z]Data are means of five traps.

Table 16. Mating frequency of SPVB females of various ages.

Age (days)	No. pairs observed	No. of pairs mating	Mating (%)
0	22	2	9
1	21	11	52
2	8	2	25
3	5	2	40
4	5	1	20
5	10	4	40

Sweet Potato Pathology

Resistance Screening for Sweet Potato Scab

Summary

Sweet potato scab is a particularly serious fungal disease in the wet, humid tropics. Several experiments were conducted to compare field resistance screening trials at two locations, to study the feasibility of a seedling screening test and to compare scab evaluation methodologies. A number of sweet potato cultivars were rated highly resistant to scab at both the Hualien and AVRDC test sites. A scab epidemic suitable for resistance screening can be induced at AVRDC, even though scab is not normally endemic. A seedling screening test is not feasible at this time. For greenhouse screening tests, the selected scab rating system evaluates the percentage of diseased stems and petioles. Under field conditions, the preferred rating system is a 0-5 scale, where a value of 1 indicates a level of disease similar to or less than the highly-resistant standard check cultivar, V2 30, and a value of 4 indicates a level of disease similar to the highly-susceptible standard check cultivar, TN New 31.

Introduction

Sweet potato scab, caused by *Elsinoe batatas*, is especially severe in wet, humid tropical environments. A scab resistance screening project was initiated at AVRDC in 1985, and a greenhouse mass-screening technique was developed. Some cultivars resistant to scab have already been confirmed in several screening tests both in the greenhouse and in the field. In this year, disease resistance screening was conducted under field conditions in both Hualien and AVRDC to determine if an environment suitable for a scab epidemic can be induced at AVRDC. A trial to study the feasibility of determining the level of scab resistance in seedling plants was conducted in the greenhouse, where seedlings were compared with cuttings taken from the same seedling after transplanting in the field. In addition, four promising evaluation methods were compared in the field and in the greenhouse screening trials.

Materials and Methods

Field resistance screening. The same cultivar and field design were used in two locations. The trials were planted in Hualien on 12 May 1987 and in AVRDC on 9 June 1987. The plot size for each tested cultivar was 1.5 × 2.5 m and contained nine cuttings of the test cultivar and one scab-infected cutting of TN New 31 (moderately susceptible check inoculum source). These scab-infected cuttings were inoculated with a spore suspension of *E. batatas* originally isolated from Hualien. Two replications were used for each trial which contained 207 test cultivars. The trial conducted at AVRDC was irrigated by an overhead sprinkler system for 15 min, twice daily at 0830 and 1600 hours, and five days per week. Disease intensity was evaluated on 1 October at AVRDC and 6 October at Hualien using a 0-5 scale, where scab levels in the test lines that were similar to TN New 31 were rated as 4, and those similar to V2-30 (highly-resistant check) were rated as 1.

Seedling test. The seeds, 250 from each cross of CN 1825 and CN 1745, treated with 98% sulfuric acid for 30 min and rinsed overnight in running water, were planted on 13 February 1987. One

month later, 96 uniform seedlings were selected from each cross and divided into four replications. Each replication also contained one-month old cuttings of V2-30, I 6 and CN 1108-13 as checks. On 24 March 1987, all seedlings and cuttings were uniformly inoculated by a spore suspension of 7.5 × 10 spore/ml of the Y.S. isolate and transferred to an inoculation chamber for three days. Seedlings and cuttings were evaluated 10 days after inoculation by using the rating system of disease area percentage of stem and petioles (SP) distal to the first fully expanded leaf. On 3 April all inoculated seedlings were sprayed with benlate and transferred to the field with 1.5 × 2 m spacing. To obtain enough cuttings, at least one cutting was taken per seedling, and rooted next to the mother plant after transplanting.

Because of space limitations, the 120-seedling clones from crosses of CN 1745 and CN 1825 were evaluated in four batches, each containing cuttings of 11 to 20 randomly selected clones from each cross. The remaining seedling clones (72) were not tested due to poor growth in the field. In each of the four trials, there were four replications with 3 to 6 cuttings per replication. In each replication, I 6, V2-30 and CN 1108-13 were used as checks. Cuttings were inoculated by a spore suspension of 1 × 10^6 spore/ml of the Y.S. isolate one month after rooting, and evaluated 10 days after inoculation by using the diseased area percentage of the stem and petioles (SP) distal to the first fully expanded leaf. All of the inoculated cutting tests were held in the incubation chamber for three days. The sweet potato scab rating system data from both the seedling and cutting trials were standardized by dividing the rating of each test plant by the rating of the susceptible check cultivar, I 6, in the same replication before performing the regression analysis.

Comparison of scab evaluation methods. Four different evaluation methods were compared, including the susceptibility rating systems (SRS) as described last year, diseased percentage of stem (S), and of stem and petiole (SP) distal to the first expanded leaf, and 0-5 scale system as described in section 'A' of this report. Ten cultivars representing a range of susceptibility or resistance were evaluated in the field using the four evaluation methods, and in the greenhouse using three of the methods (SRS, SP, S). For the evaluation in the field, five vines were randomly selected in the middle of the plot for each replication and each cultivar. A regression analysis was used to compare the relationship between the different scab evaluation methods.

Results and Discussion

Field resistance screening. In the field screening trial, severe scab epidemics occurred in both Hualien and AVRDC (Table 1). In general, a higher disease severity was observed at AVRDC. Eighteen cultivars had resistance levels that were not significantly different from V2-30 (resistant check) and were significantly different from TN New 31 (susceptible check) in both locations (Table 2). The Green Island series cultivars whose resistance was identified under greenhouse condition was confirmed as highly resistant in the field. The resistance level in most cultivars was not significantly different from the susceptible check. Heavy precipitation appeared to be necessary for the development of a scab epidemic. The overhead irrigation was only partially effective in inducing an epidemic in the absence of precipitation. A scab epidemic suitable for disease resistance screening and evaluation can be induced at AVRDC during the summer rainy season. However, the correlation coefficient (r^2 = 0.596**) of the regression analysis between the scab rating at Hualien as the independent variable and at AVRDC as the dependent variable, while significant, indicates that only a small part (r^2 = 0.355) of the total variation is explained by these two variables. Therefore, cultivars selected as resistant in one season will need to be tested in other environments to identify the clones with stable resistance.

Seedling test. The correlation coefficient of the regression between seedling disease rating and cuttings rating is only 0.1585 and not significant. The scab resistance evaluation of individual seedlings apparently does not represent the clone's level of resistance as determined by the cutting screening technique.

Comparison of scab evaluation methods. The correlation coefficients of the regressions between the SRS rating system, which is considered the system that most accurately represents the

Table 1. Susceptible cultivars identified in two locations.

Name	Acc. no.	Location		Source
		Hualien	AVRDC	
PI 324889	I 55	4.5[y]	4.5	USA
PI 288632	I 86	4.0	4.5	New Zealand
Diriri bliriri	I 972	4.0	4.0	Fiji
B 6708	I 122	4.0	4.0	USA
PI 318855	I 103	4.0	4.0	Peru
Minamiyutaka	I 970	4.0	4.0	Japan
Illula	I 971	4.0	4.0	Fiji
Kuriva 1	I 930	4.0	4.0	Papua New Guinea
TN 57	I 57	4.0	4.0	Taiwan
TN 66	I 981	4.0	4.0	Taiwan
AIS 35-2	I 989	4.0	4.0	AVRDC
Gausar Var.	I 1069	4.0	3.5	Taiwan
Merenge	I 846	4.0	4.0	Papua New Guinea
TN 67		4.0	4.0	Taiwan
CN 1370-7		4.0	4.0	AVRDC breeding line
CN 1508-93		4.5	4.0	AVRDC breeding line
CN 1510-25		4.0	4.0	AVRDC breeding line
CN 1108-13		4.0	4.0	AVRDC breeding line
CN 1701-33		4.0	4.0	AVRDC breeding line
CN 1645-20		4.0	3.5	AVRDC breeding line
TN New 31[z]				

[z]Susceptible check cultivar. [y]0-5 scale; 1 = highly resistant and 5 = highly susceptible.

Table 2. Cultivars identified as highly resistant to scab in two locations.

Name	Acc. no.	Location		Source
		Hualien	AVRDC	
V2-30[z]	I 1175	1[y]	1	Philippines
V2-1	I 1173	1	1	Philippines
TIS 2498	I 949	1	1	IITA, Nigeria
GI 6	I 1026	1	1	Taiwan
GI 13	I 1213	1	1	Taiwan
GI 19	I 1219	1	1	Taiwan
K 7	I 944	1	1	Papua New Guinea
K 61	I 943	1	1	Papua New Guinea
No. 1	I 673	1	1	Papua New Guinea
Five-mun	I 849	1	1	Papua New Guinea
71-1		1	1	Japan
71-4		1	1	Japan
71-7		1	1	Japan
Lae 2	I 483	1	1	Papua New Guinea
Ilimo 1	I 934	1	1	Papua New Guinea
Markham	I 844	1	1	Papua New Guinea
CN 1618-461		1	1	AVRDC breeding line
CN 1828-6		1	1	AVRDC breeding line
CN 1232-9		1	1	AVRDC breeding line

[z]Resistant check cultivar. [y]0-5 scale; 1 = highly resistant and 5 = highly susceptible.

level of scab resistance in a clone, and the other two systems, SP and S, under greenhouse conditions, indicate that both rating systems are highly correlated with the SRS system. However, the SRS/SP correlation explains a higher degree of the variation (r^2 = 0.9386) than the SRS/S correlation (r^2 = 0.8832). Therefore, the SP rating system has been selected for the greenhouse screening

tests. The SP rating system is considerably less complicated and time-consuming than the SRS system.

The correlation coefficients of the regressions between the SRS rating system in the field and the other systems, SP, S and 0-5 scale are 0.8429, 0.8785 and 0.8312, respectively. All of the correlation coefficients are highly significant, and also indicate a good relationship between the different rating systems. Therefore, the 0-5 scale rating system, or a modification, has been selected for field evaluations because it is simple and fast.

The correlation coefficients of the regressions between the SP greenhouse ratings and the SRS, SP, S and 0-5 scale field ratings are 0.8819, 0.8726, 0.8556 and 0.8125, respectively. All of the correlation coefficients are highly significant, and also indicate a good relationship between the field and greenhouse ratings.

Virus Elimination and Indexing at AVRDC

Summary

Virus elimination and indexing has been accomplished for the first set of promising AVRDC breeding lines. It took 21 months to complete the procedure from sprouting to distribution. This set was not heat-treated. Another 134 lines (comprising AVRDC breeding lines Set II, part of the Thailand germplasm collection and some AVRDC accessions) are ready for graft indexing. These lines have not been heat-treated. Several other batches comprising 47 lines from China, Puerto Rico, Papua New Guinea, Peru and Nigeria have been heat-treated and subjected to meristem culture and are now ready for virus indexing. All antisera (FMV, SPYDV, SPLV and SPV II) used for virus indexing have been produced at AVRDC.

Introduction

A virus elimination and virus indexing procedure for sweet potato was initiated in 1985 with the completion of a quarantine screenhouse donated by IBPGR. However, only after major modifications, which included the setting up of a tissue culture room, a transfer room, a growth room, a heat chamber and an autoclave room were completed in spring 1987 could the virus elimination and indexing scheme be fully implemented.

The procedure initially adopted was based on general knowledge on virus elimination and indexing of sweet potato and other crops and on information available at the time on sweet potato viruses, some of which were based on AVRDC experiences. The procedure will be further improved, as more information becomes available from experiments.

Materials and Methods

The virus elimination and indexing scheme is shown in Figure 1.

Virus elimination. Initially, virus elimination was by meristem-tip (0.3 mm) culture only. With the establishment of facilities for heat treatment, all materials are now first subjected to heat for two months in a growth room where conditions are 37°C, 70-78% RH, 3.1 Klux illumination at a 12-hour photoperiod. Prior to heat treatment, vigorously growing shoots are first acclimatized by keeping them at 30°C for one week, followed by two days each at 32° and 35°C. After the two-month heat treatment at 37°C, meristems of 0.3 mm are excised and tissue cultured on Love et al. medium (1987). The explants are then transferred to Kuo et al. medium (1985).

Virus indexing. Virus indexing is done by two ELISA tests, using antisera to FMV, SPYDV, SPLV and recently to SPVII. All antisera have been produced at AVRDC. The first ELISA (E1) test is done on tissue-cultured plantlets at the 4-5 leaf stage. The second ELISA test (E2) is done on tissue-cultured plantlets, derived from 1 cm stem tips of E1 negative plantlets. In addition to the two ELISA

tests, two graft indexings are also performed on mature plantlets derived from the remaining portions of the E1 negative plantlets.

Only plantlets derived from E1 and E2 and Graft 1 and Graft 2 negative plants are kept and propagated for distribution.

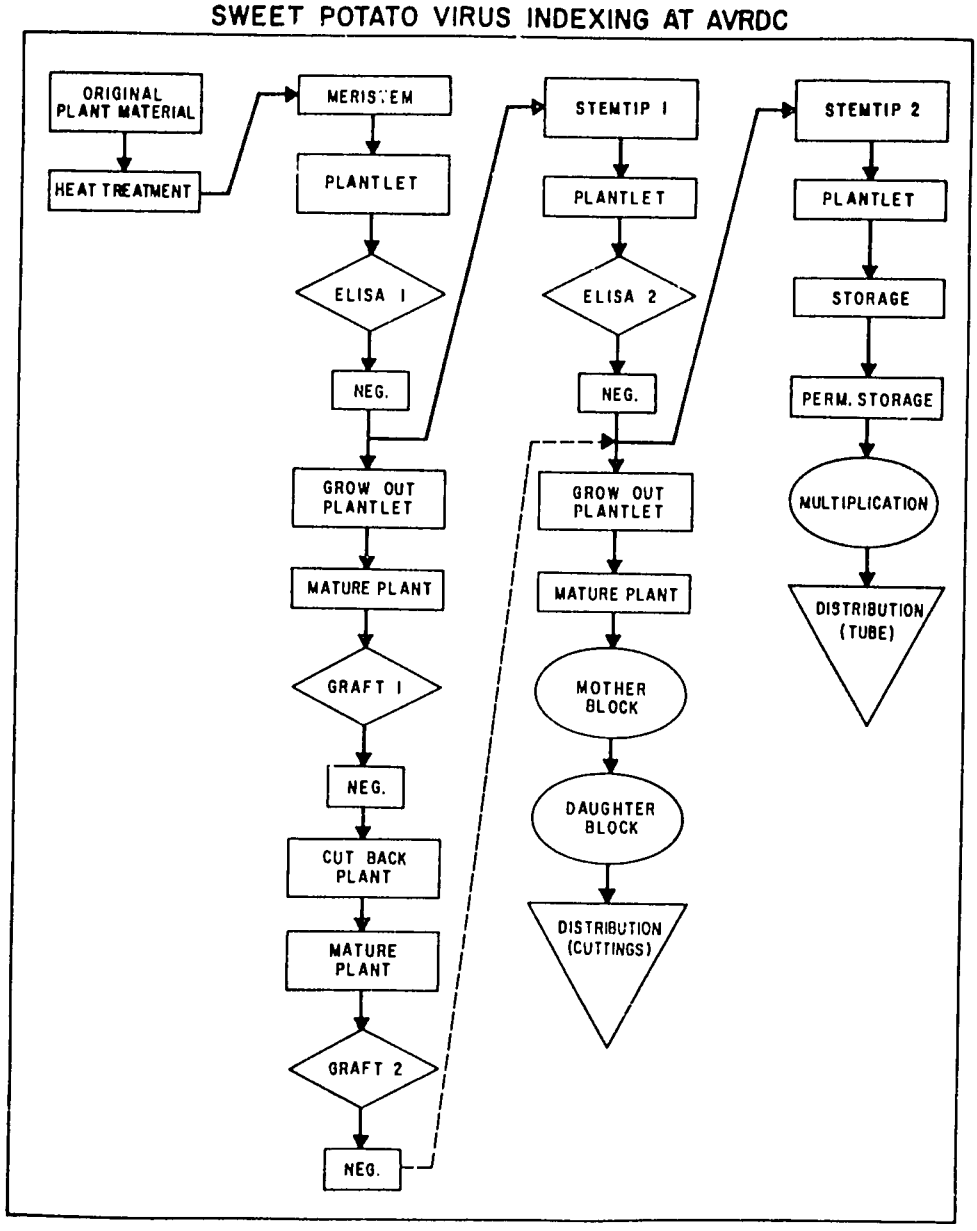


Fig. 1. Sweet potato virus indexing scheme developed at AVRDC.

Results and Discussion

The overall status of the sweet potato lines subjected to the virus elimination and indexing scheme described above is shown in Table 3. The first set of 25 AVRDC breeding lines is available for distribution. Most other lines will be ready for distribution by September 1988. A summary of the results of the first ELISA test of these lines is shown in Table 4.

Table 3. Overall status of the sweet potato virus elimination and indexing scheme at AVRDC (as of December 1987).

Material	Date Recd.	No.	Root	Present status of virus elimination and indexing at AVRDC							
				Heat	Merist.	E1[z]	G1	G2	E2	Mult.	Distr.
AVRDC Breed. Line I (SC)[y]	1985	25	25	–	X	X	X	X	X	X	X (Sept. 87)
AVRDC Breed. Line II (SC)	Nov. 86	16	16	–	X	X			X		
Thailand Germplasm (SC)	Nov. 86	100	91	–	X	X			X		
AVRDC Acc. (SC)	Apr. 87	18	18	–	X	X			X		
China Breeding Lines (TC)	May 87	5	5	X	X	X					
Puerto Rico (Root) (ST.R)	Jun. 87	15	9	X	X	X					
Papua New Guinea (SC)	Sept. 87	17	17	X							
CIP (Peru) (TC)	Oct. 87	6	6								
IITA (Nigeria) (TC)	Oct. 87	10	10								

[z]E1 = ELISA 1, E2 = ELISA 2, G1 = Graft 1, G2 = Graft 2. [y]SC = stem cutting, TC = plantlets in tissue culture, ST.R = storage root.

Table 4. Summary of ELISA 1 test of meristem-derived sweet potato materials.

	AVRDC BL 2	AVRDC Acc.	Puerto Rico[z]	Thailand
No. of lines meristemed	16	13	6	85
Total no. meristemed	300	91	40	1045
Meristems survived	146	50	24	472
Meristems tested	146	50	24	472
No. virus-infected plantlets	26(18%)	24(48%)	3(12%)	203(43%)
% positive FMV	0.7	22	4.2	4.8
% positive YDV	11.6	12	0	21.6
% positive LV	6.2	24	4.2	15.0
% positive SPVII	4.1	8	4.2	15.9

[z]Puerto Rico materials were heat-treated.

A summary of the ELISA and graft indexing for the first set of AVRDC breeding lines is shown in Table 5. A large percentage of meristem-derived plantlets still contains virus, particularly SPLV and SPYDV, which would indicate that these viruses are present in the meristematic tissue. Excision of a smaller meristem might be helpful in reducing the percentage of virus-infected plantlets. This,

Table 5. Summary of ELISA and graft indexing results of AVRDC breeding lines (Set 1).

Table 5a. ELISA 1 test of meristem derived plantlets.

Total no. of lines	25
No. of meristems excised	498
No. of meristems survived	328
Virus-infected plantlets	88 (26.8%)
% infected with FMV	1.3
% infected with SPLV	17.0
% infected with SPYDV	20.2

Table 5b. Graft 1 test of ELISA 1 negative plants.

No. of plants subjected to grafting	51
No. of virus-infected plants	8 (14.5%)
% positive FMV	3.7
% positive SPLV	0
% positive SPYDV	3.7

Table 5c. ELISA 2 test of plantlets derived from stem tips of ELISA 1 negative plantlets (ELISA 2).

No. of plantlets tested	43
Virus-infected plants	7 (16.3%)
% positive FMV	2.3
% positive SPLV	14
% positive SPYDV	0

Table 5d. Graft 2 test of negatively E1- and G1-indexed mature plants.

Total no. of plants grafted	36
No. of virus-infected plants	1 (2.7%)
% infected with FMV	2.7
% infected with SPLV, SPYDV	0

however, would probably mean a lower percentage of meristem survival. Presently, with the 0.3 mm meristems excised, the survival rate is approximately 61%.

A heat treatment of 37°C for two months is likely to be more effective in reducing virus-infected explants while not reducing the survival rate of the meristems. The first batch of lines which was heat-treated prior to excision of the meristems was found to have a lower percentage of virus infection than those which originated from nonheat-treated plantlets. However, even with the combined heat treatment and use of meristem, viruses are apparently still not completely eliminated.

A longer heat treatment of three to four months or a heat treatment at higher temperatures may prove more efficient in virus elimination, although it prolongs the already lengthy virus elimination and indexing scheme presently used which takes from 16 to 21 months.

The ELISA test is very useful in eliminating virus-infected plantlets (Table 5a). The ELISA plants thus selected for virus indexing have a much smaller chance of being contaminated with virus. The percentage of virus-infected plants is reduced with every further indexing step. However, even in E2 16% of the plantlets were found to be still virus-infected.

ELISA tests do not provide absolute positive or negative results. Using a number of different individuals for healthy and positive standards usually results in a bimodal distribution of negative

samples with low absorbance values and positive ones with high absorbance values. The two standards are separated by a large interval of absorbance units. When a large number of samples was tested, however, its absorbance values did not clearly fall within either range but were rather distributed between both ranges (usually more towards the negative side), thus making it difficult to establish clearly negative plants.

The positive/negative threshold used in AVRDC tests was set at 2X the absorbance of healthy plants which may have resulted in some false positives. However, to avoid missing any virus positive plants, a lower negative threshold was set.

The stock plantlets of the first set of breeding lines now ready for distribution were tested by an additional ELISA test (E3) to ascertain the absence of virus. None of the plantlets produced a positive ELISA reaction. Furthermore, all the grown out plants that were negatively indexed in both grafting and E1 and E2 tests were additionally tested by grinding up five randomly chosen leaves and mechanically inoculating these to *N. benthamiana*. None reacted positively. It was thus assumed that the materials sent out were free of detectable virus. In the meantime, the ELISA test procedure was changed. DAS ELISA was replaced by an indirect ELISA, which has proved to be more sensitive and which also produces less background.

Furthermore, when absorbance values are very near those of the negative checks, it becomes difficult to decide whether to classify them as negative or as very weakly positive. With meristem-derived plantlets, it is quite possible to have extremely low virus concentrations. When only very few virus particles were present in the meristems, they established very slowly, a phenomenon also observed for tissue-cultured *Solanum tuberosum*.

Comparison of Two Growth Media for Sweet Potato Meristem Culture

Summary

A new standard medium (medium L) had been proposed by IBPGR for sweet potato tissue culture. The use of this medium resulted in 41% of the meristems developing into viable plantlets compared to 53% for the AVRDC standard medium (medium K). However, when explants were first placed on medium L and then transferred to medium K, approximately 61% of the meristems produced viable plantlets. The combination of these two media therefore has now become a standard use at AVRDC.

Introduction

A medium for culturing sweet potato tissue was developed by Kuo et al. in 1985.[1] This medium has become a standard at AVRDC, even though past experience has shown that it is rather genotype dependent. This year, the IBPGR proposed a new standard medium (Love et al. 1987)[2] for sweet potato tissue culture. The purpose of this study was to compare the effect of the two media on the growth and development of meristem tips.

Materials and Methods

The growth of 16 AVRDC breeding lines and 20 lines from Thailand on standard medium (Medium K, Kuo et al. 1985) and the new medium proposed recently for sweet potato tissue culture (Medium L, Love et al. 1987) was compared. The composition of the culture media tested is shown in Table 6.

At least 10 meristems of each sweet potato line were excised and cultured in each medium. The explant (approximately 0.3 mm size) consisted of the meristematic dome with two leaf primordia. The

[1]Kuo, C.G., B.J. Shen, M.J. Shen, S.K. Green and D.R. Lee. 1985. Virus-free sweet potato storage roots derived from meristem tips and leaf cuttings. Scientia Hort. 26:231-240.

[2]Love, S.L., B.B. Rhodes and J.W. Moyer. 1987. Meristem culture and virus indexing of sweet potatoes: Practical Manual for Handling Crop Germplasm *in vitro* 1. International Board for Plant Genetic Resources.

explants were transferred to fresh medium every four weeks. In the case of medium L, the explants were first grown on medium containing NAA and BAP, and then transferred to a medium without these growth substances. The cultures were maintained in a growth room at 24-26°C, 4.7 Klux illumination (using fluorescent plant growth lights) and a 12-hour photoperiod. Growth was recorded monthly. The final observation was made four to five months after excision.

Results and Discussion

It was shown in this experiment that growth of sweet potato explants in tissue culture is highly genotype-dependent. Some cultivars showed better growth in medium L, while other cultivars apparently grew better in medium K. It was, however, observed that medium L was not superior to medium K which had been used at AVRDC (Table 7). More viable shoots and roots were found to develop on medium K. On medium L the percentage of explants with abnormal growth or no growth was much higher than on medium K. The percentage of explants developing into callus tissue was similar on both media. However, it was observed that the callus produced from explants on medium L contained several buds which failed to develop further into shoots upon transfer to another medium. A large proportion of these small buds were able to develop into viable shoots when they were transferred to medium K. Subsequently, the explants were first placed on medium L and then transferred to medium K. This method is superior to either medium alone, in producing a large number of viable plants. Sixty-one percent of the excised meristems grew to produce viable plantlets when first placed on medium L and then transferred to medium K.

Table 6. Medium formulation

Component (mg/l)	Medium L (Love et al. 1985)	Medium K (Kuo et al. 1985)
Saltbase	MS[z]	MS[y]
Sucrose	50,000	30,000
Myo Inositol	100	100
Nicotinic Acid	0	0.5
Pyridoxine HCl	0	0.5
Glycine	0	2.0
Thiamine HCl	2.0	0.1
Adenine Sulfate	0	0
Na_2 EDTA (additional)	37.3	0
GA_3	–	–
NAA	0.03 b	–
IAA	–	1.0
BAP	0.03 b	–
Kinetin	–	1.0
Agar	7,000	7,000
pH	5.2	5.7

[z]Murashige and Skoog. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant 15:473-497. [y]Transfer medium consists of all components except growth regulators.

Table 7. Comparison of two culture media for the growth of sweet potato explants.

	Medium K	Medium L
Total no. of meristems tested	395	386
No growth or abnormal growth (%)	7.2	28.8
Callus (%)	32.3	28.5[z]
Roots (%)	7.6	2.1
Callus + viable shoots + roots (%)	52.9	40.6

[z]Callus with buds which, however, did not develop further.

Use of Cytokinin-Containing Liquid Media for Rapid Mass Propagation

Summary

To achieve large numbers of aseptically propagated plants of AVRDC elite breeding lines required for distribution, a rapid *in vitro* propagation medium is needed. Three different cytokinin-containing media were tested on excised stem pieces, each containing one axillary bud in liquid culture. A medium which released the axillary bud from apical dominance and promoted the development of numerous buds that developed into viable shoots and later, plantlets, was found.

Introduction

Since the elimination of viruses through tissue culture does not result in immunity, it is essential to propagate the cured plants under sterile conditions. Obviously, reinfection is prevented as long as the plantlets remain under aseptic conditions. It is, therefore, advantageous to maintain stock materials *in vitro*. To obtain the large number of plants required for distribution of AVRDC elite breeding lines, a rapid *in vitro* propagation method is needed. At AVRDC plantlets regenerated through meristem culture have been propagated on Kuo et al. solid medium by stem sections, each containing one axillary bud. It is known that cytokinins can release axillary buds from apical dominance and allow them to develop into multiple shoots. If cytokinin is then eliminated from the medium, the buds root and produce normal plantlets within a few weeks. The effectiveness of cytokinins for the rapid multiplication of sweet potato plantlets was investigated.

Materials and Methods

Plantlets of 25 AVRDC sweet potato breeding lines regenerated through meristem culture were tested. When the plantlets were at the 4-5 leaf stage, two stem pieces, approximately 1 cm in length, were excised and placed in a horizontal position in 125 ml Erlenmeyer flasks containing 10 ml liquid medium (Media A, B and C). The flasks were maintained in a growth room, with 25.5 to 27.5°C and 4.2 Klux illumination at 16-hour photoperiod. The flasks were shaken at 100 rpm to enhance the removal of axillary bud dormancy.

The basic medium composition is shown in Table 8. Different combinations of BAP and NAA were tested.

Results and Discussion

The results are summarized in Table 9.

Medium A was not effective in promoting axillary buds. After two months, 16 of the lines completely stopped growing, 3 produced callus only while the remaining 6 produced large callus tissue and small malformed shoots.

Table 8. Composition of basic liquid medium for regeneration of sweet potato plantlets from stem pieces.

Constituent	mg/l
M & S salts (minus Na_2 EDTA)	1/2 strength
Na_2 EDTA	37.3
Thiamine HCl	0.4
Pyridoxine HCl	0.5
Nicotinic Acid	0.5
Glycine	2.0
NAA	0.5
BAP	2

Medium B appeared somewhat better. After three months all stem sections survived. However, a large proportion (15) of these produced only callus. Four produced callus and small buds and two produced a shoot which, however, was malformed. Only four lines produced roots and buds which later developed into viable shoots.

Medium C was found to be the best medium of those tested. Most stem sections produced numerous buds and roots and no callus. An average of 5.8 buds were formed from each axillary bud. All the buds later developed into viable shoots.

Medium C will now be routinely used for rapid multiplication, although some modifications in the medium composition may have to be made to reduce the number of transfer and media.

Table 9. Results of sweet potato tissue culture in liquid medium.

Entry	Medium A[z]	Medium B[y]	Medium C[x]
I-57	callus	bud (9) & root; callus & small bud(M)[w]	bud(10) & small root
I-66	callus	callus	bud(3) & root
I-4_3	callus	callus	bud(7) & root
CN 942-47	no growth	callus	bud(1) & root (brown)
CN 1028-15	callus & small shoot(M)	callus	bud(3) & root & callus
CN 1038-16	no growth	callus	bud(5) & root(M)
CN 1058-10	no growth	root & bud (2)[v]; root & bud (3)	bud(1) & root
CN 1108-13	no growth	callus & small bud (1)	browned
CN1216-10	no growth	callus	bud(3) & root
CN 1219-1	callus & small shoot(M)	callus	contaminated
CN 1232-9	no growth	callus	bud(7) & root
CN 1280-3	callus & small shoot(M)	root & bud (3)	bud(7) & small root
CN 1345-8	no growth	callus	bud(1) & root
CN 1367-2	callus & small shoot(M)	little shoot (M)	bud(7) & root
CN 1421-56	no growth	callus & shoot (3)	NT[u]
CN 1421-68	no growth	callus & small shoot (M)	NT
CN 1424-9	no growth	callus (brown)	NT
CN 1424-36	no growth	many shoots (10)(M)	bud(3) & root
CN 1448-49	callus & small shoot(M)	callus	callus & bud(1) & root
CN 1489-43	callus & small shoot(M)	shoot (2)(M)	bud(9) & root; some malformed
CN 1489-89	no growth	callus	bud(20) & root
CN 1508-84	no growth	callus	bud(5) & root
CN 1510-25	no growth	callus	bud(3) & root
CN 1517-139	no growth	callus	NT
CN 1525-11	no growth	callus & small shoot (2)(M)	NT

[z]Basic medium (Table 1). [y]Three weeks on basic medium, then transferred to basic medium with no NAA and BAP 0.1 mg/l. After four weeks transferred to basic medium with BAP.4 mg/l and NAA 0.5 mg/l. [x]Two weeks on basic medium minus NAA and BAP. Transfer to basic medium minus NAA, but BAP 0.1 mg. After two weeks changed to basic medium with 0.4 mg/l BAP, 0.5 mg/l NAA. [w]M = malformation [v]Number in parenthesis is the no. of respective tissues. [u]NT = not tested.

Comparison of Meristem-Derived and Conventionally Propagated Sweet Potato Plants

Summary

Stem cuttings of meristem-derived and vegetatively propagated plants were grown in the field in a nonreplicated trial to obtain an indication of the vigor of the meristem-derived plants and of possible mutation of morphological characters. The meristem- derived plants did not differ in overall morphology from nonmeristem-derived plants. Yields were generally comparable.

Introduction

Meristem culture, which usually involves the formation of some callus tissue, may result in genetic variability of morphology or other biochemical characters. This subject was investigated in this

preliminary study by comparing the growth of meristem- and nonmeristem-derived sweet potato plants in the field. This is expected to provide a general indication of the vigor of the meristem-derived plants.

Materials and Methods

Seventeen of the 23 AVRDC breeding lines, which had been subjected to meristem culture and virus indexed at AVRDC, were compared in the field with conventionally propagated plants of the same lines. These plants were not tested for virus, hence it is not known whether they were virus-infected or not. Of each line, five 30- to 40 cm long stem cuttings were planted on 26 May 1987 in 1.5 × 2 m plots. The distance between plants was 40 cm.

Insecticide spraying was done every three weeks with Furadan 3G. On 19 October the plants were uprooted. In cooperation with the plant breeder a visual comparison of the aboveground plant morphology, tuber skin and flesh color was conducted. Yield was also taken.

Results and Discussion

The meristem-derived plants were identical to nonmeristem-derived plants with respect to morphological characters. This indicates that meristem culture did not cause mutations with respect to general morphology. The possible mutation of other characters of biochemical nature was not tested, but should be a subject for future investigation. In general, it appeared that the yield of meristem-derived plants was comparable, in some cases even higher, than that of conventionally propagated plants. A replicated large-scale yield trial is planned for spring 1988.

Table 10. Yield of virus-free meristem-derived and conventionally propagated stem cuttings.

Variety	Meristem code no.	Meristem-derived plants (virus free)		Nonmeristem-derived plants	
		Average no. storage roots/plant	Yield kg/plant	Average no. storage roots/plant	Yield kg/plant
I-57	M6	11.3	1.23	9.8	0.89
	M7	8	1.20		
I-66	M4	7	0.84	5.6	0.28
	M5	4	0.54		
I-423	M11	6.3	0.40	5.4	0.22
CN 1028-15	M7	4.8	1.35	7.4	1.31
	M4	7	0.34		
CN 1038-16	M6	4.8	1.20	3	0.37
CN 1108-13	M7	6.3	1.38	2.4	0.44
CN 1216-10	M4	1.8	0.04	1.2	0.04
	M16	3	0.25		
CN 1219-1	M6	8.8	1.10	9	0.77
CN 1280-3	M8	4.6	0.74	11.6	0.90
	M19	8.3	1.05		
CN 1345-8	M11	9	0.90	3	0.67
CN 1424-36	M4	15.4	1.36	17.2	1.10
CN 1448-19	M1	15.6	2.08	14.4	2.04
CN 1489-43	M7	0.6	0.06	1.8	0.32
CN 1489-89	M8	7.7	1.38	5.2	1.14
CN 1510-24	M5	8.6	0.90	8.4	0.96
CN 1525-11	M3	7.4	0.48	9	0.90

Effect of Heat Treatment and Meristem Excision on Elimination of Sweet Potato Yellow Dwarf Virus

Summary

Meristem tip culture and thermotherapy have been widely used to eliminate viruses from infected tissues of a number of different crops. The effectiveness of both virus elimination methods was studied in SPYDV-infected sweet potato tissue. Results show that meristems were free of the virus, whereas some of the stem sections immediately below the meristems still contained the virus. A heat treatment of 37°C for one or two months was apparently sufficient to eliminate the virus in the tip of the stems up to 2.5 cm below the meristem. To ensure reliable elimination of viruses, it is recommended to routinely use a two-month heat treatment prior to the excision of meristems. In this case the size of the meristem would not be so critical and could possibly be somewhat larger than 0.3 mm.

Introduction

Two virus elimination methods, meristem tip culture and thermotherapy, have been widely used on different crops. The success of virus elimination by these methods, however, depends on the nature of the crop and the particular virus. The effectiveness of meristem tip culture and thermotherapy was studied on the elimination of SPYDV.

Materials and Methods

Meristem excision versus stem tips. SPYDV-infected stem tip cuttings were grown in sterile sand culture. Fifteen meristems (0.3 mm) consisting of the meristematic dome and the two leaf primordia, and 1-cm long stem tip sections immediately below the meristems were excised and placed on MS medium. When the resulting plantlets had reached the 4-5 leaf stage, all of the leaves of each plantlet were excised, pooled and tested by ELISA for SPYDV. The absorbance threshold value for negative plants was 0.086.

Heat treatment. Stem cuttings of SPYDV-infected sweet potato line CN 1345-8 were first rooted and established in sterile sand culture in a growth room (24-26°C, 4.7 Klux illumination and 12-hour photoperiod). They were then transferred to a heat chamber (3.1 Klux illumination, 12-hour photoperiod) where they were subjected to temperatures of 30° to 33° to 36° for three days each. After this heat adjustment, temperature was set at 37°C and plants were kept at this temperature for either one or two months. After the heat treatments, meristems (M), 1-cm stem tip portions just below the meristem (S1) and 1-1.5-cm stem tips just below the S1 sections (S2) were excised and transferred to AVRDC standard tissue culture medium, Medium K (Kuo et al. 1985). When the plantlets derived from these plant parts reached the 4-5 leaf stage, all of the leaves of each plantlet were excised, pooled and tested by DAS-ELISA for SPYDV. Both IgG and IgG-E were used at 1:1000 concentrations.

Results and Discussion

Meristem excision versus stem tips. The results of the ELISA test of plantlets derived from meristem tips and small stem tips for SPYDV are shown in Table 11.

It can be seen that meristem culture is effective in eliminating SPYDV from infected sweet potato. Of the nine plantlets derived from the surviving meristems, none was found to contain the virus. Six of the 15 stem tips, on the other hand, were found to be infected with the virus. Apparently, the virus was not evenly distributed within the stem tip, as some (plantlets 1, 3, 5, 7, 8, 9, 12 and 14) were found negative, and some positive, one (plant 4) with very low absorbance values indicating low concentration of virus, and the rest (plants 6 and 10) with very high absorbance values, reflecting more active virus development within the tissue.

Heat treatment. The results of the heat treatments are shown in Table 12. Both the one-month and the two-month treatments were found to be effective in eliminating SPYDV in meristems and stem tips up to 2.5 cm below the growing tip of infected sweet potato. Although the effect of heat treatment on other sweet potato viruses is not yet known (the tests are in progress), it is recommended that a two-month heat treatment be routinely used in AVRDC's virus elimination scheme, since it is not detrimental to the plant and there is a strong possibility that other viruses can also be eliminated by this technique. This would be particularly important when dealing with other non-AVRDC sweet potato materials which may be infected with viruses not yet identified for which antiserum is not available and hence for which an ELISA test cannot be done.

Elimination of Mycoplasma-like Organisms from Sweet Potato Tissues

Summary

Only limited information on the elimination of mycoplasma-like organisms (MLO), which cause sweet potato witches' broom, by meristem tip culture, thermotherapy or antibiotic treatment is available. In studies using severely infected witches' broom plant materials, it was shown that MLOs were eliminated by meristem tip culture but not by stem tips 1 cm below the meristem. A one-month treatment of stem cuttings with heat (37°C) prior to excision of stem tips of excised stem tips in tetracycline containing tissue culture medium reduced, although not completely eliminated, MLOs in such stem tips.

Introduction

Very little information on the elimination of MLO causing sweet potato witches' broom by meristem tip culture or thermotherapy is available. Kahn et al. (1971)[3] obtained an apparent cure of little leaf disease by treating stem cuttings with 500 μg/ml oxytetracycline for 48 hours or with 100 μg/ml for 48 hours and then for 72 hours. In preliminary studies conducted in 1986, 10-cm long stem pieces which were severely infected with witches' broom were treated with 5-500 μg/l tetracycline. Most stem cuttings did not survive more than three days because of severe phytotoxicity.

The application of thermotherapy, meristem tip culture and low tetracycline concentrations combined with meristem or stem tip culture was examined. A short treatment with oxytetracycline followed by excision of meristems or short stem tip cuttings was thought to reduce phytotoxicity while eliminating MLO in infected tissue.

Materials and Methods

Several methods were tested for the elimination of MLO.

Meristem tip and stem tip cultures. Meristems (0.3 mm) and 1-cm long stem tips immediately below the meristem of MLO-infected sweet potato line CN 1345-8, originally collected from Penghu Island were excised. The excised plant parts were placed on Love et al. medium and transferred to AVRDC standard medium after four weeks. At the 4-5 leaf stage, the plantlets were transferred to seven jiffy pots. The plants were observed for MLO infection both in tissue culture and after transplanting to jiffy pots or to the soil.

Heat treatment. MLO-infected sweet potato plants (line CN 1345-8) were heat treated for one month at 37°C using the heat treatment procedure described earlier.

After the heat treatment, 0.3 mm meristems and 1 cm long stem tips taken immediately below the meristem were excised. The explants were first placed on Love et al. medium and after four weeks

[3]Kahn, R.P., R.H. Lawson, R.L. Monroe and S. Hearon. 1972. Sweet potato little-leaf (witches' broom) associated with a mycoplasma-like organ. Phytopathology. pp 903-909.

Table 11. ELISA test of plantlets derived from meristems and stem tips of SPYDV-infected sweet potato plants.

Plant part	Plant no.[z]														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Meristem	–[x]	–	–	0.065	–	0.005	0.025	0.011	0.012	0.033	0.039	–	0.057	0.031	–
Stem tip[y]	0.027	0.085*	0.006	0.089*	0.068	0.421*	0.012	0.037	0.016	0.347*	0.156*	0.025	0.272*	0.033	0.238*
HCK	0.041	0.036	0.052	0.036											
DCK	0.175	0.198	0.224	0.296											

[z]Plantlet (4-5 leaf stage) derived from meristems or stem tip sections of SPYDV-infected sweet potato plants. [y]1 cm section immediately below the meristem.
[x]– = material died. *Positive reaction for SPYDV.

Table 12. ELISA readings of heat-treated SPYDV-infected sweet potato tissue.

Heat treatment	Excised[z] plant part	Plant no.														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
one month	M	0.016	0.020	0.035	0.033	–[y]	0.025	0.012	0.013	0	0.015	0.036	0.022	0.039	0.060	–
	S1	0.015	0.060	0.040	–	0.039	–	0.044	0.039	0.042	0.033	0.044	0.045	0.050	0.039	0.042
	S2	0.039	0.040	0.044	0.042	–	0.044	0.045	0.030	0.012	0.033	0.034	0.035	0.036	–	0.038
two months	M	0.033	0.040	–	0.048	–	0.033	0.045	0.036	–	0.011	–	0.015	–	–	0.021
	S1	0.030	0.028	–	0.049	0.023	0.024	0.068	0.033	0.025	0.026	0.037	0.040	0.039	0.022	0.025
	S2	0.014	0.025	0.036	0.055	0.042	0.038	0.040	0.025	0.033	0.040	0.038	0.039	0.045	0.025	0.041
HCK	0.040	0.038	0.028	0.055	0.036											
DCK	0.232	0.296	0.381	0.309												

[z]M = meristem; S1 = 1 cm section below meristem and S2 = 1.5 cm section below S1. [y]– = material died.

transferred to standard AVRDC medium. The plants were observed for MLO infection as in the procedure above.

Tetracycline treatment. Thirty stem cuttings, 10 cm long, of MLO-infected sweet potato plants were placed for three days in sterile water, containing 25, 50 and 100 mg/l tetracycline. Thereafter, the meristem (0.3 mm) and a 1 cm stem tip section immediately below the meristem were excised, placed on Love et al. medium and transferred to Kuo et al. medium after four to five weeks. The emerging plantlets were checked for the presence of MLO.

Results and Discussion

Meristem tip and stem tip cultures. Meristem-tip culture appeared to be efficient in eliminating MLO from infected sweet potato tissue, whereas all stem tips, excised immediately below the meristems, showed the presence of MLO (Table 13). MLO was absent in the meristem tips because it was found only in vascular tissue, which apparently was not yet differentiated or functional in the meristematic tissue of sweet potato. In the stem tissue immediately below the meristem and the first leaf primordia, vascular tissue was already formed and MLO had already moved into it.

Heat treatment. A one-month heat treatment seemed to have some effect in eliminating MLOs from the stem tip portions of MLO-infected plants (Table 14). Only 6.6% stem tips contained MLO compared to 100% of the nonheat-treated stem tips (experiment a). A longer heat treatment is probably necessary to completely eliminate the MLOs in the stem tip sections of infected sweet potato plants.

Tetracycline treatment. It seems that a three-day treatment of MLO-infected stem cuttings in either of the tetracycline concentrations tested was not efficient in eliminating MLO from the top 1 cm section of the stem cutting (Table 15). However, some effect was apparent since only a very small percentage of stem tips still contained MLO. A longer treatment with tetracycline may prove to be efficient in completely eliminating MLOs in the stem tip section immediately below the meristem.

Table 13. Elimination of MLO by meristem tip and stem tip culture.

	Excised plant part	
	Meristem tip	Stem tip
No. survived/total no. excised	17/20	18/20
Plantlets with MLO symptoms[z]/ no. survived	0/17	18*/18
Plants survived/plantlets transferred to jiffy pots	17/17	0/18
Plantlets with MLO symptoms[y]	0/17	–

[z]After 15 weeks in tissue culture (for meristems) and after six weeks in tissue culture (for stem tips). [y]After nine months in soil. *MLO symptoms began to appear approximately five weeks after excision of the stem tip.

Table 14. Effect of heat (37°C) on MLO-infected sweet potato.

	Meristem tip	Stem tip
No. survived/total no. excised	24/24	30/30
Plantlets with MLO symptoms[z]/ no. survived	0/24	2*/30
Plantlets survived/plantlets transferred to jiffy pots	24/24	28/30
Plantlets with MLO symptoms[y]/ plantlets survived	0/24	0/28

[z]After 15 weeks in tissue culture (meristem tip) and after six weeks in tissue culture (stem tip). [y]After nine months in soil. *Did not survive transfer to jiffy pot.

Table 15. Effect of tetracycline on MLO in sweet potato.

Plant part excised	Concentration[z]		
	25 mg	50 mg	100 mg
Meristem			
No. survived/total no. excised	30/30	28/30	21/30
Plantlets with MLO symptoms[y]/no. survived	0/30	0/28	0/21
Plantlets survived/total no. transferred to jiffy pots	30/30	28/28	21*/21
Plantlets with MLO symptoms[x]	0/30	0/28	0/21
Stem tip			
No. survived/total no. excised	30/30	19*/30	16/30
Plantlets with MLO symptoms/no. survived	2**/30	0/19*	1**/16*
Plantlets survived/total no. transferred to jiffy pots	28/30	19/19	15/16
Plantlets with MLO symptoms/plants survived	0/28	0/19	0/15

[z]MLO-infected stem cuttings were treated for three days at the different tetracycline concentrations before meristems or stem tips were excised. [y]After one month in tissue culture (without antibiotic). [x]After nine months in soil. *Very slow growth of all plantlets. **Plantlet did not survive transfer to jiffy pot.

Sweet Potato Physiology

Photosynthesis and Respiration of Self and Reciprocally Grafted Sweet Potato Leaf Cuttings

Summary

Net photosynthetic rates and gas conductance in the leaves of self and reciprocally grafted leaf cuttings were measured. High-yielding CN 1028-15 scions had the higher net photosynthetic rate, but this was reduced by the low-yielding stock, CN 1367-2. High-yielding stock increased leaf gas conductance of low-yielding scions, and thus increased photosynthetic potential. Results clearly indicated that the developing storage root had a regulatory effect on photosynthesis in the leaf. Furthermore, grafted leaf cuttings with the low-yielding stock had high specific weights. Specific leaf weight may be used as an indication of source potential and sink strength.

Introduction

Previous results showed that the leaf blade of CN 1028-15 contained more chlorophyll than that of CN 1367-2. Furthermore, studies with both self and reciprocally grafted plants or leaf cuttings revealed that CN 1028-15 retained strong sink strength which could push total dry matter production. In this investigation, photosynthesis and dark respiration of self and reciprocally grafted leaf cuttings were measured to show the relationship of photosynthesis and storage root formation.

Materials and Methods

Self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 were prepared at AVRDC, and later transferred to the National Chung Hsing University for measurements of net photosynthesis, transpiration, leaf conductance and dark respiration at 2, 3, 4, 6, 7, 10, 12 and 14 weeks after grafting.

Net photosynthetic and transpiration rates of individual leaf blades in an assimilation chamber (35 × 30 × 8 cm) under Toshiba Grolight D400, 100 Klux were measured with the CO_2 and H_2O fluxes in the chamber's atmosphere by Anard AR-600 Infrared Gas Analyzer. The assimilation chamber was maintained at 25.0 ± 0.5°C, and 75 ± 3% relative humidity (RH). After measurements of net photosynthetic rates in the daytime, grafted leaf cuttings were severed at the base of the petiole and separated into top (blade and petiole) and bottom (petiole base, fibrous and storage roots). These two parts were separately placed in the covered assimilation chambers and measured for CO_2 fluxes at 25.0 ± 0.3°C and 90% RH during the night.

Results and Discussion

At 25.0 ± 0.3°C and 75 ± 3% RH, light saturation points for net photosynthesis were 800, 600, 600 and 600 micro E/m^2/sec for CN 1028/CN 1028, CN 1028/CN 1367, CN 1367/CN 1028 and CN 1367/CN 1367, respectively, at eight weeks after grafting (Fig. 1). Net photosynthetic rates at these light saturation points were 26.82, 20.68, 19.27 and 19.47 mg CO_2/dm^2/hour, respectively. Although the CN 1028-15 scion retained high photosynthetic potential because of high chlorophyll

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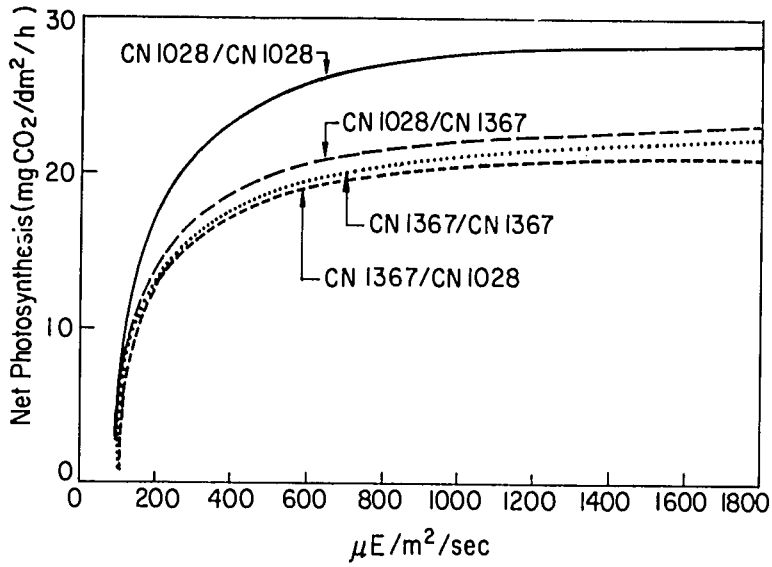


Fig. 1.
Effects of light intensity on net photosynthetic rates of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 at eight weeks after grafting.

content, net photosynthetic rate of the reciprocally grafted leaf cutting of CN 1028/CN 1367 was abated because of the CN 1367-2 stock. Net photosynthetic rates were measured from 2 to 14 weeks after grafting (Fig. 2). The results demonstrated that the maximum net photosynthetic rates occurred at four to seven weeks after grafting and then petered out. At this point, the storage root of the CN 1028-15 stock was in the rapid bulking stage which might have elicited the maximum net photosynthetic rate in the scion. The analysis of specific leaf weight (SLW) (Fig. 3) showed that the strong sink strength decreased SLW, but the weak sink strength increased. These results imply that the potential photosynthetic activity of the scion depends not only on the photosynthetic apparatus in the source leaf but also on the sink strength. Perhaps the weak sink strength in the stock has a feedback inhibiting effect on photosynthetic activity due to the accumulation of assimilates in the scion.

The comparison of leaf conductance revealed that the grafted leaf cuttings with the CN 1028-15 stock brought about high leaf conductance regardless of the leaf photosynthetic potential. On the contrary, the CN 1367-2 stock reduced the leaf conductance of the CN 1028-15 scion (Fig. 4).

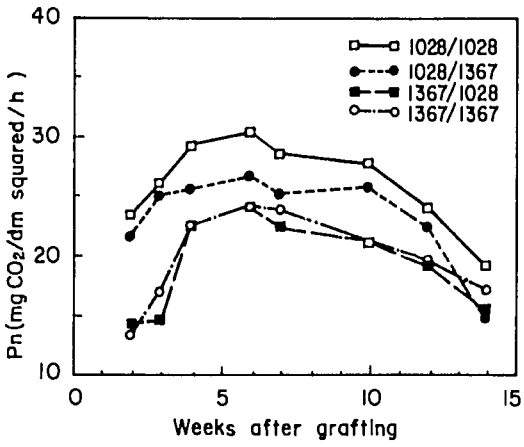


Fig. 2. Changes in net photosynthetic rates of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 14 weeks of growth.

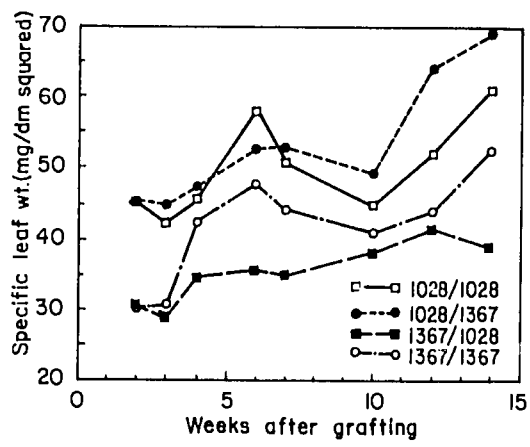


Fig. 3. Changes in specific leaf weight of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 14 weeks of growth.

Respiration rates of the underground part declined with advancing of growth (Fig. 5). The CN 1028-15 stock had lower respiration rate than the CN 1367-2 stock, due likely to the massive fibrous roots in the CN 1367-2 stock. Results not presented here showed that respiration rate in the nonstorage root part was higher than the storage root, and respiration rate of the storage root part of the CN 1367-2 stock was higher than that of the CN 1028-15 stock. These results suggest that although cell division and expansion of the developing storage root require high respiration rate, the small sink size in the CN 1367-2 may not be able to fully utilize the translocated assimilates in the developing storage root, and exhaust them through high respiration rate.

Results also imply that photosynthetic activity is important for dry matter production, but the sink strength in the developing storage root has a regulatory mechanism on the photosynthetic activity in the source potential. The specific leaf weight may serve as a parameter for assessing source potential and sink strength in plant breeding.

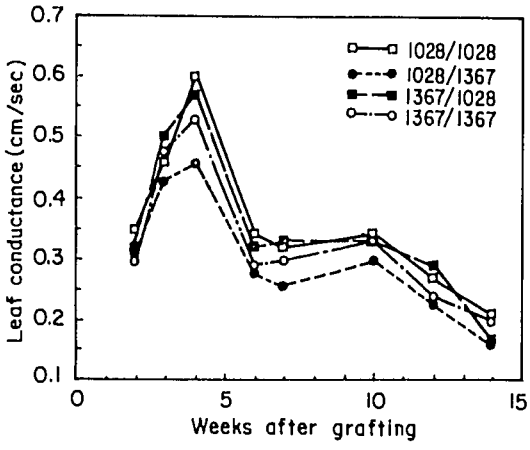


Fig. 4. Changes in leaf conductance of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 14 weeks of growth.

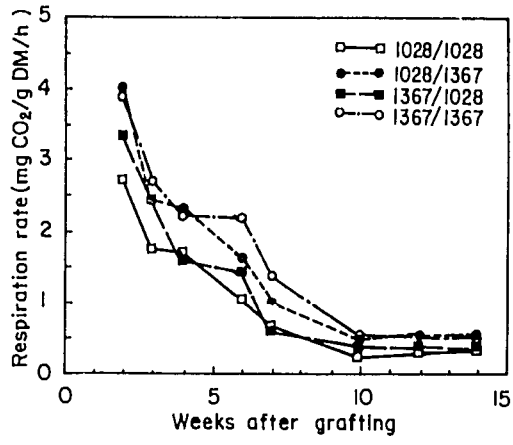


Fig. 5. Dark respiration rates of the underground part of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 14 weeks of growth.

Anatomical Observations on Self and Reciprocally Grafted Leaf Cuttings

Summary

Anatomical observations were carried out on self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2. A large amount of starch granules were found deposited in leaf blades and petioles when CN 1367-2 (with weak sink strength) was used as the stock. The developing storage roots of CN 1028-15 had greater anomalous cambium number and large parenchyma cells which, as indications of strong sink strength, could accommodate more assimilates from the leaf.

Introduction

Anatomical observations were conducted on self and reciprocally grafted leaf cuttings of high-yielding clone, CN 1028-15, and low-yielding clone, CN 1367-2, to further understand the nature of source-sink relationship in sweet potato.

Materials and Methods

Self and reciprocally grafted leaf cuttings were prepared in the end of October 1986, and grown under greenhouse conditions. At 2, 3, 4 and 12 weeks after grafting, the leaf blade and upper petiole,

and storage roots were sampled and fixed in 70% FAA fixative, dehydrated in the TBA series, infiltrated and embedded with paraffin, and finally sectioned with rotary microtome to obtain paraffin sections with 12 micrometer thickness. Paraffin sections were later affixed to slides coated with Haupt's adhesive and stretched with 4% formalin. They were stained with safranin-fast green for histological observation, or periodic-basic fuchsin for polysaccharide observations.

Results and Discussion

Based on chemical analysis, last year's results showed that more starch accumulated in the upper petiole of the grafted leaf cuttings, with CN 1367-2 (having weak sink strength) as the stock. Anatomical observations on the blade midrib at three weeks after grafting showed that more starch granules were accumulated in the ground tissue parenchyma and xylem and phloem parenchyma of grafted combinations, with the CN 1367-2 stock. Furthermore, CN 1028-15, as the scion, aggregated greater starch granules in the midrib of grafted leaf cuttings with the same stock. Similar phenomena were also observed in the midrib and upper petiole of the scion at other growth stages. These observations confirm previous contentions that when the weak sink strength stock (CN 1367-2) was used for grafting, assimilates accumulated in the scion, and hence reduced photosynthetic activities.

The bulking of the storage roots in sweet potato is the result of cell division of the vascular cambium and anomalous cambium. Anomalous cambium originates in the parenchyma of the central portion of the axis, frequently occurring as cylinders which surround groups of xylem elements, and may increase in width until a region of considerable size is formed; thus, playing an important role in the bulking of storage root. Storage roots of grafted leaf cuttings with high sink strength (CN 1028-15) stock started to swell at three weeks after grafting, differentiate large amounts of anomalous cambium, and aggregate a mass of starch granules in the parenchyma. Some starch granules also occurred in the phloem parenchyma of the vascular cambium. On the other hand, there were little anomalous cambia differentiated in grafted leaf cuttings with CN 1367-2 stock at the same stage. At six weeks after grafting, grafted leaf cuttings with CN 1367-2 stock started to form anomalous cambium. CN 1028-15 scion in grafted leaf cuttings with the same CN 1028-15 stock at 12 weeks after grafting conduced to more starch granules in the parenchyma of storage root than CN 1367-2 scion.

The determination of the number of anomalous cambium (Fig. 6) and size of parenchyma cells (Table 1) in storage roots of grafted leaf cuttings revealed that the CN 1028-15 stock had more anomalous cambium number and large parenchyma cells than the CN 1367-2 stock. These results imply that the bulking of storage roots relies on the differentiation of anomalous cambium. High sink strength stock with active differentiation of anomalous cambium produces a greater amount of large parenchyma cells to accommodate more starch granules. The source potential, on the other hand, influences the development of storage root through the supply of assimilates; the weak sink strength in the developing storage roots contributes to starch deposition elsewhere other than the storage roots.

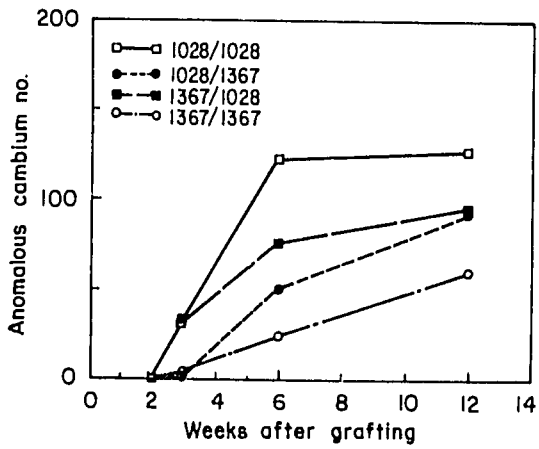


Fig. 6.
Differential increments in the anomalous cambium number of developing storage roots of self and reciprocally grafted leaf cuttings with CN 1028-15 and CN 1367-2 clones.

Table 1. Average parenchyma cell size ($\times 10^{-3}$ mm^2/cell) of developing storage roots of grafted leaf cuttings of sweet potato.

Grafting combination (scion/stock)	Parenchyma cell size (weeks after grafting)	
	6	12
CN 1028/CN 1028	4.59 ± 1.03[z]	8.03 ± 1.05
CN 1028/CN 1367	3.26 ± 0.39	5.47 ± 0.63
CN 1367/CN 1028	4.25 ± 0.58	6.32 ± 0.76
CN 1367/CN 1367	2.86 ± 0.78	5.88 ± 0.86

[z]Means of 23 determinations ± standard deviation.

Potassium Content in Self and Reciprocally Grafted Leaf Cuttings

Summary

Potassium contents in different parts of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 were determined. High K content in nonstorage organs of grafted leaf cuttings with the high-yielding CN 1028-15 stock may be related to the ready translocation of assimilates to the developing storage roots. In storage roots this may be related to starch formation.

Introduction

Potassium is known to be involved in translocation by accelerating the export of assimilates from the leaves or the import of assimilates to the site of utilization or storage, and in starch synthesis by increasing starch synthetase activities. Last year, it was reported that high starch content was accumulated in the leaf blade, upper and lower petioles, petiole base and fibrous roots in grafted leaf cuttings with the low-yielding CN 1367-2 stock. On the other hand, high soluble sugar content was detected in the petiole base, and fibrous and storage roots in grafted leaf cuttings with the high-yielding CN 1028-15 stock. The present study aimed to analyze potassium content in different parts of self and reciprocally grafted leaf cuttings, and relate the role of potassium to the translocation of carbohydrates in terms of source-sink characteristics of a high-yielding clone, CN 1028-15, and a low-yielding clone, CN 1367-2.

Materials and Methods

Twenty leaf cuttings each of self and reciprocal grafts were sampled at 3, 5, 7, 9, 12 and 16 weeks after grafting. They were measured for leaf area, fresh and dry weights, and the different parts of the leaf cuttings for soluble sugar and starch contents. The detailed procedures and results of these analyses were reported last year. The present report describes the analysis of potassium content in different parts of the grafted leaf cuttings.

Results and Discussion

Potassium concentrations in different parts of the leaf cuttings decreased with advancing growth (Figs. 7, 8, 9 and 10). The concentrations in storage root were lower than in other parts; they also decreased in three to five weeks after grafting but increased in grafted leaf cuttings with the CN 1028-15 stock (Fig. 10).

Grafted leaf cuttings with the CN 1028-15 stock accumulated more potassium in all parts than those with the CN 1367-2 stock, except in fibrous root. There was a large accumulation of K in the fibrous root of the grafted leaf cuttings with the CN 1367-2 stock, probably because CN 1367-2 produced more fibrous root which easily absorbed more K, but not readily translocated to other parts of the leaf cuttings.

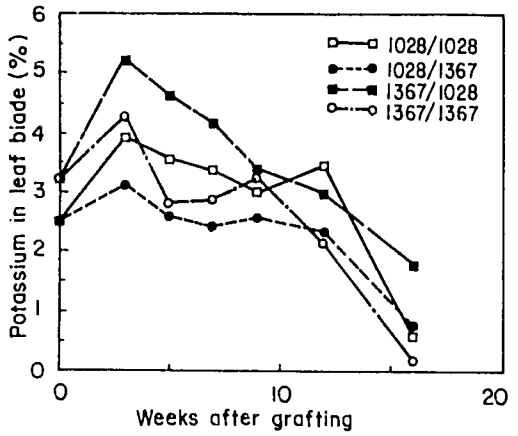


Fig. 7. Changes in K concentrations in the leaf blade of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 16 weeks of growth.

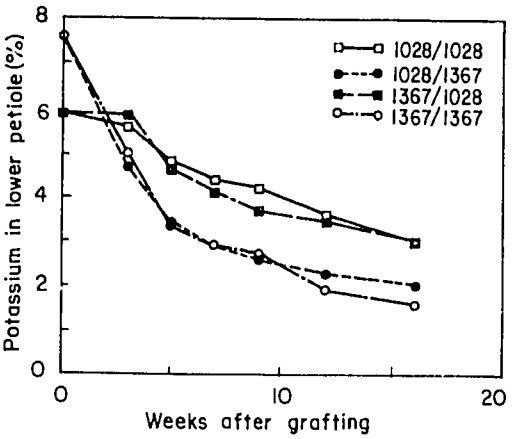


Fig. 8. Changes in K concentration in lower petiole of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 16 weeks of growth.

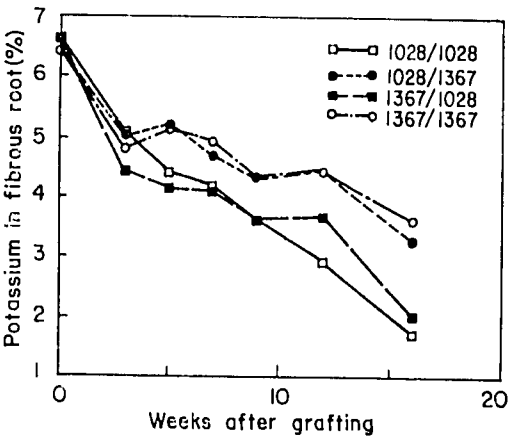


Fig. 9. Changes in K concentration in fibrous root of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 16 weeks of growth.

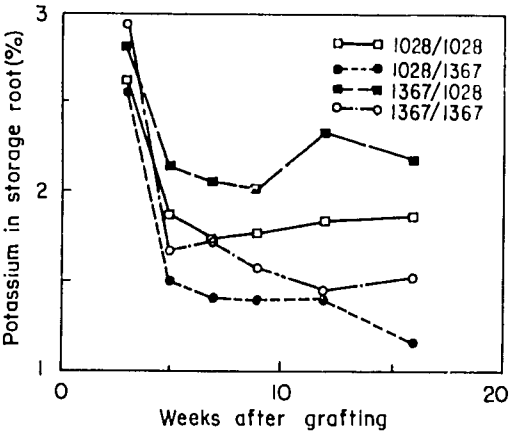


Fig. 10. Changes in K concentration in storage root of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during 16 weeks of growth.

After carbon is assimilated, part of the assimilate is translocated out of the leaf into the stem in the form of sucrose, and eventually to the site of utilization or deposition, e.g. storage root. Little is presently known about the process of loading, transport and unloading of assimilates in the sweet potato. Based on the leaf cutting as a transporting system model, it is interesting to note that the grafted leaf cuttings with low-yielding stock retained low K concentration but high starch concentration in the leaf blade, upper petiole, lower petiole and petiole base. It is possible that low K inhibits the loading and transport of sucrose in the leaf blade and petiole, and hence these assimilates are converted to starch, which inhibit photosynthesis through feedback mechanism. On the contrary, when a high-yielding clone was used as the stock in the grafted leaf cuttings, relatively high K concentrations were found in these parts of the leaf cutting, thus less starch was accumulated.

Since both fibrous and storage roots are the potential sites of deposition for assimilates, the starch contents in these depend on both the availability of translocated sucrose and the activities of enzymes involved in starch synthesis. Fibrous roots of grafted leaf cuttings with the CN 1028-15 and CN 1367-2 stocks had less K and starch, due likely to low K preventing normal activities of enzymes involved

in starch synthesis. Fibrous roots of grafted leaf cuttings with the CN 1367-2 stock retained high K, thus promoting starch formation.

Storage roots of grafted leaf cuttings with the CN 1028-15 stock retained higher levels of K than those with the CN 1367-2 stock. Storage roots of both CN 1028/CN 1028 and CN 1367/CN 1028 had high starch content probably due to their high K for starch synthesis. Storage roots of CN 1028/CN 1367, even though with low K, also had comparable starch contents as those of CN 1028/CN 1028 and CN 1367/CN 1028, which is likely due to the ready availability of sucrose from the high source potential (CN 1028-15). Storage roots of self-grafted leaf cuttings of CN 1367/CN 1367 had the least starch concentration due to the low availability of sucrose from the source leaf and the low K in the storage root sink to synthesize starch.

The photosynthesis, transport and storage system in the sweet potato can be regarded as a highly integrated series of processes. Results presented here indicate that the source-sink characteristics of the plant is important to the storage root formation, and this relationship may be mediated through potassium. Thus, the potential effects of potassium on storage root formation can be further explored, and the relationship between potassium and yield difference tested.

Changes in Cytokinins and Auxins During Storage Root Development of Grafted Leaf Cuttings

Summary

Fibrous and storage roots of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 were determined for endogenous hormonal contents during the initiation of storage root development. Both zeatin riboside and indoleacetic acid (IAA) increased with advancing storage root development, and high-yielding grafted leaf cuttings of CN 1028/CN 1028 contained high amounts of both zeatin riboside and IAA. Both zeatin riboside and IAA are probably needed for the bulking of storage roots.

Introduction

Sink strength appears to relate with cambial activity, and may depend on certain endogenous growth substances. Cytokinin had been isolated from the storage root of sweet potato, and seemed to play a role in storage root formation. This report attempted to determine the changes in endogenous levels of cytokinins and auxins during storage root development of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2, to clarify the sink strength of developing storage roots.

Materials and Methods

Fibrous root and pencil or storage root of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 were sampled at 3, 5, 7 and 9 weeks after grafting, which were made on 16-18 June 1986. They were extracted with 80% cold methanol twice, evaporated in vacuo, and purified with PVP to exclude color and phenolic compound. The filtrate was partitioned with ethyl acetate at pH 2.5, and the remaining aqueous layer partitioned with n-butanol at pH 8.0. The organic fractions were evaporated in vacuo before developing on TLC to obtain fractions corresponding to GAs, IAA, ABA zeatin and zeatin riboside. These fractions were later concentrated and determined for respective plant hormones with HPLC by Merck LiChrosorb RP-18 R f 30-4 (7 micrometer) column.

Results and Discussion

No GAs, ABA and free zeatin could be detected in this experiment; therefore, the significance of these plant hormones in the storage root development is not discussed. The total amount of zeatin riboside was higher in the developing storage root than in the fibrous root at 5, 7 and 9 weeks after grafting (Fig. 11). There were comparable amounts of zeatin riboside between the fibrous root and

the storage root at three weeks after grafting but a rapid increase of zeatin riboside occurred in the developing storage root thereafter, although a well-nigh constant amount remained in the fibrous root.

The total IAA amount in the fibrous root stayed high at three and five weeks after grafting, but declined thereafter (Fig. 12). High IAA amount in the fibrous root at early stages was likely related to the initiation of fibrous root. The largest storage root formation in CN 1028/CN 1028 had high amount of auxins. The total IAA amount in the storage root was lower than in the fibrous root at three and five weeks after grafting, but increased thereafter.

The close relationship between rate of cell division and level of endogenous cytokinins and auxins had been demonstrated in several plants. As reported earlier, the bulking of storage roots was accompanied by continuous differentiation of anomalous cambium and subsequent division and enlargement in parenchymatous cells. High amounts of IAA at five to seven weeks after grafting may be responsible for the bulking of storage roots via the differentiation of anomalous cambium and subsequent cell division.

On the other hand, since cytokinins are known to have roles in mobilization effects and cambial activity, the high amount of zeatin riboside in the storage roots of CN 1028/CN 1028 and CN 1028/CN 1367 could have roles in these effects of the developing storage roots. However, the zeatin riboside amount in developing storage roots of CN 1028/CN 1367 fell short of these effects for bulking of storage root probably due to lack of IAA. Since the production site of these plant hormones in the sweet potato is far from clear, the relationship between hormonal content and physiological processes, such as differentiation of anomalous cambium, cell division and subsequent cell enlargement in the storage root cannot be conclusively deduced.

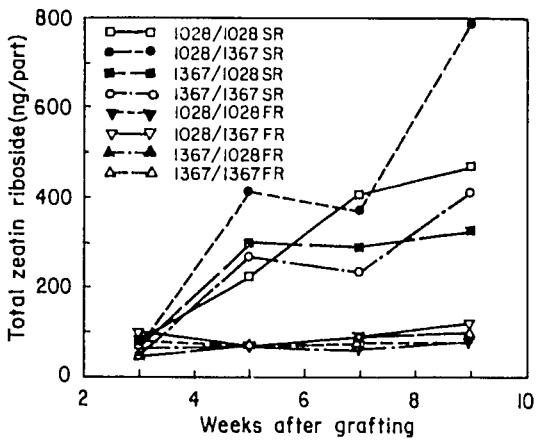


Fig. 11. Increment of zeatin riboside content in storage root (SR) and fibrous root (FR) of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during nine weeks of growth.

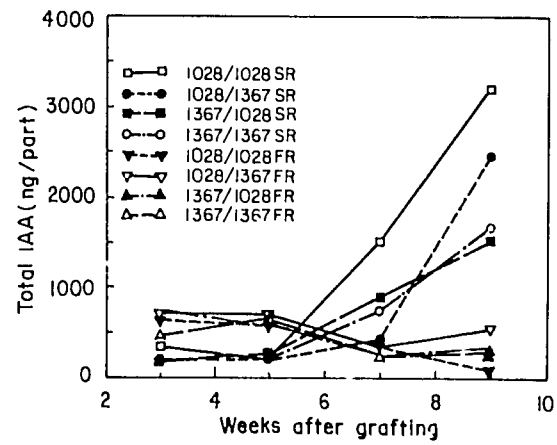


Fig. 12. Increment of IAA content in storage root (SR) and fibrous root (FR) of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during nine weeks of growth.

Enzymatic Activities of Starch Synthesis of Self and Reciprocally Grafted Leaf Cuttings

Summary

Self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 were determined for enzyme activities of starch synthesis. Starch synthesis in the developing storage roots is probably controlled by the availability of carbohydrates rather than enzymatic activities.

Introduction

Storage root development in sweet potato builds on cell number and enlargement and starch accumulation in parenchymatous cells. Sucrose is generally considered to be the major carbohydrate, as a precursor of starch granules, reaching the storage root from the leaf. Little is known, however, about carbohydrate metabolism in the developing storage root. This study examined the relationship between enzymatic activities of carbohydrate metabolism and storage root development of grafted sweet potato leaf cuttings.

Materials and Methods

Grafted leaf cuttings of CN 1028/CN 1028, CN 1028/CN 1367, CN 1367/CN 1028 and CN 1367/CN 1367 were sampled on 3, 5, 7 and 9 weeks after grafting. Leaf blade, petiole base, fibrous root and storage root of sampled leaf cuttings were cold extracted with buffer solution and determined for the activities of invertase, amylase, sucrose synthase, and soluble and granular-bound starch synthases.

Results and Discussion

The CN 1367-2 scion leaf had higher invertase activities than the CN 1028-15 scion leaf (Fig. 13). Since CN 1367-2 had a larger leaf area development than CN 1028-15, it is possible that invertase cleaved sucrose to release hexose for leaf expansion. The high invertase activities in the CN 1367-2 scion leaf imply that CN 1367-2 leaf itself as a sink is stronger than the stock for the assimilates. The CN 1028-15 stock with strong storage-root sink strength slightly reduced invertase activities in the CN 1367-2 scion leaf, whereas the CN 1367-2 stock with weak storage-root sink strength slightly increased invertase activities in the CN 1028-15 scion leaf. It appears that the sink strength in the storage root has a regulatory function on invertase in the leaf.

Sucrose synthase activity was hardly detected in the petiole base, fibrous root and storage root except that which occurred in the leaf (0.02 to 0.13 μ mole glucose/min/g fresh weight) at five weeks after grafting. It is postulated that sucrose in reserve tissue is either converted to free sugars via invertase action or is directly converted to the sugar nucleotides via the sucrose synthase reactions. The presence of invertase, but not sucrose synthase, in the storage root of sweet potato probably supports the notion

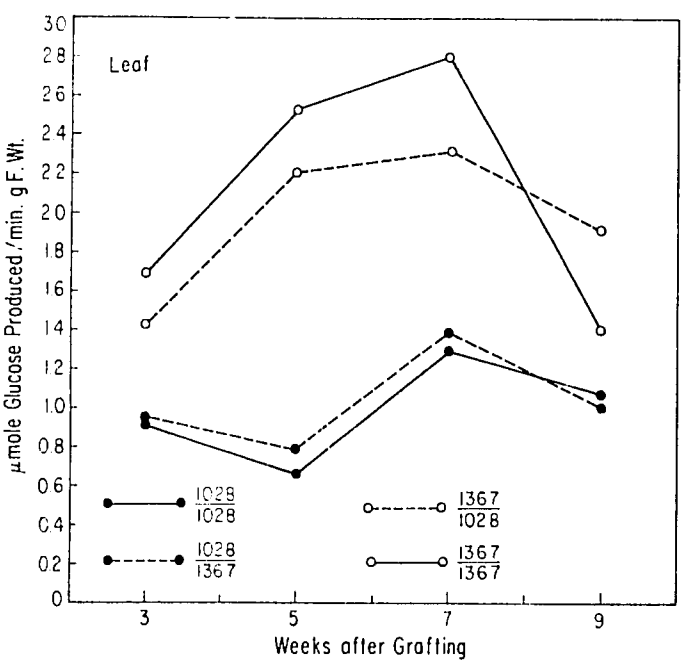


Fig. 13.
Changes in invertase activities in the leaf blade of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during nine weeks of growth after grafting.

that invertase is responsible for starch synthesis in the developing storage root. However, the failure of detecting sucrose synthase in the storage root because of experimental procedure is not ruled out; the presence of sucrose synthase in the storage root of sweet potato has been reported.

Soluble starch synthase is the enzyme responsible for the α-1,4-glucosidic linkage of starch. Activities of this enzyme in the leaf blade of four grafted leaf cuttings remained constant at four stages of sampling. Activities in the developing storage root, however, were higher than in the leaf blade but decreased from three to nine weeks after grafting (Fig. 14). A similar but less active pattern also occurred in granular-bound starch synthase. This trend of decreasing enzymatic activities is probably attributed to increased storage root size with advancing growth. The total activities of both soluble and granular-bound starch synthases were higher in CN 1028/CN 1028 than in other grafted leaf cuttings.

The CN 1028/CN 1028 leaf cuttings had less amylase, a degradation enzyme of starch, activities in the storage root throughout its development than other grafted leaf cuttings (Fig. 15). The total activity of this enzyme in CN 1028/CN 1028 was also lower than the leaf cutting grafted with CN 1367 stock. Low amylase activities are desirable to prevent the degradation of starch in the storage root.

Results presented here suggest that starch synthesis in the developing storage root of sweet potato is controlled, probably not by enzymatic activities of starch synthesis but by the availability of assimilates manipulated by source potential or sink strength. Since the mechanisms involved in starch biosynthesis of storage roots in the sweet potato are probably passive and still not fully understood, little is to be gained at present by breeding for varieties with certain starch synthetic enzymes. It is more worthwhile to look into hydrolytic activities of amylase, since less amylase was related with high yield and high starch content in the storage root.

Assessment of Source Potential and Sink Strength by Rooted Leaf Cutting Method

Summary

Thirty-five sweet potato clones without prior selections for any agronomic characteristic were assessed for source potential and sink strength, i.e. total and storage root dry matter production,

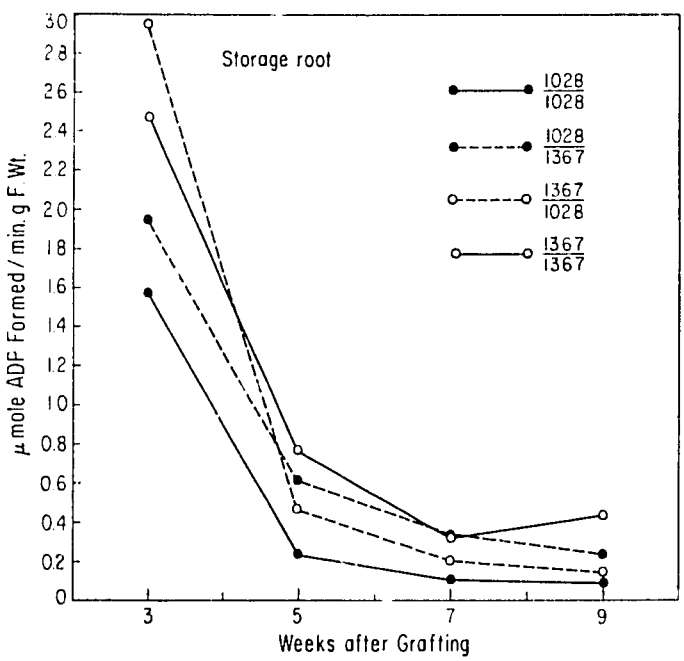


Fig. 14.
Changes in soluble starch synthase activities in the developing storage roots of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during nine weeks of growth after grafting.

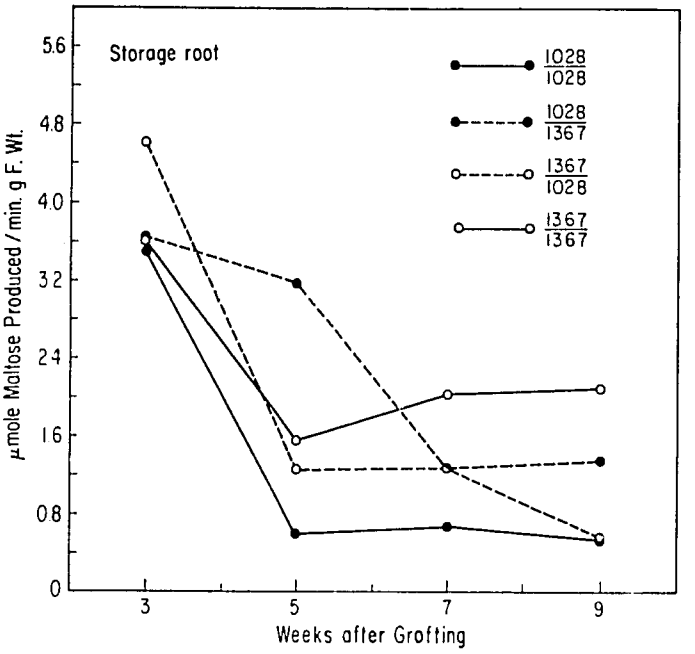


Fig. 15.
Changes in amylase in the developing storage roots of self and reciprocally grafted leaf cuttings of CN 1028-15 and CN 1367-2 during nine weeks of growth after grafting.

by grafting of rooted leaf cuttings with themselves or low-yielding CN 1367-2 or high-yielding CN 1028-15 as scions. None of the 35 clones outyielded the high-yielding CN 1028/CN 1028 in storage root dry matter. However, the results clearly indicate that the rooted leaf cutting could be used as an easy method for assessing source potential or sink strength in sweet potato.

Introduction

Previously it had been shown that the potential of dry matter and storage root production of sweet potato under field conditions was reflected in rooted leaf cuttings. The present study aimed to evaluate the feasibility of using rooted leaf cuttings for assessing source potential and sink strength of sweet potato using 35 clones which were not subjected to prior selections for any agronomic characteristics.

Materials and Methods

Leaf cuttings of 35 nonselected sweet potato clones were first rooted and then grafted on 13 April 1987 using their or CN 1367 leaves as scions. They were grown under greenhouse conditions and sampled at 100 and 130 days after grafting. Sampled leaf cuttings were determined for leaf area, fresh and dry weights of blades, petioles and fibrous and storage roots. The results were compared with those on grafted leaf cuttings in 1986 using their or CN 1028 leaves as scions.

Results and Discussion

The mean dry matter production at gram/leaf cutting of 35 self grafts (Fig. 16) (mean = 3.62, range = 1.74-6.32) was slightly less than the high-yielding CN 1028/CN 1028 (4.36), more than the low-yielding CN 1367/CN 1367 (3.19), and comparable with CN 1028/CN 1367 (3.15) and CN 1367/CN 1028 (3.19). However, the mean dry matter production of 35 clones as stocks was slightly increased with the CN 1028 scion (mean = 4.71, range = 2.70- 6.59), but substantially decreased with the CN 1367 scion (mean = 2.40, range = 1.43-3.41). Self grafts of CN 1760-45, CN 1760-47 and CN 1760-49 produced more dry matter than the high-yielding self graft of CN 1028/CN 1028. The results confirmed that CN 1367 is an inefficient source for assimilate production, while CN 1028 is an efficient one.

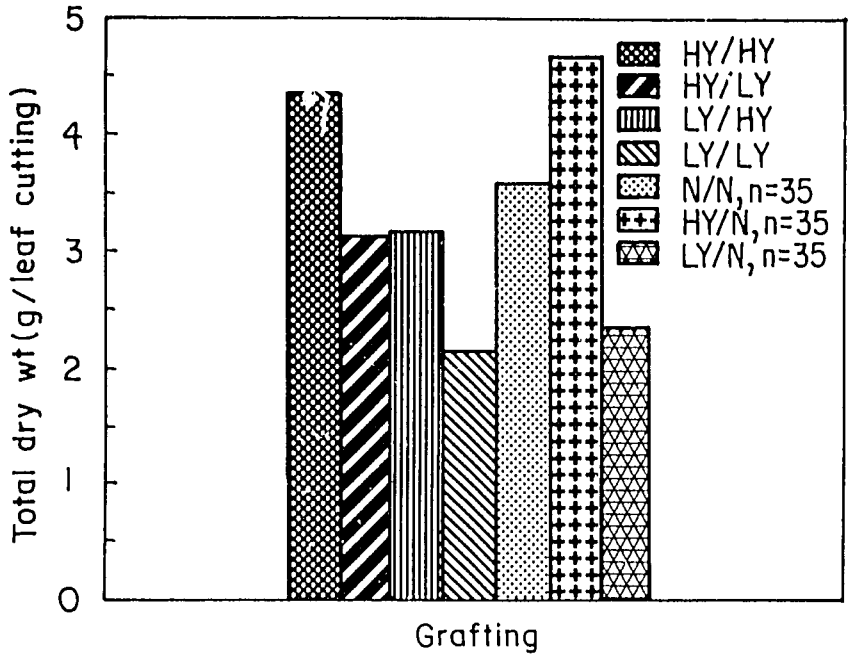


Fig. 16. Total dry matter production of grafted leaf cuttings after 100 days of growth; HY = CN 1028, LY = CN 1367, N/N (scion/stock) = mean of 35 self grafts.

The mean harvest index at the percentage of 35 self grafts (Fig. 17) (mean = 52, range = 13-72) was less than the high- yielding CN 1028/CN 1028 (70), but more than the low-yielding CN 1367/CN 1367 (30) and CN 1028/CN 1367 (41), and comparable with CN 1367/CN 1028 (60). However, the CN 1028 scion tended to increase the mean harvest index of 35 clones as the stocks (mean = 59, range = 44-75), and the CN 1367 scion tended to decrease (mean = 45, range = 15-60). None of the self grafts of 35 nonselected clones had higher harvest index than CN 1028/CN 1028. The results indicate that CN 1028 was not only an efficient source for assimilate production but also a strong sink in developing storage roots for the assimilates, which would also slightly increase the source potential.

Although self grafts of CN 1760-45, CN 1760-47 and CN 1760-49 had more dry matter than the high-yielding CN 1028/CN 1028, they produced only storage root dry matter comparable with CN 1028/CN 1028, which were attributed to low harvest indices in these three self grafts. On the other hand, self grafts of CN 1760-31, CN 1760-62 and CN 1760-72 had comparable harvest indices and storage root dry matter as CN 1028/CN 1028. The results show that the harvest index in addition to dry matter production is an important factor determining the yield potential of sweet potato.

Evaluation of Varietal Difference in Amylase, Total Soluble Sugar and Starch

Summary

Eight sweet potato clones were examined for amylase activities, soluble sugar and starch contents in leaves and/or storage roots from *in vitro* plantlets or callus, rooted leaf cuttings and field-grown plants, to establish screening parameters for nonsweetness in sweet potato. Soluble sugar contents and amylase activities varied greatly with environmental and plant factors, and their characteristics need to be further studied before an easy screening method could be established.

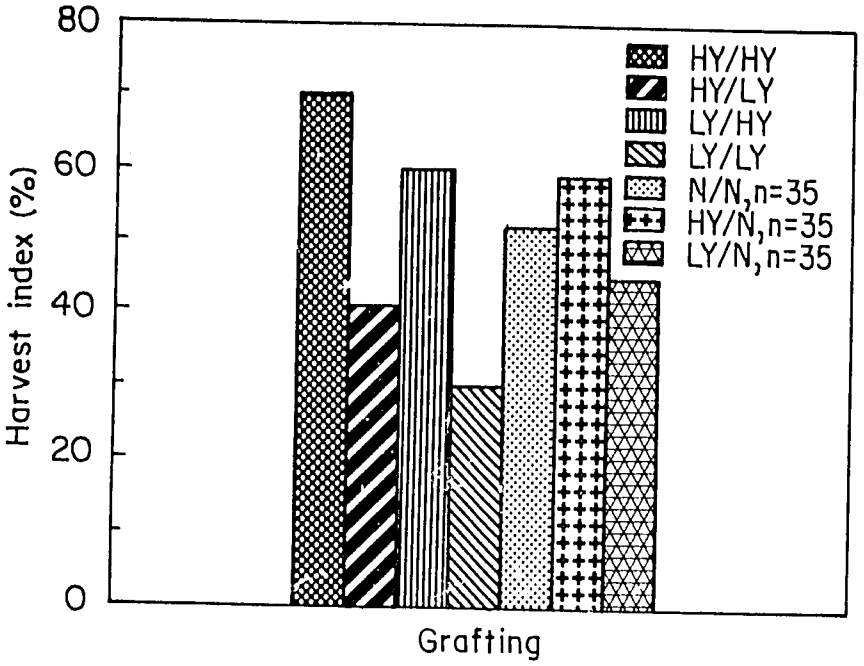


Fig. 17. Harvest indices of grafted leaf cuttings after 100 days of growth. HY = CN 1028, LY = CN 1367, N/N (scion/stock) = mean of 35 self grafts.

Introduction

The storage roots of certain sweet potato clones from Puerto Rico and Japan were reported to contain less amylase, and thus were less sweet. This study compared the sugar and starch contents, and amylase activities among *in vitro* plantlets, pot-grown leaf cuttings and field-grown plants of these clones with standard cultivars. The aim of this study was to develop screening methods for low sugar in sweet potato.

Materials and Methods

Low sugar clones, WT 71-8, WT 71-9 and WT 71-10, from Japan and I 1192 (Ninety-nine) from Puerto Rico, and standard cultivars or breeding clones, I 423 (Tainan 71), I 981 (Tainung 66), CN 1108-13 and CN 1367-2, were tested.

Plantlets and calli derived from meristems were grown on MS medium containing 30 g/l sucrose. Plantlets were grown under light, whereas calli were grown in the dark. Three replicates, each with 12 test tubes containing a single plantlet or callus, were sampled after 80 days of growth to determine amylase activities and soluble sugar and starch contents in shoot and root of plantlets, as well as in callus.

In a separate experiment, rooted leaf cuttings were grown and harvested 80 days after planting. Similarly, field-grown sweet potatoes were sampled at 75, 125 and 150 days after planting. Sampled leaf cuttings and plants were measured for amylase activities and soluble sugar and starch contents.

Results and Discussion

Sugar content in the storage root of field-grown plants harvested at 75 days after planting varied (Table 2). CN 1367-2 and I 1192 had lower sugar content than the other entries. A similar trend was also observed in rooted leaf cuttings. I 1192 (Ninety-nine) was reported to be a nonsweet cultivar, and present results on soluble sugar content supported this. However, low soluble sugar contents in both CN 1367-2 and I 1192 could be attributed to the delayed development of storage roots. The storage roots of both clones did not exceed 2.0 cm in diameter at 150 days after planting.

There was also a varietal difference in the starch content (Table 3). Storage roots of I 981 and WT 71-9 contained more starch than the other entries in both field-grown plants and rooted leaf cuttings. I 1192 and CN 1367-2 had low sugars but intermediate levels of starch. Normally sweet potatoes contain amylase, which is heat stable or active, and digests the starch to release short-chain starch residues and the soluble, reducing sugar, maltose. It has been reported in the literature that I 1192 from Puerto Rico and WT 71 series from Japan contained less amylase, and were thus less sweet. Data in Table 4 also show that I 1192 had less amylase activities in the storage root from field planting but not the WT 71 series. A similar trend also occurred in the rooted leaf cuttings, except amylase activity in I 981 which was not detected.

At present no relationship could be established between soluble sugar content and amylase activities probably because total soluble sugar instead of maltose was measured. Although the relationships between starch content in storage roots of leaf cuttings and field-grown plants could be observed, the relationships of soluble sugar contents and amylase activities in leaf or storage roots of plantlets, callus, rooted leaf cuttings or field-grown plants are less clear. It appears that the characteristics of amylase and its effects as influenced by environmental and plant factors, and the relationship with starch synthesis or degradation in sweet potato need to be further studied before the nonsweetness in sweet potato and the development of easy methods to screen germplasms and breeding clones for nonsweetness can be pursued.

Table 2. Soluble sugar content (% dry weight) in leaf, storage root and callus of sweet potato.

Clone	Plantlets		Callus	Leaf cutting		Plant	
	Shoot	Fibrous root		Leaf	Storage root	Leaf	Storage root
I 423	5.26 ab[z]	4.09 c	3.38 d	3.07 c	11.03 e	3.66 b	21.73 a
I 981	5.05 ab	12.68 a	5.66 b	3.30 c	13.13 d	2.42 cd	18.63 b
I 1192	6.03 a	6.54 b	3.75 cd	3.31 c	11.43 e	2.64 cd	9.65 d
CN 1108-13	5.96 a	13.02 a	5.05 bc	3.00 c	20.44 b	4.02 b	19.27 b
CN 1367-2	5.77 a	7.57 b	7.59 a	2.58 d	8.45 f	1.77 d	4.73 e
WT 71-8	4.33 b	5.05 c	6.40 ab	3.78 b	13.15 d	2.68 cd	11.94 c
WT 71-9	4.55 b	6.72 b	5.60 b	4.89 a	15.04 c	5.21 a	11.93 c
WT 71-10	5.08 ab	4.78 c	5.96 b	3.21 c	21.97 a	3.22 bc	11.27 c

[z]Mean separation within a column by Duncan's multiple range test at 5% level.

Table 3. Starch content (% dry weight) in leaf, storage root and callus of sweet potato.

Clone	Plantlets		Callus	Leaf cutting		Plant	
	Shoot	Fibrous root		Leaf	Storage root	Leaf	Storage root
I 423	3.40 bc	2.48 e	2.75 bc	4.70 b	47.9 b	3.49 a	35.7 c
I 981	2.72 cd	3.75 b	3.23 bc	5.52 a	51.8 a	2.02 cd	48.8 b
I 1192	1.72 d	2.52 e	2.34 c	[illegible] 75 d	42.5 c	2.55 bc	38.1 c
CN 1108-13	2.53 cd	2.83 de	3.38 b	1.78 f	39.2 cd	3.05 ab	46.6 b
CN 1367-2	3.41 bc	3.11 cd	4.96 a	2.53 de	37.4 d	1.57 d	37.4 c
WT 71-8	4.40 ab	2.83 de	4.66 a	2.19 ef	13.5 e	2.47 bc	27.1 d
WT 71-9	5.36 a	5.55 a	3.43 b	4.00 c	53.9 a	3.60 a	58.7 a
WT 71-10	2.39 cd	3.55 bc	4.30 a	2.22 d-f	41.8 c	3.23 ab	33.2 c

Table 4. Amylase activities (nano mole maltose/g F.W/min) in leaf, storage root and callus of sweet potato.

Clone	In vitro shoot	Callus	Leaf cutting		Plant	
			Leaf	Storage root	Leaf	Storage root
I 423	353 ab[z]	389 b	272 ab	148 b	405 a	127 c
I 981	329 ab	236 c	0 d	0 e	399 a	170 a
I 1192	0 c	0 d	322 a	109 d	148 d	95 d
CN 1108-13	0 c	0 d	307 ab	142 bc	270 c	136 c
CN 1367-2	290 b	496 a	147 c	120 cd	191 d	85 d
WT 71-8	318 ab	0 d	346 a	228 a	324 b	128 c
WT 71-9	368 a	0 d	319 a	221 a	248 c	125 c
WT 71-10	286 b	0 d	242 b	134 bc	240 c	153 b

[z]Mean separation with column by Duncan's multiple range test at 5% level

Effect of Temperature on Rooted Leaf Cuttings

Summary

Rooted leaf cuttings were planted in January and May to investigate clonal differences in growth and yield under different temperature conditions. Both I 423 and CN 1517-139 produced high total dry matter and storage roots under high temperature conditions. However, there was a decreasing trend in starch content under high temperature conditions.

Introduction

It has been observed that high temperature is detrimental to the storage root yield of sweet potato, possibly by inhibiting photosynthesis or translocation. This study investigates the effect of ambient temperature in two seasons on storage root formation and some growth characteristics of five sweet potato clones.

Materials and Methods

Leaf cuttings of I 423 (Tainan 17), I 424 (Tainan 18), CN 1028-15, CN 1108-13 and CN 1517-139 were planted on 6 January 1987 and 19 May 1987, respectively. These were grown under greenhouse conditions with monthly mean air temperature ranges of 19.5° to 28.3°C and 29.4° to 30.9°C for January and May plantings, respectively, and monthly mean soil temperature ranges of 23.5° to 32.7°C and 32.2° to 35.7°C, respectively. Leaf cuttings were sampled at 0, 4, 8, 12, 16 and 20 weeks after planting and investigated for dry matter of different parts and other growth characteristics.

Results and Discussion

Rapid leaf area expansion, dry matter accumulation and storage root formation occurred in the May planting, probably due to high temperature in the early growth. However, leaf cuttings in the January planting lived longer than the May planting — up to 20 weeks after planting — while only I 423 endured up to 20 weeks in the May planting. Clonal differences in total dry matter production appeared in the later stages of growth; I 423 and CN 1517-139 had more dry matter and storage root yield in May than in January plantings at 12 weeks (Table 5), which was also reflected in I 423 at 16 weeks in May planting.

Both I 423 and CN 1517-139 had about the same number of storage roots at 12 weeks of both January and May plantings; however, decreasing storage root number and size was seen in I 424 and CN 1108-13 under high temperature conditions (Table 5). On the contrary, I 423 and CN 1517-139 showed an increasing storage root size under high temperature conditions. The time-wise integral of storage root number and storage root size showed that CN 1028-15 was the highest yielder in January planting, and I 423 was the highest and CN 1517-139 the second highest in May planting. Therefore, both I 423 and CN 1517-139 seem to have some level of heat tolerance in terms of storage root formation.

Table 5. Storage root formation of rooted leaf cuttings of sweet potato grown under two different temperature conditions.[z]

Clone	Yield (g/cutting)		Storage root no./cutting		Storage root size (g/root)	
	Jan.	May	Jan.	May	Jan.	May
I 423	5.11 c[y]	12.69 a***[x]	1.78 a	1.97 a	2.91 c	6.50 a*
I 424	8.48 b	2.19 c**	1.53 ab	0.78 b	5.71 ab	2.62 b
CN 1028-15	12.17 a	8.55 b*	1.69 ab	1.60 a	7.21 a	5.64 a
CN 1108-13	7.09 b	1.22 c*	1.22 b	0.75 b	5.89 a	1.54 b**
CN 1517-139	5.03 c	8.86 b	1.41 ab	1.50 a	3.82 bc	6.16 a

[z]Measured at 12 weeks after planting. [y]Mean separation within column by Duncan's multiple range test at 5% level. [x]Significant between two plantings at 5% (*) or 1% (**) levels, respectively.

High storage root yield in CN 1028-15 in the January planting was attributed to high partition of dry matter to the developing storage root, i.e. strong sink strength, since it had the highest harvest index. This preferable partition of dry matter to storage root in CN 1028-15 was disrupted by high temperature; a similar reduction also occurred in I 424 and CN 1108-13 but was less extensive in CN 1517-139. On the contrary, harvest index in I 423 was slightly increased in the May planting.

Total dry matter production of I 423 and CN 1517-139 at 12 weeks was higher in the May planting than in the January planting, whereas reduction of dry matter occurred in I 424 and CN 1108-13 at 12 weeks under high temperature conditions. Dry matter increment continued in I 423 from 12 to 16 weeks under high temperature conditions, but declined in CN 1517-139 under the same conditions. High dry matter production and less reduction of harvest index could be attributed to high storage root yield under high temperature conditions.

Total soluble sugar content in storage roots increased under high temperature conditions (Table 6). A similar trend also occurred in the leaves of CN 1028-15 and CN 1517-139. In spite of the increase in the total soluble sugar in storage root under high temperature conditions, starch content decreased under the same conditions, but the extent of reduction was small in I 423, CN 1028-15 and CN 1517-139. A reducing trend in starch content in storage roots was observed during the last month of growth in January planting, which probably can be attributed to the increasing soil temperature.

From these results it can be speculated that relatively high mean temperature, 25° to 30°C, is required for early growth of leaf cutting to enable the early establishment of the plant for maximum photosynthesis and early initiation of storage root growth. However, temperatures which exceed 30°C may be detrimental to photosynthesis and translocation for some clones. In the later growth period, soil temperature above 30°C could decrease starch content in the storage root.

Table 6. Total soluble sugar and starch contents (% of dry weight) in storage roots of sweet potato rooted leaf cuttings grown under two different temperature conditions.[z]

Clone	Total sugar		Starch	
	January	May	January	May
I 423	15.71 a[y]	16.43 a	44.62 c	32.20 bc
I 424	12.10 b	16.33 a	61.23 a	19.11 d**
CN 1028-15	13.15 b	16.02 a*[x]	59.63 ab	40.01 ab**
CN 1108-13	12.59 b	17.29 a*	55.87 b	26.03 cd*
CN 1517-139	7.85 c	10.19 b	59.00 ab	42.28 a**

[z]Measured at 12 weeks after planting. [y]Mean separation within column by Duncan's multiple range test at 5% level. [x]Significant between two plantings at 5% (*) or 1% (**) levels, respectively.

Tomato Breeding

Crosses and Populations

Progenies from crosses to develop nematode-resistant tropical lines have been undergoing selection for important characters required for tropical adaptation. New tropical lines now coming out of the program carry nematode resistance. Screening and selections have been made from segregating populations with resistances to bacterial leaf spot and potato virus Y (PVY).

In 1987, 14 special crosses were made to incorporate fruit firmness into the tropical genetic background. In the processing type, 12 crosses were made to develop new inbred lines which combine heat tolerance, disease resistance, fruit firmness, good vine cover and compact growth habit.

An additional 30 crosses were also made to breed cherry-type tomato lines which are adapted to hot, humid conditions. A total of 24 crosses were also made to incorporate resistance to tomato yellow leaf curl virus into AVRDC's tropical fresh market and processing lines.

Evaluation of New Germplasm for Heat Tolerance

Summary

Fifteen new introductions were evaluated for fruit-setting ability during the 1987 hot, humid summer. None compared favorably with the heat-tolerant (HT) line, CL 5915-153-3-3-0. However, the new materials produced firmer fruits than AVRDC's HT checks and carried usable levels of heat tolerance, especially when compared to heat-sensitive (HS) check, TK 70, and HT check, CL 5915-93-1-0-C-1. Some of the best Campbell HT lines had already been used as sources of firmness and heat tolerance in the AVRDC tropical tomato program. These new materials will be valuable additions to the heat-tolerant parental stocks.

Introduction

New germplasm are routinely evaluated each year in the AVRDC tomato program for important characters needed to adapt tomato in the tropics. As part of this activity, plant breeders evaluate them for heat tolerance and other desirable horticultural traits.

Materials and Methods

As in 1986, all entries tested in 1987 were from the Campbell Research Institute's heat tolerance program. The nature of this collaborative project between AVRDC and Campbell Soup Company was given in the 1986 Progress Report.

Fifteen Campbell HT lines were sown on 22 May 1987 along with heat-tolerant (HT) checks, CL 5915-153-3-3-0 and CL 5915-93-1-0-C-1, and the heat-sensitive (HS) check, TK 70. Young seedlings were transplanted to large pots (ca. 8″ internal top diameter) on 17 June and grown under shade condition using AVRDC's regular greenhouse management practices. The experimental design used was randomized complete block with two replications. Each plot comprised of six potted individuals.

At flowering time, the second to the sixth clusters of each plant were tagged to determine the percentage of fruit set. The other traits recorded were: marketable fruit load, culled fruits, total fruit yield, fruit size and cracking incidence. In addition, component traits of the reproductive process that are highly influenced by high temperature, such as stigma exertion and antheridial cone splitting, were also observed.

Results and Discussion

The best new materials are listed in Table 1. Compared to the HT check, CL 5915-153-3-3-0, the new introductions were inferior in performance under summer conditions at AVRDC. However, they possessed better fruit firmness and were already comparable to another tropical line, CL 5915-93-1-0-C-1, in many of the important characters. When compared to the HS check, TK 70, the level of heat tolerance in the new introductions was high.

Table 1. Horticultural characters of the best new introductions vs the checks under shade house conditions, AVRDC, summer 1987.

Entry	Fruit set (%)	Total fruit load (no./plt.)	Marketable fruit load (no./plt.)	Total fruit yield (g/plant)	Marketable fruit yield (g/plant)	Fruit size (g)	Firmness[z]
HT 214-WG1B	43.9 b	34 b-d	14 b	567 c	323 c	24 ab	MF
HT 214-GF4B	37.9 b-d	34 b-d	7 c	455 cd	180 d	28 ab	F
CL 5915-93 (HT ck)	37.3 b-d	35 b-d	17 b	790 b	554 b	34 a	S
CL 5915-153 (HT ck)	53.3 a	60 a	29 a	965 a	705 a	27 ab	S
TK 70 (HS ck)	0.0 e	0 f	0 d	0 g	0 e	–	–
Mean of all entries	34.7	27	6	362	163	24	
CV (%)	11.5	20	30	15	27	24	

[z]S = soft, MF = moderately firm, F = firm

Bacterial Wilt Resistance of Tropical Lines and Other Germplasm Stocks

Summary

Eight sets of genetic materials were screened for bacterial wilt (BW) resistance using the field screening method developed in 1986. Regression analyses of two trials indicated that the distribution of inoculum in the BW nurseries was homogeneous. The coefficients of variation (CV) which were generally below 25%, provided further proof of the adequacy of the tests.

Bacterial wilt-resistant genetic materials, comparable in level to L 285 and CLN 65-349, possibly the two most resistant stocks in the AVRDC program, were found in all eight trial sets. The most advanced materials already have multiple resistance to BW, tomato mosaic virus (ToMV) and nematode; moreover, they have been selected for other important traits, such as good fruit set under hot conditions, crack resistance, improved fruit size and relative fruit firmness.

In tests of large-fruited F_1 hybrids, the proportion of the hybrids with good BW resistance was generally higher when both parents possessed BW resistance, even in varying degrees, than when one of the parents was susceptible. However, resistant F_1's could still be found in the latter crosses, although the frequency of those that compare favorably with the resistant checks, L 285 and CLN 65-349, was lower than in crosses among resistant parents.

Introduction

Bacterial wilt (BW) resistance is one of the most important components of tropical adaptation in tomato. All new lines from the AVRDC program undergo a rigorous test for resistance to the bacterial wilt pathogen. Similarly, introduced stocks which are purported to be resistant to bacterial wilt are also carefully evaluated for potential use as parental stocks.

In 1986, the AVRDC plant pathologists and breeders developed a novel scheme of field testing for bacterial wilt resistance. The new method (1986 Progress Report) was reliable as evidenced by reasonably low CVs in most of the trials, homogeneous inoculum distribution in most experiments, and good infection levels on the susceptible check, L 390.

This technique was widely adopted in 1987 to test the bacterial wilt resistance of newly developed breeding lines, hybrids and other genetic stocks.

Materials and Methods

Including the last BW test in fall 1986, eight sets of materials were screened for resistance in 1987. Further information about these materials are given in Table 2.

To create a uniform inoculum distribution in all tests, L 390, a highly susceptible cultivar, was seeded thickly in the BW nursery, four rows to a bed, with rows 20 cm apart. Seeding of the susceptible cultivar was normally 6 to 8 weeks before transplanting. At seven-leaf stage, the leaves of L 390 were cut with sickles to provide the avenue for wilt infection. BW inoculum was immediately sprayed using a power sprayer. The field was plowed and prepared for planting of test materials when nearly 100% of the susceptible plants had died. To further insure good inoculum potential in each bed, the new beds were prepared exactly at the same location as the original beds.

Each test line was transplanted to two 4-m long rows with 40 cm space between plants. For relative comparisons, susceptible (L 390) and resistant (L 285) plants were planted alternately at the center of each bed. All tests were replicated twice in a randomized complete block design.

Survival rate (%) was transformed to arcsin multiplied by the square root of the percentage prior to statistical analyses. In addition, the relative resistance of each test line against the highly resistant check (L 285), designated as RRL, and against the best breeding line (CLN 65-349-349-2-0), designated as RRB, was calculated to determine their levels of resistance. Further analyses were done to compare the RRL of each entry with its within-plot RRL (derived by comparing its survival rate with that of L 285 in the same bed). This analysis was done in two independent trials to test the homogeneity of inoculum distribution in the nursery.

Table 2. Sets of materials screened for BW resistance in 1987.

Code number	Total entries	Sowing date	Transplanting date	Remarks
TB86-12	95	8/25/86	9/30/86	Further selections from CL 5915 series
TB87-12-1	65	4/14/87	5/13/87	New 'BWR' introductions
TB87-12-2	72	4/14/87	5/12/87	Large-fruited F_1 hybrids and parents
TB87-12-4	28	4/14/87	5/13/87	Selections from advanced lines
TB87-12-5	43	5/5/87	6/ 5/87	Selections from advanced lines
TB87-12-6	44	7/28/87	9/ 2/87	Nematode-resistant BC_1F_5 tropical line
TB87-12-7	78	7/28/87	8/27/87	Nematode-resistant BC_1F_5 tropical line
TB87-12-8	100	7/28/87	9/ 2/87	Nematode-resistant BC_1F_5 tropical line

Results and Discussion

The BW infection levels of the susceptible check, L 390, were good. Survival rates of L 390 in the eight tests ranged from 0 to 38%. Although the upper limit was high, this value was obtained in only one test, in fall 1986 when the temperatures were mild. The coefficients of variation (CVs) in the tests were good, mostly below 25%, except Sets 87-12-5 and 87-12-8, both with CVs greater than 30%.

Figures 1 and 2 show the close relationship between the two types of RRLs (vs L 285 in the same plot and in another plot) in two experiments. Homogeneity of inoculum distribution was, therefore, unquestionable in these trials.

Table 3 summarizes the results of screening the Set TB86-12 in fall 1986. The results confirmed the excellent resistance levels in the CL 5915-93 and CL 5915-223 series, as had been noted by AVRDC's international cooperators. All the series listed in Table 3 have been in the international distribution list since 1984.

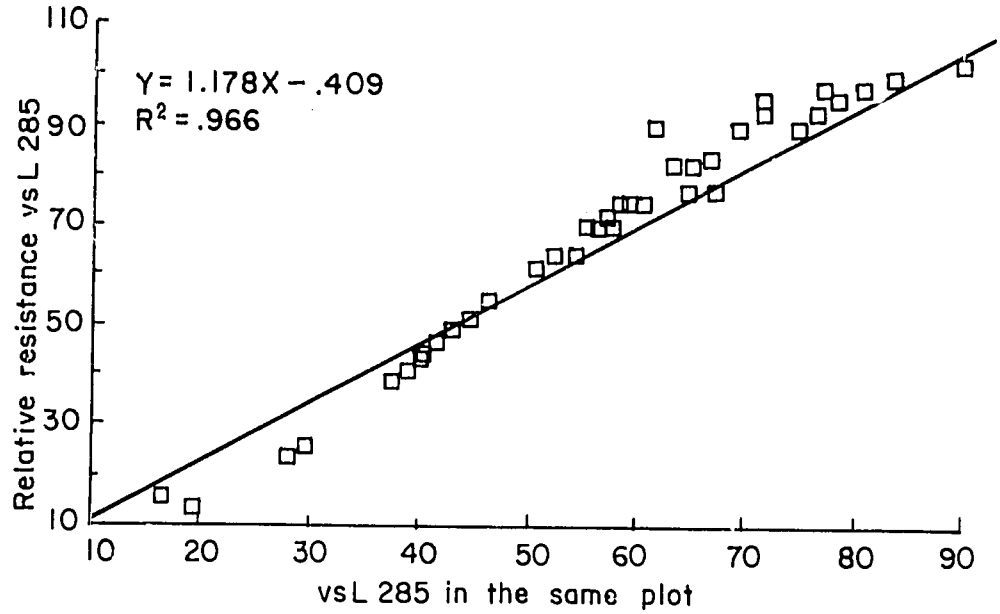


Fig. 1. Regression of relative resistance based on independent plot of L 285 to relative resistance based on L 285 within plots in Set TB86-12, AVRDC, fall 1986.

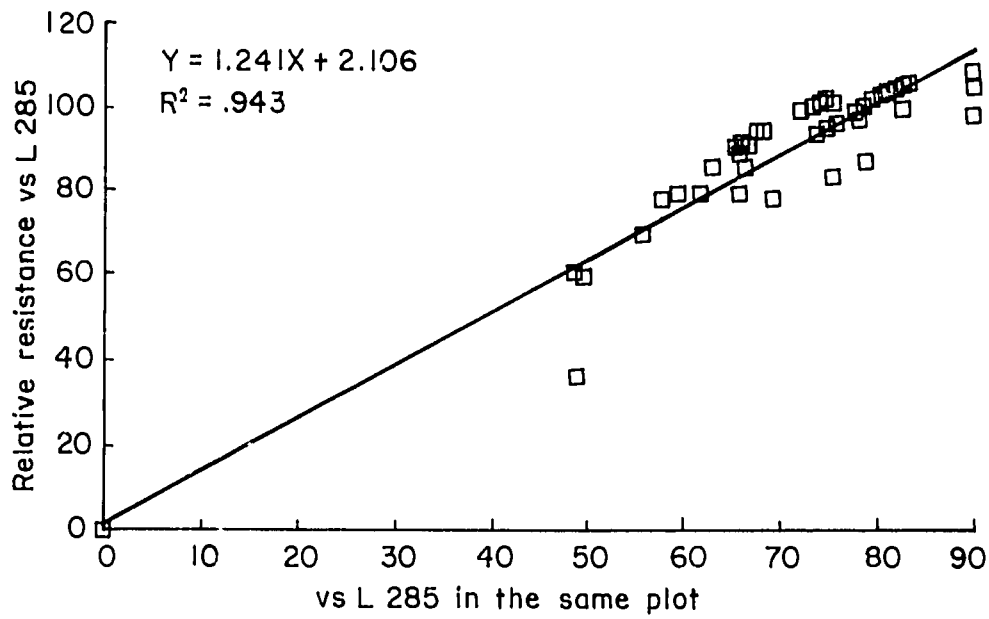


Fig. 2. Regression of relative resistance based on independent plot of L 285 to relative resistance based on L 285 within plots in Set TB87-12-1, AVRDC, fall 1986.

Screening of new introductions which were reported by their donors to carry BW resistance showed a number of promising stocks (Table 4). Some of these new germplasm were observed to produce large fruits during the trial, e.g. CRA series and Caraibe. They should be useful as parental stocks in the AVRDC breeding program, especially to improve the fruit size of tropical tomatoes.

The most promising BW-resistant and large-fruited F_1 hybrids from crosses of parent stocks with varying degrees of resistance are given in Table 5. Except for FMTT 28, these F_1's came mainly from crosses in which both parents carried varying levels of resistance. A summary chart comparing the BW reaction relative to the better BW parent from two types of crosses is shown in Figure 3. When both parents carried BW resistance, about 75% of the F_1's were at least equal in performance to the better resistant parent. In contrast, about 70% of the crosses had lower BW resistance than the better resistant parent when one of the parents was susceptible. It is clear, therefore, that good levels of resistance in both parents are essential to attain a good level of resistance in the F_1 hybrid. Exceptional cases do exist, however, as may be noted in Figure 3

Table 3. Frequency of selections from advanced breeding families highly resistant to bacterial wilt, AVRDC, fall 1986.

Series or families	Number of HR Lines[z]
CL 5915-93	13
CL 5915-222	1
CL 5915-223	5
CL 5915-206	4
CLN 65-349	2

[z]HR = highly resistant (100% survival rate).

Table 4. New bacterial wilt-resistant introductions vs check cultivars, AVRDC, 1987.

Entry	Source	Varietal name	Survival	RRL[z]	RRB[y]
BL 355	Malaysia	MT 10	100 a	109	100
BL 410	Philippines	TM 2	100 a	109	100
BL 312	Guadeloupe	CRA 94-6-3	100 a	109	100
BL 350	Malaysia	MT 5	100 a	109	100
BL 323-20	Guadeloupe	CRA 84-26-3-20	100 a	109	100
BL 333	Guadeloupe	CRA 84-58-1	100 a	109	100
BL 342	Guadeloupe	CRA 84-79	97 ab	107	97
BL 341	Guadeloupe	Caraibe	97 ab	107	97
BL 162	Japan	LS 89	97 ab	107	97
BL 352	Malaysia	MT 7	97 ab	107	97
BL 347	Malaysia	MT 2	97 ab	107	97
BL 176	Panama	19L × 1-12LV #12 F7	97 ab	107	97
CLN 65-349-2-0[x]	AVRDC	–	100 a	109	100
L 285[x]		Chang No. 1	91 a-c	100	91
L 390[w]		Nantzu Apple type	0 g	0	0

[z]RRL = relative resistance against resistant accession, L 285. [y]RRB = relative resistance against resistant breeding line, CLN 65-349-2-0. [x]Resistant check. [w]Susceptible check.

Table 5. Promising bacterial wilt-resistant and large-fruited F_1's vs checks, AVRDC, 1987.

Combination	Type of cross[z]	Survival rate (%)	RRL[y]	RRB[x]
FMTT 51	MR/HR	97	97	107
FMTT 43	MR/HR	97	97	107
FMTT 54	HR/HR	97	97	107
FMTT 28	HR/HS	94	94	104
FMTT 18	HR/HR	94	94	104
FMTT 48	HR/HR	94	94	104
FMTT 37	HR/R	94	94	104
FMTT 38	HR/R	93	93	104
FMTT 19	HR/HR	91	91	100
L 285[w]	HR	100	–	110
CLN 65-349-2-0[w]	HR	91	91	–

[z]MR = moderately resistant; HR = highly resistant; HS = highly susceptible; R = resistant. [y]RRL = relative resistance against resistant accession, L 285. [x]RRB = relative resistance against resistant breeding line, CLN 65-349-2-0.

The best entries from Sets 87-12-4 and 87-12-5 are given in Table 6. Most of these tropical selections compared favorably in the BW resistance levels with L 285 and CLN 65-349, possibly the two most resistant genetic materials in the AVRDC program.

The most promising nematode-resistant tropical lines are given in Table 7. These new lines carry multiple resistances to bacterial wilt, nematode and tomato mosaic virus. In addition, they have been selected for fair to excellent fruit set during the hot season, improved fruit size, crack resistance and relative firmness. The selected lines from these tests will be evaluated in replicated yield trials in summer 1988.

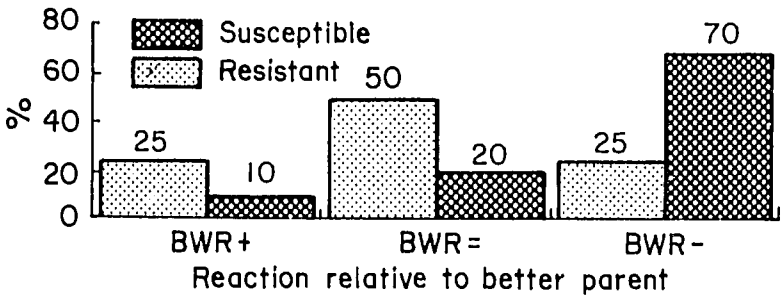


Fig. 3. Comparative resistance of F_1's derived from crosses among resistant stocks vs crosses among susceptibles with resistant parents (Note: BWR + = resistance is higher than the better resistant parent; BWR = resistance is equal to the better parent; BWR – = resistance lower than the better parent).

Table 6. Bacterial wilt reaction of the best advanced breeding lines vs checks, AVRDC, 1987.

Entry	Survival rate (%)	RRL[z]	RRB[y]
Set 87-12-4			
L 285[x]	94 a-d	100	98
CLN 65-349-2-0[x]	96 ab	102	100
CL 6046BC$_3$F$_2$(2)-51-1-0-20-5	100 a	106	104
CL 5915-206-2-2-32-14	97 ab	103	101
CL 5915-206-2-1-0-11	96 ab	102	100
CL 6046BC$_3$F$_2$(2)-51-1-0-8-17	96 ab	102	100
L 390 (sus ck)	0 g	0	0
Set 87-12-5			
L 285[x]	100 a	100	103
CLN 65-349-2-0[x]	97 ab	97	100
CL 6046BC$_3$F$_2$(2)-51-1-0-20-5-18	88 a-c	88	91
CL 6046BC$_3$F$_2$(2)-51-1-0-20-5-9	73 a-d	73	75
CL 6046BC$_3$F$_2$(2)-51-1-0-8-17-7	64 a-e	64	66
CL 6046BC$_3$F$_2$(2)-51-1-0-8-17-5	64 a-f	64	66
L 390[w]	0 j	0	0

[z]RRL = relative resistance against resistant accession, L 285. [y]RRB = relative resistance against resistant breeding line, CLN 65-349-2-0.

Analysis of Segregation for Heat Tolerance: Evidence from a Different Cross

Summary

Genetic analysis of the cross CL 5915-153-3-3-0/BL 267 did not readily show the characteristic bimodality of distribution that was evident in the 1986 genetic materials. Given the unexpected

Table 7. Bacterial wilt reaction and other horticultural characters of the best new tropical lines carrying nematode resistance vs checks, AVRDC, summer 1987.

Entry	Survival rate (%)	RRL	RRB	Fruit set[z]	Fruit size[y]	Cracking	Firmness[x]
Batch VI							
CLN 475BC$_1$F$_2$-265-7-0	100	100	100	G	M	None	F
CLN 657BC$_1$F$_2$-188-0-5	100	100	100	G	ML	None	MF
CLN 698BC$_1$F$_2$-24[illegible]-0-7	100	100	100	G	SM	None	MF
CLN 698BC$_1$F$_2$-371-[illegible]	100	100	100	F	M	None	F
CLN 657BC$_1$F$_2$-274-0-[illegible]	100	100	100	G	M	None	MF
CLN 657BC$_1$F$_2$-285-[illegible]29	100	100	100	G	M	None	MF
CLN 657BC$_1$F$_2$-285-0-17	100	100	100	E	M	None	MF
CLN 65-349-2-0 (res ck)	100	100	100	G	M	None	FL
285[v]	100	100	100	VP	VS	–	–
Batch VII							
CLN 656BC$_1$F$_2$-36P-7	100	103	100	G	L	None	F
CLN 656BC$_1$F$_2$-36P-11	100	103	100	F	ML	Slight radial	F
CLN 656BC$_1$F$_2$-36G-29	100	103	100	F	M	Slight radial	MF
CLN 684BC$_1$F$_2$-58-5	100	103	100	F	ML	Slight radial	MF
CLN 656BC$_1$F$_2$-36G-30	100	103	100	F	L	None	F
CLN 65-349-2-0 (res ck)	100	103	100	F	M	None	F
L 285[w]	97	100	97	VP	VS	–	–
Batch VIII							
CLN 729BC$_1$F$_2$-264-0	100	116	100	E	M	None	MF
CLN 657BC$_1$F$_2$-283-0	100	116	100	E	SM	None	MF
CLN 698BC$_1$F$_2$-244-0-12	100	116	100	G	SM	None	MS
CLN 657BC$_1$F$_2$-214-0-4	100	116	100	E	SM	None	MS
CLN 657BC$_1$F$_2$-214-0-9	100	116	100	E	M	None	F
CLN 65-349-2-0 (res ck)	100	116	100	G	M	None	F
L 285[w]	86	100	86	VP	VS	–	–

[z]VP = poor; F = fair; G = good; E = excellent. [y]VS = very small; SM = small to medium; M = medium; ML = medium to large; L = large. [x]MS = moderately soft; MF = moderately firm; F = firm. [w]Resistant check.

heterozygosity of the heat-sensitive parent, BL 267, this was not surprising. There were still compelling indications that the number of heat tolerance genes differentiating the parents in the present cross may also be as few as had been concluded in the 1986 study.

A single backcross to the recurrent tropical parent did not show any decisive advantage over selfing to produce F_2's in terms of increased frequency of selectable individuals. The advantage, if any, is not enough to offset the tedium of manual pollinations to produce the backcross progenies.

Introduction

In 1986, preliminary evidence that heat tolerance could be controlled by a limited number of genetic factors with major effects on the trait along with an undefinable number of minor genes was obtained. However, the proof was obtained only from one cross. In 1987, therefore, additional evidence was obtained, by reexamining the behavior of heat tolerance in another cross using the same filial families as in the 1986 study.

Materials and Methods

This study concentrated on the cross between CL 5915-153-3-3-0, a tropical line with excellent level of heat tolerance, and BL 267, a Campbell line carrying fruit firmness and nematode resistance. The tropical line served as the recurrent parent (P1) in the only backcross made for this combination.

A complete set of P_1, P_2, F_1, F_2, BC_1F_1 and BC_1F_2 families were obtained from the cross. All seeds were sown on 22 May 1987 and transplanted to pots (ca. 5" internal diameter) under the shade on 22 June. Population sizes were: 36, 36, 36, 216, 36 and 216 plants for P_1, P_2, F_1, F_2, BC_1F_1 and BC_1F_2, respectively.

At flowering time, four clusters per plant of the different families were tagged carefully to ensure that only flowers of similar age were sampled for determination of fruit set percentage.

The fruit set data, transformed to arcsin $\sqrt{\%}$, of heat-tolerant P_1 plants served to build a 5% confidence interval about its mean and the derived range was used in arbitrarily scoring heat tolerance of individual plants from different families. Similarly, this range was derived for the heat-sensitive P_2 family to serve as the arbitrary score value for heat sensitivity.

Results and Discussion

The mean fruit set of BL 267, the intended heat-sensitive parent, was not low in this study, indicating that it was not very sensitive to heat (Fig. 4). Some of its higher fruit set values overlapped with

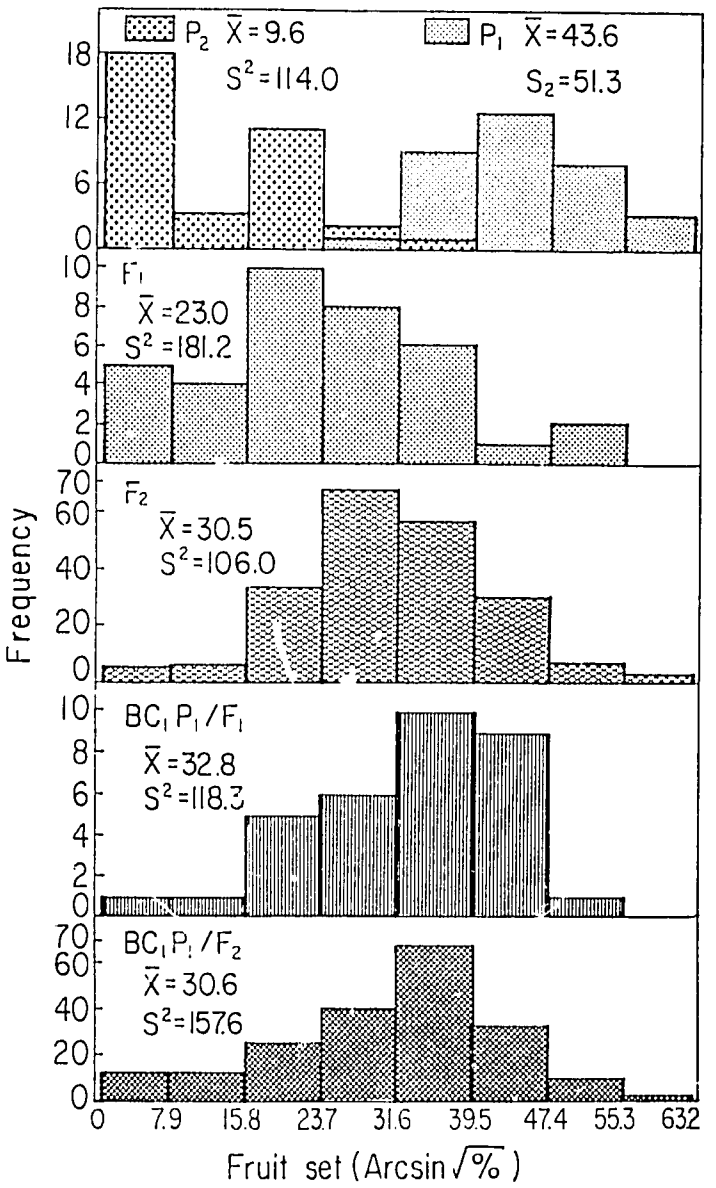


Fig. 4.
Distribution of fruit set under high temperature among parents, F_1, F_2 and backcross families.

the lower values of the heat-tolerant parent. Moreover, the variance for fruit set of this parent was large, even larger than that of the F_2 population.

The measures of dispersion, such as variance and standard deviation, did not behave as expected, i.e. nonsegregating groups, such as the parents (especially P_2) and F_1 showed larger variations than the F_2 and BC_1F_2 populations. In fact, the F_1 population had the highest variance, implying that one or even both parents were not genetically stable for the heat-tolerant genes.

The bimodal distributions of fruit set that were distinct in the F_2 and BC_1F_2 generations in the 1986 study of another cross was not highly evident in the present materials. The P_2 family, probably segregating as supposed above, did exhibit a discrete distribution pattern. To a lesser intensity, the F_1 generation also displayed a similar trend. However, the population size of the F_1 family was small to adequately detect this behavior. While the present evidence is not as pronounced as in the 1986 materials, it is still a tenable argument that heat tolerance behaves as a quasi-quantitative trait, likely controlled by a few major genetic factors and a number of minor genes providing a background effect to the trait.

Based on the confidence interval around the mean fruit set of the HT parent, plants with fruit set values ranging from 41.12 to 46.12 (mean of $P_1 \pm 95\%$ confidence interval) were classified as 'heat tolerant' (**HT**). In contrast, fruit set ranging from 5.90 to 13.22 (mean of $P_2 \pm 95\%$ confidence interval) delimit the 'heat sensitive' (**HS**) category. In addition to these types, three other categories were adopted to score plants that did not fall within the above ranges. These were: intermediate or **Int** (mean fruit set between the range for HT and HS); **HS –** (mean fruit set lower than 5.90); and **HT +** (mean fruit set greater than 46.12). This HT+ category may be considered as 'transgressive' types.

The comparative distribution of the discrete fruit set categories in various generations is shown in Figure 5. If only the categories HT+ and HT are selected from segregating families, one backcross to the heat-tolerant parent does not offer a decisive advantage over straight selfing to produce F_2's as far as the proportion of selectable individuals are concerned (Fig. 6). This proportion was just slightly higher in the BC_1F_2 than in the F_2 family. The proportion of 'transgressive' types was also slightly higher in the former generation (Fig. 5).

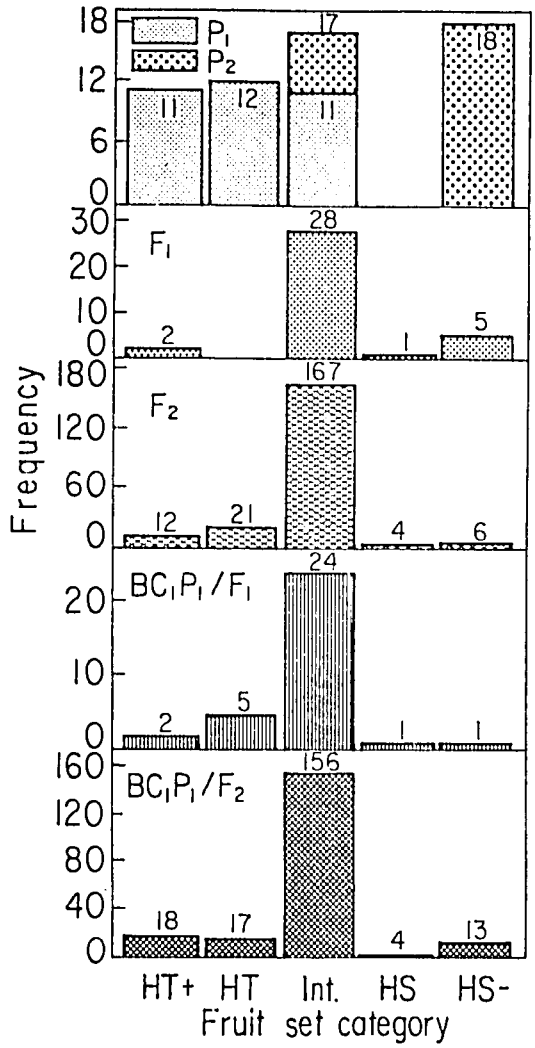
Variation in Quality Between Near-Isogenic Determinate and Indeterminate Tropical Lines: Preliminary Results

Summary

Two near-isogenic lines differing in growth habit were compared for various fruit-quality attributes. The indeterminate isoline proved to be superior in major quality parameters like soluble solids, total solids, color and sugar-acid ratio to its determinate counterpart. Moreover, vitamin C was also significantly higher in the indeterminate isoline. Regulating the fruit load by maintaining a fixed number of developing clusters per plant also improved the vitamins A and C contents, resulted into higher sugar-acid ratio, and produced slightly more acidic fruits. From these preliminary results, selection of indeterminate tropical lines should lead to new genotypes with better quality than could be obtained with determinate tomatoes. The use of indeterminate varieties may also be combined with the traditional pruning system to obtain further improvements in quality.

Introduction

At the inception of AVRDC's tropical tomato program, the AVRDC tomato breeders aimed mainly at developing determinate tropical lines. Economics was the overriding factor for this choice: bush tomatoes are cheaper to grow because they do not need staking. While this goal was relevant at that time to the needs of most national programs in the developing world, there have also been persistent requests from others for tropical lines with better quality and improved fruit size to supply their quality-conscious tourist industries.



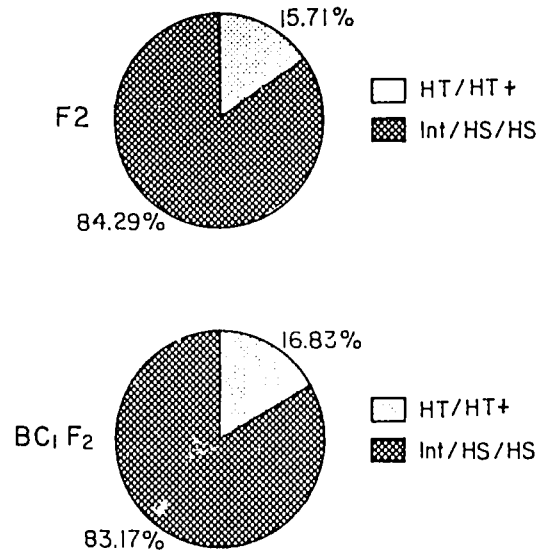


Fig. 6. Relative proportion of selectable (HT and HT+) and nonselectable (Int, HS and HS−) among F_2 and BC_1F_2 families.

Fig. 5. Distribution of fruit set categories among parents, F_1, F_2 and backcross families.

It is well-known that fruit size can be regulated by pruning axillary shoots and regulating the fruit number per truss. AVRDC breeders, therefore started the selection of indeterminate lines in 1981. Indeterminate cultivars are more amenable to pruning than the bushy, determinate tomato. Apart from suitability for pruning, there have been studies in temperate countries (Emery and Munger 1970)[1] showing that certain components of fruit quality, such as soluble solids, attain better levels in the indeterminate than in the determinate tomatoes. To confirm whether breeding for indeterminate tropical lines would result in improved fruit quality under tropical conditions, two near-isogenic lines varying in growth habit were extracted from one BC_3F_2 population and their quality attributes compared.

Materials and Methods

The near-isogenic determinate (sp) and indeterminate (sp+) lines were extracted from a BC_3F_2 population of CL 6046, derived from the cross CL 1131/Moperou, using the former, a tropical line, as the recurrent parent. Theoretically, these lines share only 94% common genetic background and

[1]Emery, G.C. and H.M. Munger. 1970. Effects of inherited differences in growth habit on fruit size and soluble solids in tomato. Amer. Soc. Hort. Sci. 95(4):410-412.

may not be the most ideal genetic material for this study. However, results from using them should provide a good preliminary trend for various quality attributes.

The isolines were sown on 1 October 1986 and transplanted to the field on 29 October. The experimental design used was split plot with isolines as the main plot and pruning as the subplot. The pruning treatment involved maintaining only two branches per plant, each allowed to develop only five fruit clusters, or a total of 10 trusses per plant. This treatment was included to determine if quality can also be improved by regulating the fruit load per plant. Each plot consisted of two double-row 6 m^2 beds with rows spaced 60 cm apart and plants within the row at 40 cm apart. The experiment was replicated three times. The following quality attributes were measured: β-carotene, vitamin C, pH, Brix, titratable acidity, Hunter color, total solids and sugar-acid ratio (SAR).

Results and Discussion

The quality attributes of determinate vs indeterminate isolines are shown in Figure 7.Only traits which showed significant differences are included in the chart. The indeterminate isoline showed superiority in all important quality parameters, such as soluble solids (Brix), color, total solids and sugar-acid ratio. High sugar-acid ratio, in particular, is known to impart good overall tomato flavor. In addition, the indeterminate line also showed significantly higher vitamin C content than the determinate line. From these results, it seems certain that breeding an indeterminate tropical tomato would lead to improved fruit quality under tropical conditions.

The effect of regulating the number of fruits per plant on fruit quality is depicted in Figure 8. Pruning resulted in higher contents of vitamins C and A (β-carotene), more acidic fruits, and higher sugar-acid ratio (for better flavor) than when all fruits were allowed to develop.

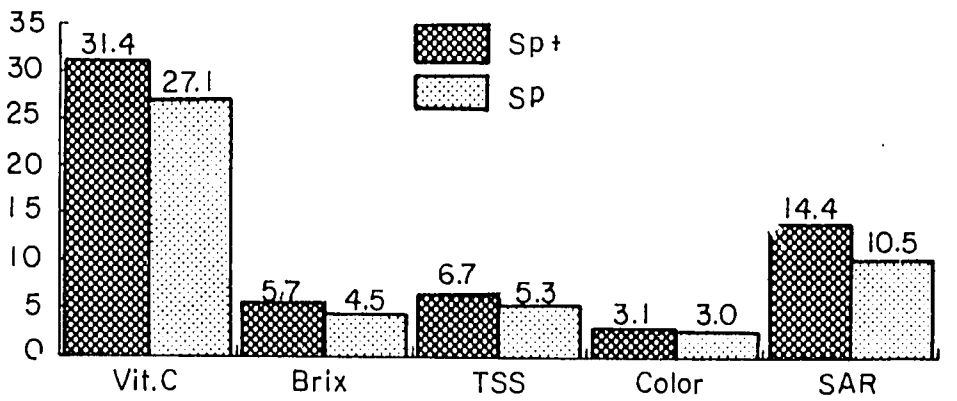


Fig. 7. Comparative fruit quality parameters of indeterminate and determinate tomato isolines.

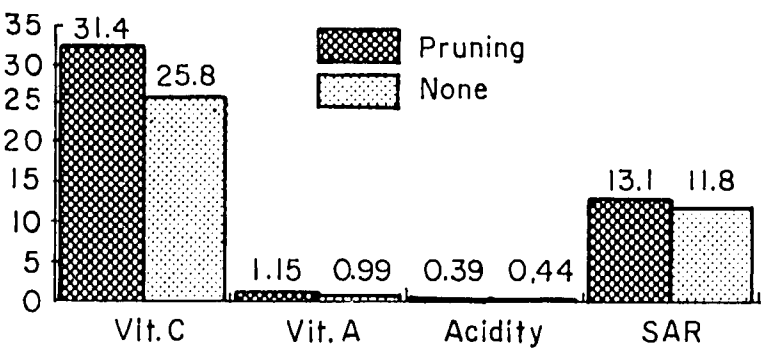


Fig. 8. Comparative fruit quality parameters between pruning and non-pruning treatments.

Yield Trials of Tropical Breeding Lines

Summary

Three batches of tropical lines were evaluated in the 1987 summer season. Of the few nematode resistant tropical lines tested, none proved to be superior in yield and heat tolerance to the heat-toleran checks. The lines that showed advantage in fruit firmness will be further tested in 1988.

Amo ıg the bacterial wilt- and ToMV-resistant lines, one entry [CLN 294B_1F_2(G)-28-17-1 outyield .d the heat-tolerant check, CL 5915-153-3-3-0, and produced firmer, less cracked fruits withou blotchy ripening symptoms. This line will be included in the internaıional distribution list.

Introduction

The tropical tomato program continued the selection of new lines possessing the two most importan attributes for tropical adaptation, namely, heat tolerance and bacterial wilt resistance. In addition, resistance to other diseases, such as tomato mosaic virus and nematode, and better traits like fruit firmness, crack resistance and improved size, are also important breeding goals. All new lines that are stable for disease resistance and other characters are evaluated for yield and other characters during the hot, humid season.

Materials and Methods

Three types of materials were evaluated for general performance in the observational trials during the 1987 summer season.

Two batches consisted of the first few sets of bacterial wilt and nematode-resistant lines which had not been tested thoroughly for heat tolerance. One group comprised of 14 indeterminate lines tested against the heat-tolerant, indeterminate check, CL 5915-206-2-2-0-4; the other was made up of seven determinate lines tested against the heat-tolerant, determinate check, CL 5915-153-3-3-0.

The other batch consisted of 43 bacterial wilt and ToMV-resistant selections which had been selected previously for fruit firmness. All lines were determinate and were, therefore, compared to the heat-tolerant check, CL 5915-153-3-3-0.

Trials of determinate lines generally consisted of single- row, 4.8-m long plots, with rows spaced 1.5 m apart and plants within the row at 40 cm apart. The trial of indeterminate lines consisted of double-row 4.8-m long plots, with rows 75 cm apart and plants within the row at 40 cm apart. All trials were replicated twice. The three trials were sown on 8 May 1987 and transplanted to the field on 9 June.

Results and Discussion

Of the few nematode-resistant lines evaluated in the 1987 summer season, none proved to be superior in fruit set and yield to the heat-tolerant checks. However, some of the new lines did show clear advantages in fruit firmness and will be further tested in the 1988 summer season.

The best performing lines from the third trial batch are listed in Table 8. The best new line, CLN 294 B_1F_2(G)-28-17-1, significantly outyielded the heat-tolerant check, CL 5915-153-3-3-0. Moreover,

Table 8. Yield and other horticultural characters of the best determinate tropical lines vs the check (Batch III), AVRDC, summer 1987.

Entry	Yield (t/ha)		Fruit set	Fruit size	Cracking[z]	Blotchy ripening	Firmness[y]
	Total	Marketable	(%)	(g)			
CLN 294BC_1F_2(G)-28-17-1	26.9 a	26.7 a	15.8 a-e	34.4 d-h	SL,C/R	None	MF
CLN 295BC_1F_2(G)-51-10	19 5 a-c	19.5 a-c	16.7 a-d	23.1 i-l	S,C/R	Moderate	MF
CLN 294BC_1F_2(G)-28-10-1	19.1 a-d	17.3 a-d	13.1 b-h	31.5 d-i	S,R	None	MF
CL 5915-153-3-3-0 (HT ck)	15.7 b-f	15.4 b-g	26.1 a	28.1 e-l	S,C/R	Moderate	MS

[z]SL, C/R = slight, concentric/radial cracks; S, C/R = severe concentric/radial cracks; S, R = severe radial cracks. [y]MF = moderately firm; MS = moderately soft.

this line produced moderately firm fruits without blotchy ripening symptoms and with slight concentric and radial cracking.

Yield Trials of Processing Tomato

Summary

Four preliminary and six advanced trials of new processing hybrids were conducted in the 1986 winter and 1987 spring seasons, respectively. Outstanding hybrids selected from the 1986 PYTs showed the following desirable characteristics: high yield, good soluble solids content, fruit firmness and, in a few cases, better concentrated harvest than the check cultivars. The best selections from these trials were entered in the advanced trials conducted in the 1987 spring season.

The best performing hybrids in the AYTs also showed the same desirable characteristics as in the PYTs, except that the soluble solids content in these trials generally tended to be lower, presumably because of the high soil moisture and temperature conditions during the harvest period. The soluble solids content of the selected hybrids were always comparable, however, with that of the normally good solids check, TK 70. Four hybrids performed consistently well in both winter and spring cropping seasons.

Mulching with black plastic invariably improved the productivity of tomatoes in the advanced trials without undue effects on their processing quality. However, mulching encouraged excessive vegetative growth and greater incidence of foliage diseases.

Introduction

As reported in 1986, the tropical lines are now major parental stocks in the development of processing tomato hybrids. The infusion of tropically adapted genotypes into the processing tomato program has been accelerated especially in the use of lines with improved firmness and disease resistance.

In 1987 the search for processing hybrids with heat tolerance, resistance to diseases such as ToMV, nematode and bacterial wilt, acceptable processing qualities, improved fruit firmness and concentrated set was continued.

Materials and Methods

Four sets of preliminary trials (PYT) were conducted in winter 1986. The hybrids selected from these PYTs were then entered in the six sets of advanced trials (AYT) conducted in spring 1987. In all trials, Tainan No.3 (originally PT 3027), Tainan Selection No. 2, and TK 70 served as the common check cultivars. Additional information on these trials are given in Table 9.

Table 9. Preliminary and advanced yield trials conducted in winter 1986 and spring 1987.

Expt. Code	Total entries	Date sown	Date transplanted	Plot size	No. of replications	Type of trial
Winter 1986						
TB86-15-14	30	9/8/86	10/7/86	12 m^2	2	Preliminary
TB86-15-15	24	9/8/86	10/7/86	12 m^2	2	Preliminary
TB86-15-16	24	9/8/86	10/7/86	12 m^2	2	Preliminary
TB86-15-17	26	9/8/86	10/7/86	12 m^2	2	Preliminary
Spring 1987						
TB87-15-1	14	12/12/86	1/19/87	24 m^2	3	Advanced
TB87-15-2	12	12/12/86	1/19/87	24 m^2	3	Advanced
TB87-15-3	12	12/12/86	1/19/87	24 m^2	3	Advanced
TB87-15-4	14	12/29/86	2/9/87	24 m^2	3	Advanced
TB87-15-5	12	1/9/87	2/17/87	24 m^2	3	Advanced
TB87-15-6	10	1/9/87	2/17/87	24 m^2	3	Advanced

One out of three replicates in each of the advanced trials was mulched with black plastic to determine if this treatment affects yield and quality. If not, this practice could be adopted as a general cost-reduction method in tomato yield trials and other experiments. The other replicates were mulched with standard rice straw. Theoretically, the confounding of the mulching treatment with the replicate in these trials should not affect the treatment differences.

Yield and other horticultural characters were recorded according to AVRDC's standard procedures. To enable the full expression of concentrated fruit set, fruits of each entry were allowed to stay on the vine for as long as possible before the first harvest was taken. The actual yield at first harvest was used as an indicator of the potential for once-over harvest.

Results and Discussion

The most promising hybrids from the four PYT sets are listed in Tables 10 to 13. All selections produced moderately firm to very firm fruits, had solids content of 5% and higher and good yields. PT 4026 and PT 4121 in Group V trial (Table 10) showed the best concentrations of yield among the new hybrids, both giving high actual yields at first picking. The check, TN-3, also showed good concentration of harvests in two trials. The huge advantage in concentrated harvests of the new hybrids is obvious when compared with TK 70. Whereas TK 70 averaged only 20% harvestable fruits at first picking, 60% to 70% of the final marketable yields of hybrids, like PT 4026 and PT 4121, could be harvested once.

It is well known that high fruit yield normally leads to low solids content. This relationship is depicted in two of the four PYTs (Figs. 9 and 10). While the negative trend in the yield and soluble solids relationship was still evident, the points were well-scattered along the regression lines that simultaneously selecting for genotypes with high yield and high solids was not difficult. These desirable hybrids are those enclosed within the "elite entries" quadrant of the scattergrams. The minimum limits of this quadrant are soluble solids content of 5% and total yield of 85 t/ha.

The hybrids that performed well in the advanced trial sets are given in Tables 14 to 16. Generally, the soluble solids in the spring crop was lower than in the winter crop. Since most of the spring crop was harvested at the onset of the rainy periods and high temperatures, the reduction of solids content was hardly surprising. Solids content of the tomato fruits generally decreased when the soil moisture and ambient temperatures were high.

Although the soluble solids contents of the selected hybrids were low, they were always comparable to that of the normally high solid check, TK 70, in the same trials. The selected hybrids generally yielded well compared to the check cultivars. Moreover, they produced moderately firm to firm fruits.

The yield at first picking of TK 70 in the spring crop improved over its winter performance. On the average, 30% or more of TK 70's yield could be secured at first harvest. However, its absolute first harvest yields in the six advanced tests were poor. In contrast, first harvest yields of some hybrids, e.g. PT 4027 (Group I), PT 4060 (Group II-A), PT 4148 (Group II-B), PT 4163 (Group II-C) and others, were over 50 t/ha at first picking. The proportion of final marketable yield that could be picked at first harvest ranged from 70% to 80% for these hybrids.

Four hybrids performed consistently well in both winter and spring cropping seasons. These stable performing hybrids were: PT 4149, PT 4165, PT 4060 and PT 4110.

Without any exception, mulching of the replicates in all advanced trials improved the productivity of tomatoes with no pronounced effect on processing quality. Results from two of the six advanced trials are depicted in Figures 11 and 12. While the benefits from mulching are obvious, some of the possible adverse effects include greater incidence of foliar diseases, especially *Alternaria solani*, and excessive vegetative growth which could hamper normal field operations.

International Cooperation

Germplasm Distribution

AVRDC's seed distribution in 1987 reached 95 cooperators in 59 countries. Total seed packets distributed was 2,136. A total of 124 new introductions from different sources was also received.

Table 10. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the preliminary yield trial (Group V), AVRDC, winter 1986.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (g)	pH	Brix°	Acidity	Hunter color	Firmness	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
PT 4165	109.8 a	53.0 a-e	102.0 a-c	52.4 a-e	86 b	4.19 fg	5.00 a-e	0.37 a-c	2.84 a-d	MF	E	G
PT 4026	102.6 a-c	69.6 a	96.8 a-d	67.4 a	69 e-h	4.28 a-f	5.10 a-e	0.31 b-i	2.68 b-d	MF	G	G
PT 4121	100.6 a-c	60.5 a-c	96.8 a-d	59.8 ab	86 b	4.19 fg	5.55 ab	0.33 a-g	2.86 a-c	F	G	G
PT 4172	89.6 a-c	53.0 a-e	84.8 a-d	52.2 a-e	71 d-g	4.20 d-g	5.08 a-e	0.34 a-g	2.66 c-e	MF	G	G
PT 4149	76.1 a-c	49.8 a-f	73.3 a-d	48.9 a-f	54 kl	4.19 fg	5.75 a	0.37 a-d	2.66 c-e	MF	G	F
PT 4071	75.5 a-c	48.8 b-g	73.3 a-d	48.1 a-f	55 jk	4.26 b-f	5.45 a-d	0.31 d-j	2.66 c-e	VF	F	G
PT 4118	70.1 bc	41.2 c-i	68.8 cd	40.9 b-g	58 h-k	4.21 d-g	5.25 a-d	0.33 a-h	2.70 b-d	MF	G	F
TN-3 (ck)	78.8 a-c	29.1 g-j	75.8 a-d	28.7 f-i	56 jk	4.30 a-d	5.08 a-e	0.31 d-j	2.43 h	MS	F	F
TN-2 (ck)	92.2 a-c	55.7 a-d	90.2 a-d	55.4 a-d	87 b	4.24 b-f	4.85 a-e	0.27 ij	2.74 a-d	F	G	F
TK 70 (ck)	104.5 a-c	23.6 h-j	96.0 a-d	23.3 g-i	88 ab	4.23 b-f	4.60 b-e	0.32 b-i	2.65 c-f	S	E	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

Table 11. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the preliminary yield trial (Group VI), AVRDC, winter 1986.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (g)	pH	Brix°	Acidity	Hunter color	Firmness	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
PT 4110	98.2 a-c	46.4 b-f	95.1 ab	44.8 b-e	89 b-f	4.28 ab	5.20 a-d	0.33 de	2.41 f	MF	E	E
PT 4022	84.8 a-c	48.8 b-d	79.8 ab	47.7 bc	63 gh	4.29 ab	5.17 a-e	0.33 de	2.82 a-e	MF	F	F
PT 4146	80.6 a-c	47.5 b-e	77.8 ab	46.7 b-d	64 gh	4.27 ab	5.15 a-e	0.32 e	2.64 c-e	MF	F	G
PT 4056	79.1 a-c	51.5 a-d	77.0 ab	50.7 a-c	66 f-h	4.24 ab	5.20 a-d	0.32 e	2.69 b-e	MF	G	G
PT 4161	76.6 a-c	42.7 d-g	74.1 ab	42.1 c-g	73 d-h	4.17 b	5.35 a	0.39 a-d	2.83 a-d	MF	F	F
TN-3 (ck)	106.2 a	64.8 a	103.8 a	63.8 a	62 gh	4.24 ab	4.85 a-g	0.34 b-e	2.82 a-e	MS	F	F
TN-2 (ck)	85.2 a-c	41.9 d-g	84.1 ab	41.8 c-g	82 d-g	4.27 ab	5.15 a-e	0.25 f	2.69 b-e	F	G	F
TK 70 (ck)	93.8 a-c	14.1 i	91.3 ab	13.6 i	92 a-d	4.25 ab	4.92 a-g	0.37 b-e	2.79 a-e	S	E	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm. [y]F = fair; G = good; E = excellent.

Table 12. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the preliminary yield trial (Group VII), AVRDC, winter 1986.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (g)	pH	Brix°	Acidity	Hunter color	Firmness	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
PT 4063	96.3 a-g	27.6 d-h	95.2 a-f	27.3 d-h	95 bc	4.17 f	5.17 a-e	0.35 ab	2.64 e-g	VF	G	G
PT 4060	95.7 a-g	48.2 c-d	94.9 a-f	47.9 cd	78 de	4.18 d-f	5.50 a	0.33 ab	2.79 a-f	MF	G	G
PT 4151	91.7 a-g	29.2 d-h	89.6 a-g	28.7 d-h	90 c	4.23 a-f	5.30 a-d	0.33 ab	2.63 fg	MF	F	P
TN-3 (ck)	101.1 a-e	71.0 ab	98.7 a-e	69.7 ab	65 f	4.18 ef	4.75 c-e	0.34 ab	2.87 a-c	MS	F	F
TN-2 (ck)	99.2 a-f	42.1 c-g	97.9 a-e	41.9 c-g	92 bc	4.23 a-f	4.65 de	0.29 b	2.61 fg	F	G	F
TK 70 (ck)	104.3 a-d	23.8 f-h	102.1 a-d	23.6 f-h	92 bc	4.21 c-f	4.80 b-e	0.39 a	2.78 a-f	S	E	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

Table 13. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the preliminary yield trial (Group VIII), AVRDC, winter 1986.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (g)	pH	Brix°	Acidity	Hunter color	Firmness	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
PT 4126	87.3 a-c	28.3 a-c	85.4 a-c	28.2 a-d	75 e-h	4.22 b-e	5.10 a-d	0.33 b-e	2.80 a	F	E	G
PT 4098	87.0 a-c	24.6 a-c	85.2 a-e	24.4 a-d	83 b-f	4.21 b-e	5.98 a	0.33 b-e	2.70 ab	F	F	F
TN-3 (ck)	87.3 a-c	33.2 ab	83.0 a-c	32.6 a-c	64 h	4.26 a-e	5.10 a-d	0.31 de	2.70 ab	MS	F	F
TN-2 (ck)	82.8 a-d	31.3 ab	77.9 a-d	31.3 ab	84 b-f	4.26 a-e	5.65 ab	0.27 e	2.67 ab	F	G	F
TK 70 (ck)	94.8 ab	17.9 c	90.7 ab	17.7 d	91 a-d	4.13 e	5.22 a-c	0.39 ab	2.77 ab	S	E	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

Table 14. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the advanced yield trial (Group I), AVRDC, spring 1987.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (g)	pH	Brix°	Acidity	Hunter color	Firmness	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
PT 4065	85 a	47 bc	78 a	44 a-c	71 c-e	4.09 d	4.55 ab	0.40 a-c	2.56 a	MF	C	G
PT 4149	80 a	46 bc	72 ab	43 bc	70 de	4.24 ab	4.68 a	0.31 d	2.49 bc	MF	G	G
PT 4165	79 ab	43 cd	71 ab	42 c	98 a	4.24 ab	4.45 a-c	0.42 ab	2.39 bc	MF	F	G
PT 4027	73 a-c	55 a	68 a-c	53 a	61 e	4.13 cd	4.68 a	0.39 a-c	2.48 ab	MF	F	F
TN-3 (ck)	67 b-d	29 e	58 cd	27 d	76 cd	4.31 a	3.80 d	0.32 cd	2.45 a-c	MS	F	F
TNS-2 (ck)	65 c-d	24 ef	59 cd	23 d-f	91 a	4.27 ab	4.10 cd	0.31 d	2.58 a	F	F	F
TK 70 (ck)	61 d	19 f	56 d	18 ef	92 a	4.32 a	4.65 a	0.37 b-d	2.55 a	S	E	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

Table 15. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the advanced yield trials for Groups II-A, II-B and II-C, AVRDC, spring 1987.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (%)	pH	Brix°	Acidity	Hunter color	Firmness[z]	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
Group II-A												
PT 4060	86 a	55 b	78 a	53 b	72 b	4.19 bc	4.50 a-c	0.31 d	2.39 f	F	F	F
TN-3 (ck)	70 b	30 c-e	60 bc	28 c-e	72 b	4.24 a-c	4.18 c-f	0.36 b-d	2.56 a-c	MS	F	F
TNS-2 (ck)	81 a	34 cd	74 a	33 cd	94 a	4.19 bc	4.27 b-e	0.31 cd	2.56 a-d	F	F	F
TK 70 (ck)	58 d	22 e	53 cd	21 e	97 a	4.27 ab	4.47 b-d	0.37 b-d	2.64 a	S	G	E
Group II-B												
PT 4156	83 a	48 b	75 a	46 b	75 c	4.22 b	4.32 a-d	0.32 d-f	2.40 ab	F	G	G
PT 4148	80 ab	56 a	74 a	54 a	61 d	4.21 b	4.47 a-c	0.31 ef	2.40 ab	MF	G	F
PT 4106	80 ab	53 a	73 a	51 a	64 d	4.22 ab	4.32 a-d	0.34 c-f	2.42 ab	MF	F	G
TN-3 (ck)	71 a-c	31 cd	63 ab	30 c-f	73 c	4.21 b	3.85 e	0.34 d-f	2.48 a	MS	F	F
TNS-2 (ck)	73 a-c	33 cd	67 a	32 c-d	96 b	4.28 ab	4.20 b-e	0.29 f	2.46 ab	F	F	F
TK 70 (ck)	69 a-c	22 e	62 ab	20 g	97 b	4.32 a	4.58 a	0.34 c-f	2.50 a	S	G	E
Group II-C												
PT 4163	75 a	57 a	67 a	56 a	70 fg	4.19 c-d	4.65 a-c	0.50 a	2.79 ab	MF	F	E
PT 4028	75 a	52 ab	64 a	50 ab	75 d-g	4.24 b-d	4.17 d-e	0.37 de	2.78 ab	MF	F	G
TN-3 (ck)	57 bc	44 b-d	49 b	41 bc	67 g	4.28 ab	3.93 f	0.35 e	2.65 cd	MS	F	F
TNS-2 (ck)	44 cd	26 c	37 bc	25 d	94 a	4.23 b-c	4.73 ab	0.39 c-e	2.64 d	F	F	F
TK 70 (ck)	48 b-d	37 c-e	42 bc	34 cd	80 b-f	4.31 a	4.93 a	0.41 b-e	2.74 a-d	S	G	E

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

Table 16. Yield and other horticultural characters of the best processing hybrids vs check cultivars in the advanced yield trials for Groups III-A and III-B, AVRDC, spring 1987.

Entry	Total yield(t/ha)		Marketable yield(t/ha)		Fruit size (%)	pH	Brix°	Acidity	Hunter color	Firmness[z]	Vine cover[y]	Vine compact[y]
	Final	First harvest	Final	First harvest								
Group III-A												
PT 4057	76 a	52 a	68 a	48 a	61 f	4.18 ab	4.78 ab	0.52 ab	2.85 a	MF	F	F
PT 4110	73 a-c	42 b	63 ab	38 bc	101 cd	4.23 a	4.70 a-c	0.47 b-d	2.72 a-c	MF	F	F
PT 4112	69 a-d	33 c	63 ab	30 cd	120 a	4.15 ab	4.63 a-c	0.51 ab	2.75 a-c	MF	F	F
TN-3 (ck)	72 a-c	30 cd	58 a-c	26 de	63 f	4.21 ab	4.40 c	0.44 cd	2.83 ab	MS	F	F
TNS-2 (ck)	61 b-f	31 cd	50 b-d	27 de	106 bc	4.23 a	5.00 a	0.41 d	2.79 ab	F	F	F
TK 70 (ck)	54 ef	27 cd	46 cd	24 de	96 cd	4.20 ab	4.97 a	0.54 a	2.84 a	S	G	E
Group III-B												
PT 4043	78 a	42 ab	70 a	36 b-d	86 c	4.24 c	4.47 bc	0.41de	2.56 b	MF	F	F
PT 4124	73 ab	34 cd	67 ab	32 c-e	124 a	4.21 c	4.43 bc	0.48bc	2.56 b	F	F	F
TN-3 (ck)	71 ab	33 cd	59 a-c	30 de	69 e	4.29 b	4.30 c	0.41 de	2.60 b	MS	F	F
TNS-2 (ck)	66 bc	34 cd	58 a-c	32 c-e	104 b	4.25 bc	4.67 b	0.39 e	2.63 b	F	F	F
TK 70 (ck)	58 c	26 d	50 c	24 e	98 b	4.20 c	5.17 a	0.52 a	2.90 a	S	G	G

[z]S = soft; MS = moderately soft; MF = moderately firm; F = firm; VF = very firm. [y]F = fair; G = good; E = excellent.

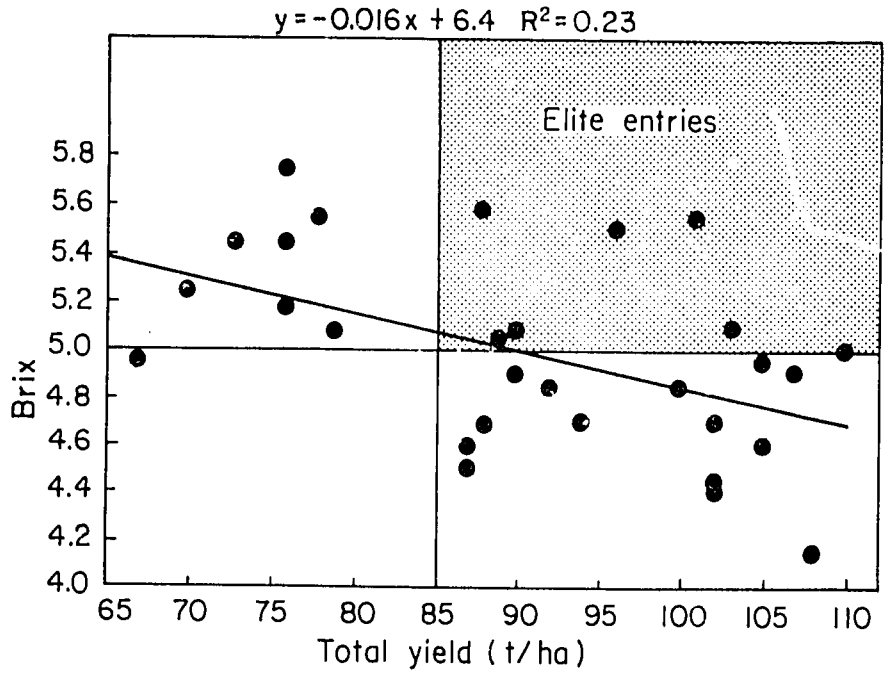


Fig. 9. Relationship between soluble solids and total yield in Group V PYT, AVRDC, winter 1986.

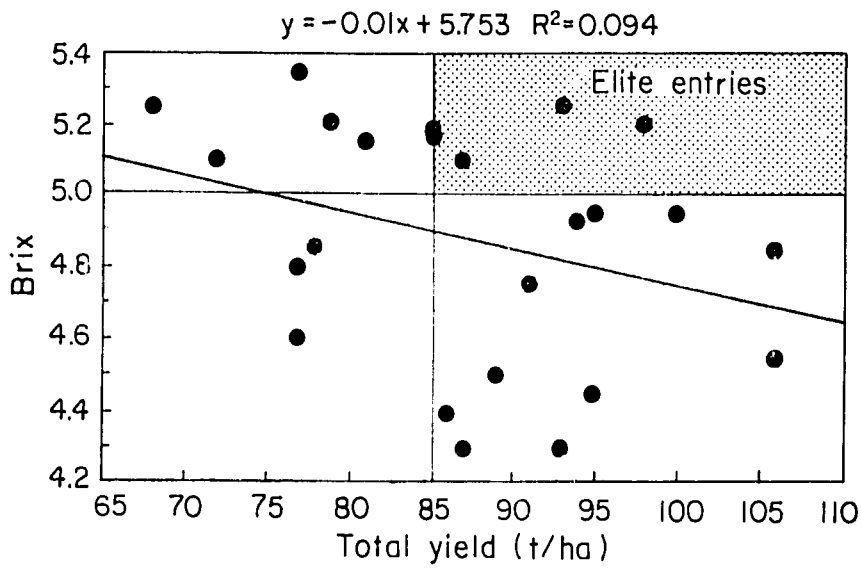


Fig. 10. Relationship between soluble solids and total yield in Group VI PYT, AVRDC, winter 1986.

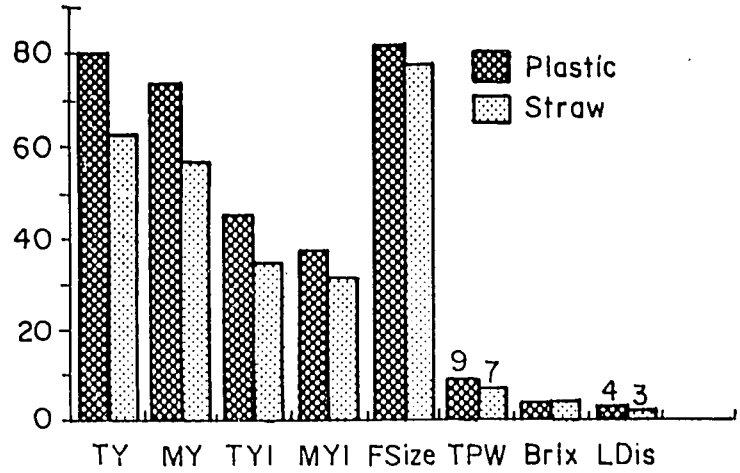


Fig. 11. Comparison of yield and other horticultural characters between replications mulched with black plastic and with rice straw in the advanced trial (Group I), AVRDC, spring 1987.

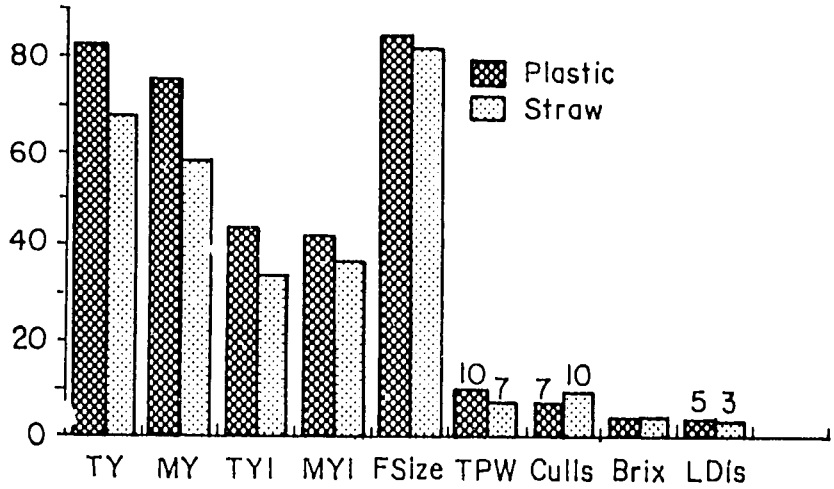


Fig. 12. Comparison of yield and other horticultural characters between replications mulched with black plastic and with rice straw in the advanced trial (Group II-A), AVRDC spring 1987.

Official Cultivar Releases

Three AVRDC tropical lines were released in two tropical countries in 1987, bringing the total releases since 1978 to 54 tropical lines in 22 countries. The 1987 releases are discussed below:

- CL 2784-1-1-4 is the first tomato line released in the Philippines. This is a processing type which consistently gave 16% higher yield than the check, Roma VF, in tests at seven locations during two consecutive dry season plantings. This line, coded BPI-Tm P-1 but also known locally as 'Mapula', the vernacular term for 'red', was also reported to possess better processing traits than Roma VF, i.e. bigger fruits, intense red color and soluble solids content of 6.3%.
- Two tropical lines were officially released to tomato farmers in Trinidad and Tobago by the Ministry of Food Production. These lines are CL 1131-0-0-43-4-12 named CES No. 1 (Centeno Selection No. 1), and CL 143-0-10-3-1-10, named CES No. 2 (Centeno Selection No. 2). The special attributes that were reportedly found in these lines are: heat tolerance (desirable for wet

season production); suitability to high density planting; extreme tolerance to bacterial wilt; resistance to fruit cracking; marketable yields of as high as 90 t/ha in four pickings; firm fruits with good solids content and excellent red color.

Trial Feedbacks

The highlights of reports of tomato trials conducted by AVRDC cooperators in 1987 as well as in previous years are given below:

- Shell Petroleum Development Corp., Nigeria Ltd. tested five tropical lines in Bendel State, Nigeria during the wet and dry seasons. According to the cooperator, lines CL 5915-93-1-0, CL 5915-93-1-0-C-1 and CL 5915-223-2-1-0 have commercial potential in that area and he would like AVRDC to sell the seeds of these lines there.
- A collaborative project between FAO and the Senegal Institute for Agricultural Research tested 19 AVRDC lines against two local checks, Xin (CL 143-0-13-3-UG) and Xina, a nematode-resistant variety developed from Xin, during their hot, humid season. Four out of the 19 lines have been included in the 1988 advanced trials. These were: CL 5915-93-1-0-L-2-0, CL 5915-206-2-2-0-4, CLN 229BC$_1$F$_2$-4-1-4-1-1 and CLN 236BC$_1$F$_2$-26-3-3-15. The last two belong to the first batch of the nematode-resistant tropical lines from the AVRDC tropical program.
- Sementi Nunhems S.R.L. tested eight AVRDC lines during the summer season at St. Agata, Italy. Lines PT 1565-2 and CLN 496 were reported to possess good quality and resistance to common leaf diseases.
- The NTT Integrated Area Development Project in Kupang, Indonesia evaluated six AVRDC tropical lines against two local checks in two locations during 1986: Oefau/Soe, 900 m above sea level, and at Besi Pae/Bed lands, 50 m above sea level. Although yields at Oefau/Soe were extremely low (below 10 t/ha), the AVRDC lines were decidedly better than the local cultivars. The reason given for the poor yields under the cool highland conditions of Oefau/Soe was eagerness of farmers to prematurely harvest the crop before data could be collected. In the hot, humid location of Besi Pae/Bed lands, the best marketable yield of 20 t/ha was obtained from CL 5915-206-2-5-0. In contrast, the local check yielded only 10 t/ha although its fruit size was larger than those of the best AVRDC line. The project continued to test the best AVRDC lines in 1987.
- In another 1986 trial at Semarang, Indonesia, a cooperator at Akademi Farming Semarang found one line, CL 5915-39-1-2-0, which outperformed the locally recommended cultivar, Ratna, a selection from an AVRDC germplasm that was released in Indonesia in 1980. Marketable yield of this line was about 15 t/ha, whereas Ratna yielded 10 t/ha. Its fruit size was also larger than those of Ratna.
- The Elkod Research Center in the People's Democratic Republic of Yemen conducted a heat tolerance trial in 1985 involving five AVRDC tropical lines and two check cultivars. The test was done in the coastal farm with temperatures during the growing period ranging from 29° to 34°C. Under this adverse condition, the fruit set of CL 9-0-0-1-3-0 was rated as heavy compared with the other entries in the trial. The total recorded yield of CL 9 was 9.3 t/ha, whereas the check cultivars yielded only 2 to 3 t/ha. This trial was supposed to have been repeated in 1986 and 1987.
- Six AVRDC processing tomato hybrids were included in the 1987 summer trial at Tokoituku Research Station, Cook Island. Two of these hybrids, TM 103 and PT 862, had no bacterial wilt infection in the 1985 winter season trial. However, in the summer trial, these hybrids had mortality rates of 75% and 73%, respectively, indicating that their levels of BW resistance may not be adequate or that their resistance may have broken down at high temperatures and high nematode infestation rate. The evaluation for the summer season of other AVRDC tropical lines, e.g. CL 5915-206, which have better resistance than any of the AVRDC processing hybrids, will be continued.

Tomato Entomology

Screening and Selection for Tomato Fruitworm Resistance

Summary

In continuation of the tomato fruitworm (*Heliothis armigera*) resistance breeding program, 26 BC_3F_3 families were evaluated for fruitworm resistance and desirable horticultural characters. There was a significant negative correlation between the fruit number per plant and fruitworm damage. Nineteen resistant plants belonging to 10 families were selected for further improvement of horticultural characters.

Introduction

Tomato fruitworm (TFW), *Heliothis armigera* Hüebner (Lepidoptera: Noctuidae), is a polyphagous insect that infests tomatoes and several other economically important crops in Southeast Asia. The adult insect lays eggs on the foliage and the larvae, after initial feeding on the foliage, move to the fruit and bore inside. In 1980 the TFW resistance in two *Lycopersicon esculentum f glabratum* accessions which had shown resistance to other lepidopterous insect pests elsewhere was confirmed. This accession was crossed with high-yielding breeding lines carrying desirable horticultural characteristics. During subsequent seasons, the entomologist and plant breeder worked together to select lines carrying TFW resistance and improved horticultural characters, such as fruit size, which required backcrossing. In the 1986-87 season, BC_3F_3 was screened for resistance to TFW, and plants carrying higher level of TFW resistance and desirable horticultural traits were selected.

Materials and Methods

Based on the entomologist's and plant breeder's observations on TFW damage and desirable horticultural traits, respectively, 26 plants were selected from the screening of BC_3F_2 population in 1985-86 season. In autumn 1986, 26 families derived from these 26 plants along with six susceptible families were screened in the field for resistance to TFW.

Tomato seeds were planted in small plastic pots and one-month old seedlings were individually transplanted in the field in single rows on the top of 1.5-m wide beds with a distance of 1 m between two adjacent plants in each 30 m row. Every fifth row was transplanted to a susceptible line and on both ends of each row, one plant of the resistant parent was planted.

Starting with the flower initiation in the earliest flowering entry, a uniformly large number of laboratory-reared TFW pupae were released throughout the field.

On occasions throughout the season, each of the 30 plants of each family was observed and the fruitworm damage and total number of fruits on each plant recorded. The percentage of fruit damage of all observations was combined. At the same time, the number of fruits on each plant was recorded and each of the fruits weighed to select plants with bigger fruits. Fruit number, fruit size and the percentage of fruits damaged in each family were analyzed by simple linear regression to find correlation between pairs of characters.

Results and Discussion

The percentage of fruits damaged among the progenies of 26 families ranged from 7.32 to 20.40%. The fruit sizes varied between 29 and 97 g/ripe fruit and the number of fruits per plant from 78 to 163. In 16 out of the 26 families, there was significant negative correlation between the number of fruits per plant and the percentage of fruits damaged by TFW. The average r^2 was -0.26. It would, therefore, appear that with greater yield, the lesser the TFW damage among the progenies. However, in only one out of six susceptible families was there a similar significant negative correlation; there was no correlation in the rest of it.

In only two families was there a significant positive correlation (r^2 = 0.30). In the remaining 24 families, there was no significant correlation between fruit size and fruit damage. This implies that among the progenies one can have bigger fruit size and resistance to TFW. No significant correlation was found in fruit size and fruitworm damage in six susceptible families. Among the progenies in four families, there was significant positive correlation between fruit size and number of fruits per plant. In the remaining 20 families, there was no significant correlation between fruit size and fruit number per plant. This was also true among the susceptible families.

Based on low fruit damage, greater number of fruits per plant and bigger fruit size and desirable horticultural characters, 19 plants belonging to 10 families were selected for further testing and improvement in horticultural characteristics.

Association of Trichome Density and Foliage Characters in Tomato

Summary

An F_2 population of a cross between tomato fruitworm- (*Heliothis armigera*) resistant *Lycopersicon hirsutum* f *glabratum* and susceptible *L. esculentum* was surveyed for the presence of high density of glandular trichomes which contain 2-tridecanone, a chemical responsible for imparting the fruitworm resistance in certain *L. hirsutum* accessions. In certain entries, foliage showing *L. esculentum* characters possessed high trichome density but the larval mortality in these entries was not always related to the trichome density. It seems that quantitative measurement of 2-tridecanone in foliage or bioassay with *H. armigera* is necessary to judge the inheritance of the fruitworm resistance compared to the trichome density.

Introduction

In 1980 AVRDC research confirmed the resistance of two *Lycopersicon hirsutum* f *glabratum* accessions to tomato fruitworm (TTW), *Heliothis armigera* Huebner (Lepidoptera: Noctuidae). The resistant accessions have very high trichome density on the foliage, light green leaves and distinctly small and green fruits. A 2-tridecanone chemical in glandular trichomes on the leaves killed the freshly emerged larvae of *H. armigera* which laid eggs on the foliage and which, after initial feeding on foliage, bore into the fruits.

AVRDC plant breeders have crossed these *L. hirsutum* accessions with high-yielding tomato breeding lines with desirable horticultural characters. Selection of progeny on the basis of low fruitworm damage and study of fruit size in these selections indicated that resistance level declined with bigger fruit size.

Since the resistance factor is the presence of the trichomes on the leaves, high trichome density in the foliage is essential. High trichome density seems to be associated with small leaflets and light green chlorophyll. These selections also have smaller fruits. Commercial tomato cultivars have bigger leaflets, dark green foliage and bigger fruits. It was, therefore, felt that dark green and bigger leaflet foliage is essential for bigger fruits. This experiment was, therefore, conducted to see whether dark green and bigger leaflets can also have high trichome density.

Materials and Methods

F_2 seeds from a straight cross between tomato fruitworm resistant *L. hirsutum* f *glabratum* and *L. esculentum* were obtained from the tomato breeder. The seedlings were raised in flats in the greenhouse and transplanted in the field as a single row on 1.5-m wide raised beds. A distance of 1.5 m was maintained between two adjacent plants in each row. At both ends of each row, one seedling of *L. hirsutum* was transplanted and on either ends of the field two rows were planted to tomato fruitworm-susceptible and high-yielding tomato breeding lines. Two months after transplanting, the entire planting was observed and the F_2 progeny derived *L. hirsutum* × *L. esculentum* cross was marked into those having cultivated tomato type foliage. Entomologists sampled the foliage of each selection as well as those of *L. hirsutum* and *L. esculentum* checks, and counted the number of glandular trichomes on the upper and lower surfaces.

Freshly excised leaflets were placed in a petri dish lined with moist filter paper, and 10 tomato fruitworm eggs were placed on it. The number of eggs hatched was recorded.

Freshly sampled leaflets were placed in each of the 30 petri dishes and one first instar tomato fruitworm larva was released on each sample. Larvae development was observed through the fourth instar and the mortality in each instar was recorded.

Results and Discussion

The results of the trichome density survey, tomato fruitworm egg hatching and larval mortality are summarized in Table 1. Trichome density ranged from 3 to 248 trichomes/20 mm^2 on the upper and 17 to 257 trichomes/20 mm^2 on the lower leaf surface among the F_2 progenies of a cross between *L. hirsutum* and *L. esculentum*. There was a highly significant positive correlation ($r = 0.78^{**}$) between the trichome density on the upper and lower leaf surfaces (Fig. 1). In certain entries, trichome density was equal to or greater than that in the resistant checks. This shows that *L. esculentum* foliage can have high trichome density. Although the trichomes were morphologically of the glandular type, it was not possible to decide whether all of them produced high level of 2-tridecanone, the chemical secreted by the trichomes that is responsible for the mortality of the lepidopterous larvae.

Except for one of the two *L. hirsutum* checks, there was no significant difference in egg hatching rate despite wide variation in trichome density. In one resistant check, 76W-PI134417-A, egg hatching

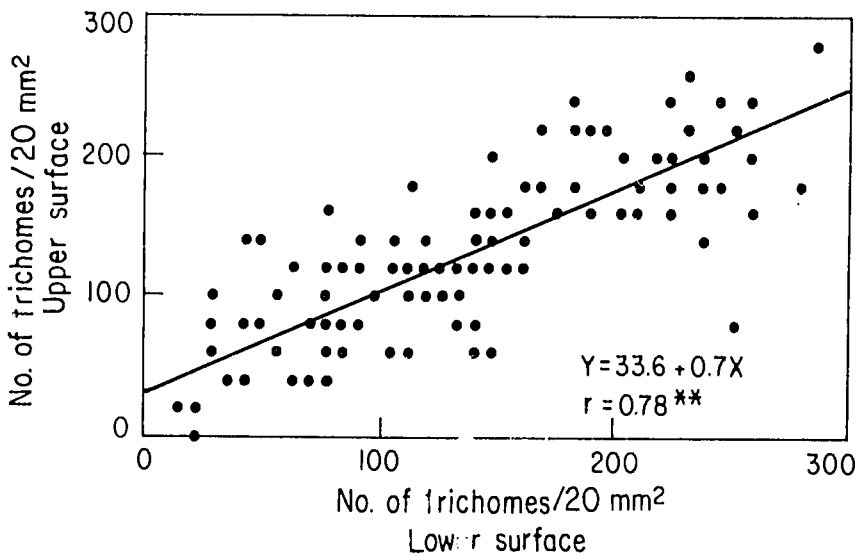


Fig. 1. Correlation between the glandular trichome density on the upper and lower leaf surfaces of the progeny of *L. hirsutum* and *L. esculentum*.

Table 1. Trichome density, egg hatching and larval development of tomato fruitworm on the *L. esculentum* type foliage of a cross between *L. esculentum* and *L. hirsutum*.

Plant no.	No. of trichomes/ 20 mm^2 surface[z]		Egg hatching	Larval survival (%) during various instars			
	Upper	Lower	(%)	1st	2nd	3rd	4th
817	281	284	90 a	13.3 bc	0.0 b	0.0 b	0.0 b
321	232	257	100 a	13.3 bc	6.7 b	6.7 b	0.0 b
864	260	228	90 a	13.3 bc	3.3 b	0.0 b	0.0 b
145	248	223	93 a	16.7 bc	10.0 b	0.0 b	0.0 b
875	200	261	93 a	24.3 bc	3.3 b	3.3 b	0.0 b
285	226	230	97 a	23.7 bc	6.7 b	6.7 b	3.3 b
691	192	236	83 ab	26.7 b	3.3 b	3.3 b	0.0 b
559	237	182	97 a	23.3 bc	0.0 b	0.0 b	0.0 b
576	225	191	97 a	16.7 bc	3.3 b	0.0 b	0.0 b
736	216	197	93 a	17.7 bc	6.7 b	3.3 b	0.0 b
1099	207	204	87 a	26.7 bc	10.0 b	6.7 b	0.0 b
701	205	200	93 a	31.0 abc	13.3 b	10.0 b	0.0 b
660	222	181	97 a	23.3 bc	6.7 b	6.7 b	0.0 b
19	189	208	90 a	6.7 c	0.0 b	0.0 b	0.0 b
131	195	148	97 a	20.3 bc	3.3 b	3.3 b	0.0 b
827	111	120	93 a	21.3 bc	3.3 b	0.0 b	0.0 b
157	118	112	87 a	26.0 bc	18.0 b	14.7 b	0.0 b
307	111	113	87 a	38.7 ab	16.7 b	13.3 b	0.0 b
543	104	114	87 a	36.7 ab	13.3 b	13.3 b	3.3 b
441	33	40	83 ab	11.7 bc	0.0 b	0.0 b	0.0 b
130	23	23	100 a	33.3 abc	26.7 ab	23.3 b	3.3 b
548	29	17	87 a	20.0 bc	0.0 b	0.0 b	0.0 b
1016	3	21	90 a	22.0 bc	0.0 b	0.0 b	0.0 b
76W-PI134417-A[y]	207	226	67 b	8.3 b	8.3 b	0.0 b	0.0 b
77W-PI734417-1[y]	228	251	90 a	20.0 bc	10.0 b	6.7 b	0.0 b
CL 5915x	148	51	83 ab	55.5 a	49.3 a	49.3 a	29.0 a

[z]Average of three points on each side of the leaf surface. [y]Resistant checks. [x]Susceptible check.

was significantly reduced. In the same entry, the survival of the first instar larvae was also significantly reduced (Table 1).

Tomato fruitworm larvae did not survive beyond the fourth instar in the F_2 progenies with foliage similar to that of L. esculentum, except in three entries. Even among the remaining three entries, the survival rate in the fourth instar was a mere 3.3%, whereas in the susceptible check, 29% of the larvae survived into the fourth instar.

It appears that trichome density alone can not determine whether the foliage is toxic to the insect pest. It is, therefore, necessary to rely on bioassay of the insect larvae or chemical analysis of the leaves for determining the concentration of 2-tridecanone.

Utilization of Sex Pheromone to Control Tomato Fruitworm

Summary

Preliminary studies during 1985-86 showed the potential for achieving communication disruption between male and female insects by the use of a commercial, slow-release formulation of tomato fruitworm sex pheromone. Thus, studies were conducted between October 1986 and February 1987 to investigate this in the field. The tomato crop was grown by two methods: staking as is usually done for fresh-market production and nonstaking, common in processing tomato production.

Biolure, a commercial slow-release pheromone dispenser, was placed 1 m above the soil surface with a 5 m grid throughout the treatment field. Observations on fruit damage were monitored at intervals starting with the appearance of substantial number of ripe fruits.

The percent fruit damage in the pheromone-treated processing type tomato field was 19.3%, 11.1% and 19.0%, respectively, on 19 January, 3 and 9 February 1987, as against 5.7%, 5.3% and 5.4%, respectively, in the control field. The fruit damage was uniform throughout the field. In the staked field, fruit damage was 10.1% in the treated field and 7.3% in the control field on 3 February, and 12.8% and 7.8% in the treated and control fields, respectively, on 20 February 1987. There was no significant difference in percentage of fruits damaged in the border area (11.4%) and in the center (14.2%) of the treatment field as well as in the check fields, (8.2% and 7.4%, respectively). Virgin female-baited traps caught significantly less males in the treated than in the check field (4/trap in treated; 16/trap in control). There was no significant difference in marketable yield in the treated and check fields. Greater fruitworm damage in the pheromone-treated area appeared to be due to the migration of mated females from the neighboring corn field, which were present near the pheromone-treated area but not in the vicinity of the control field. Partial failure of communication disruption due possibly to reduced concentration of pheromone cannot be ruled out. In view of the potential for mated female migration, a larger field size seems to be essential for successful control of fruitworm by communication disruption.

Introduction

Tomato fruitworm (TFW), *Heliothis armigera* Huebner (Lepidoptera: Noctuidae), is a polyphagous insect that attacks tomatoes in Taiwan and the rest of Southeast Asia. The larvae of this pest bore into tomato fruits and destroy the quality and marketability of the fruits. At present farmers use large quantities of insecticides to control the pest. The intensive use of insecticides, besides increasing production cost and health hazards, also kills the parasites and predators which otherwise help to reduce the pest population. Insecticide use also results in pests becoming resistant to chemicals being used, which in the long run, renders these and related chemicals useless.

AVRDC has been working on alternative methods of TFW control which also includes utilization of female sex pheromone. This work is done in cooperation with other institutes in Taiwan, including Yang Ming Medical College, Academia Sinica and Fu Ren University, and is funded by Taiwan's National Science Council. AVRDC is responsible for the mass rearing of TFW for extraction and characterization of the pheromone chemicals by the chemists, and testing of synthetic chemicals in the field to judge their utility in practical control of TFW.

Based on the results of laboratory tests and preliminary field studies in the 1985-86 season, field tests conducted in 1986-87 used the pheromones to disrupt their sexual communication, thus, preventing mating and multiplication of the population.

Materials and Methods

Tomato cultivation. Four parcels of land, each measuring 0.2 ha, were rototilled and after the application of basal fertilizers worked into 1.5-m wide beds. Tomato seedlings were transplanted as a single row on each bed. Tomatoes in two land parcels were further cultivated by training each plant on a 1.5-m high bamboo pole erected next to it. This is a common method of tomato cultivation when the crop is grown for fresh-market utilization. In two other land parcels, the plants were left on the ground undisturbed. This method of cultivation is commonly used when the fruits are to be utilized for processing. Customary cultural practices such as fertilizer application, weeding, disease control, etc. were identical in all four fields. No insecticide was applied in any field to control the insect pests.

Sex pheromone application. Soon after initiation of flowering in two land parcels, one planted to fresh market tomato and the other to a processing tomato type, a Biolure dispenser (Biolure Inc. Oregon, USA) was placed 1 m above the soil surface at the junction of a 5 m grid throughout the field. Each Biolure dispenser contained two sex pheromone components, Z-11-hexadecenal and Z-9-tetradecenal at a ratio of 9:1. According to the manufacturer's tests, each dispenser had a

slow-release rate of 600 μg pheromone mixture per day for 90 days. This application rate amounted to 23.8 g of pheromone per hectare. To protect from direct sunlight and rain, dispensers were stuck inside covers of plastic petri dishes, and the covers were mounted upside down in the field. The remaining two parcels of land situated 800 m away from the pheromone-treated plots served as checks. A distance of only 10 m was maintained between the two checks, one of which was planted to fresh-market type tomato and the other to a processing type.

Communication disruption evaluation. In each plot, two sticky paper traps each baited with seven 3-day old virgin females of TFW moth, were set 1 m above the soil surface. The female moths were replaced after every four days and the number of male moths trapped in each trap was recorded everyday.

Fruit damage observation. TFW damage to tomatoes was monitored at intervals starting with the appearance of substantial numbers of ripe fruits. At each observation, 150 plants were sampled and the number of damaged fruits, healthy fruits and weight of marketable fruits recorded. From the data percentage of fruits damaged and marketable yield per hectare were computed.

In separate observations, 75 plants from the outer three rows on all four sides and 75 plants from the central 20 m × 20 m area were sampled, and the percentage of TFW damaged fruits in both areas was calculated.

Results and Discussion

Communication disruption. The success of mating communication disruption was judged by the capture of male moths in virgin female-baited traps. Table 2 summarizes the number of TFW male moths captured in virgin female-baited traps placed for one week between the second and third harvests in pheromone-treated and check plots.

Substantially more males were captured in both staked as well as nonstaked control fields compared to the pheromone-treated fields. The less males caught in the treated fields is believed to be due to the high concentration of synthetic pheromone present compared to the control with no pheromone, except that emitted by the ambient population of TFW females. This indicated the potential of synthetic sex pheromone in disrupting mating communication under field condition.

Table 2. Capture of male TFW moths in virgin female-baited traps.

No. male moths/trap			
Staked field		Nonstaked field	
Pheromone-treated	Control	Pheromone-treated	Control
4	16	2	6

Fruit damage and yield. The results of the fruit damage by TFW in pheromone-treated and control fields are depicted in Figure 2. Surprisingly, the percentage of fruits damaged in pheromone treated fields under both management regimes was substantially higher. These results were unexpected considering that substantial communication disruption was observed in pheromone-treated plots. The treated fields were located near a corn field; the corn being an alternate TFW host, while the control fields were bordered by rice and sugarcane, both of which are not preferred by TFW. It is likely that TFW female moths, which already mated in the corn fields, emigrated to the neighboring pheromone-treated tomato field and laid eggs unhindered. TFW moths are strong fliers and are reported to migrate long distances from each field at night. In addition only partial communication disruption was observed as some males were also caught in the treated field (Table 1). For 100% communication disruption, the pheromone concentration may have to be increased which could very well be uneconomical.

There was no significant difference in fruits damaged in the border area and center of the field (Table 3). This indicated that the mated females can fly across the field and do damage in the border as well as in the center.

As expected the marketable and total yield followed a similar trend as the fruit damage. There was either no difference or the control plots had higher yields than the treated plots (Fig. 3).

Based on past findings, in areas where multiple cropping is followed and when the insect is polyphagous, the immigration of mated insects from the nontarget crop to the treated crop will make the use of sex pheromone for TFW control almost impractical, especially if the field is small, which is common in Taiwan and the rest of the tropical areas.

Table 3. TFW damage in the border and center areas of the tomato field.

Area	Fruits damaged (%)			
	Staked field		Nonstaked field	
	Pheromone-treated	Control	Pheromone-treated	Control
Border	11.45	8.22	22.47	5.46
Center	14.16	7.38	15.69	5.25

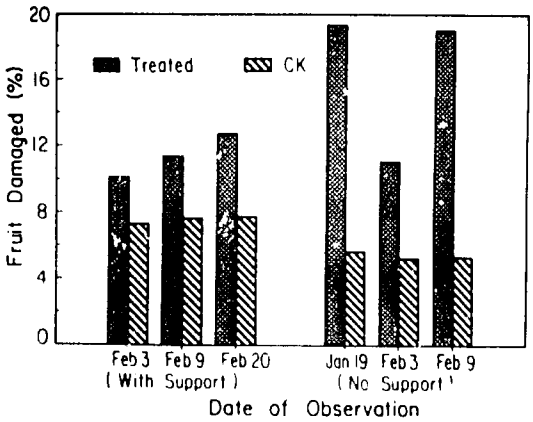


Fig. 2. Extent of fruit damage by TFW in pheromone-treated and control fields at three observation intervals.

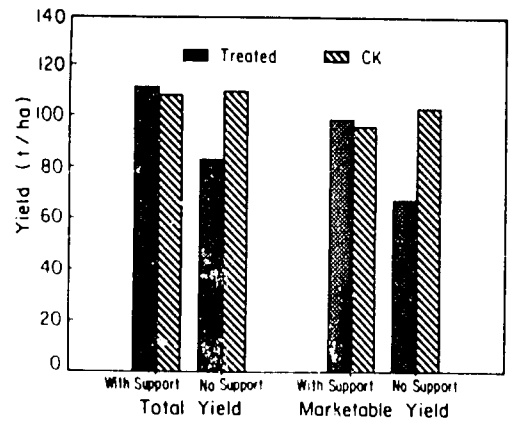


Fig. 3. Total and marketable tomato fruit yield in pheromone-treated and control fields.

Tomato Pathology

Screening for Virus Resistance

Summary

Both cucumber mosaic virus (CMV) and tomato leaf curl virus (TLCV) are important viruses of tomato in the tropies and subtropics, causing considerable yield losses. Commercial cultivars with resistance are not yet available. Materials with reported resistance to TLCV were tested both in Thailand and at AVRDC but were found to be susceptible. The resistance of L 533 could not be confirmed.

Introduction

Both CMV and TLCV cause considerable yield losses in tomato in the tropics and subtropics. Resistance is not yet available so far in commercial cultivars. There are, however, reports of CMV tolerance/resistance in wild *Lycopersicon* species and of TLCV resistance/resistance in *L. hirsutum* and *L. pimpinellifolium*. The wild species in the AVRDC germplasm collection are presently being screened to identify sources of resistance to CMV.

For several years, AVRDC has been cooperating with INRA/Montfavet in screening TLCV-resistant materials developed at the Institut National de la Recherche Agronomique (INRA). The screening was either done in Thailand, where TLCV is endemic, or at AVRDC by grafting.

Materials and Methods

TLCV. Seven lines with reported resistance to TLCV (VL 8, VL 81, VL 81a, VL 82b, VL 256, VL 282 and VL 340) as well as plants of seeds collected from eight individual symptomless plants of VL 84, which had been selected in Thailand under epiphytotic conditions were tested. Of each line or cultivar, 5 to 10 plants were screened. Screening was done by the double grafting method, described in the 1985 Progress Report.

CMV. Forty-seven accessions comprising mainly of *L. pimpinellifolium* and *L. esculentum* var. *cerasiforme* and Acc. 128 to 148 (Acc. 4423-4450) were screened with two isolates of CMV (Peets isolate and NT-9 which produces yellow mosaic). A total of 25 to 30 plants were usually inoculated. All symptomless plants were tested by ELISA. One line, Acc. 5339 (*L. peruvianum*) was screened for the third time, with both CMV isolates using materials from a single plant, which had only 10% disease incidence with Peet's strain in a previous screening.

Results and Discussion

TLCV. All the lines screened were found susceptible in the grafting test, including those originating from single plants of VL 84, selected under epiphytotic conditions in Thailand. This line, originating from a cross of *L. pimpinellifolium* × *L. hirsutum* seems to be a symptomless carrier of the virus. It does appear that many of the lines developed at INRA for leaf curl resistance may not be immune to the virus, but are symptomless carriers. Because of the difficulty in isolating and purifying the virus and antiserum, rating has to be done either by symptom observation or by grafting to

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susceptible plants, such as *N. benthamiana*, which show clear symptoms. Most wild *Lycopersicon* species do not produce the typical leaf curl symptoms when infected (either in the field, after white fly transmission or by grafting to TLCV-infected plants). Thus, ratings and/or selections should be supported by verification of virus presence (by grafting) to detect truly resistant plants.

CMV. All the lines screened were found susceptible. Resistance to CMV does not appear to be present in wild type Lycopersicon species. Employing biotechnology, i.e. the incorporation of the protein coat of a mild, symptomless strain of CMV into the tomato genome, may have to be considered in the future to obtain resistance against this virus. Cooperation with researchers at the Biotechnology Laboratories at the National Chung Hsing University is being explored.

Preliminary Studies on Bacterial Spot of Tomato

Summary

Bacterial spot (BS) caused by *Xanthomonas campestris* pv. *vesicatoria* is a serious foliar disease of tomato in the tropics. AVRDC recently selected BS and its causal organism for intensive research. Hawaii 7998 was more resistant to BS on leaf, petiole, stem and peduncle than Flora-Dade, but not on fruit. The 35- to 44-day old plants of both varieties had the highest percentage of diseased leaf area. Across different inoculum densities, the data for the resistant variety, Hawaii 7998, was always distinctly less than the susceptible variety, Flora-Dade. Increasing inoculum densities dramatically increased all disease parameters in Flora-Dade. Optimum inoculum concentration for mass-screening trials was determined to be 10^8 cfu/ml. Increasing inoculation pressure did not consistently affect the disease parameters measured. The results indicated that CLN $363B_1F_2$-167-1-0 has a moderate level of resistance. The data indicated that lesion size is the most stable single disease parameter that reflects the field level of resistance for these varieties across inoculation pressures. However, further research is necessary to confirm this observation.

Introduction

Bacterial spot (BS) in tomato caused by *Xanthomonas campestris* pv. *vesicatoria* (XCV) is one of the main foliar diseases in tropical and subtropical areas. The windy, warm and rainy climate is suitable for the occurrence and development of the disease. The pathogen can reportedly infect all tomato parts above the ground. The foliar symptoms are small dark greasy-appearing spots with a yellow halo. The spots may enlarge and develop a characteristic grayish center. They can coalesce and cover most of the leaf in susceptible tomato. The symptoms on petiole, stem and peduncle are similar to the foliar symptom and are frequently observed as circular to elongate necrotic spots. The symptoms on green fruit are small dark raised spots, sometimes surrounded by water-soaked margins. These spots often enlarge and become brown and scabby.

Recently, the Crop Improvement Program at AVRDC selected bacterial spot of tomato, and its causal agent *X. c.* pv. *vesicatoria*, for intensive research. The principal objective of this research was to identify and improve the level of resistance to XCV and to incorporate this resistance into improved tropically adapted varieties. Therefore, studies were initiated to determine suitable conditions for artificial inoculation, i.e. the most susceptible stage of plant, the optimum inoculum density and inoculation pressure, to develop an effective mass screening and evaluation method to identify resistant material.

Materials and Methods

Inoculum preparation. The XCV isolate, XV2, was used in these experiments. The bacteria were stored on PDA slants at 4°C. The 24-hour old cultures of XV2 grown on 523 medium at 30°C were used to prepare the inoculum. The bacterial cells were washed from plates, suspended in

distilled water, and then passed through four layers of cheesecloth. The concentration of the bacterial suspension was determined with a spectrophotometer at a wave length of 600 nm.

Effect of plant age on the disease severity and incidence of BS. Two tomato varieties were used, Flora-Dade, reportedly highly susceptible to BS and Hawaii 7998, reportedly highly resistant. Seeds of both varieties were sown in clay pots every 10 days and thinned to one plant/pot. All plants were grown outdoors under a shed with a clear plastic roof. The 26-, 35-, 44-, 55-, 65- and 76-day-old plants were inoculated at the same time. Bacterial suspension of 10^8 cfu/ml (O.D. value = 0.19 at 600 nm) was sprayed on all aboveground plant parts using an airbrush with 1.5 kg/cm^2 pressure. Control plants were sprayed with distilled water. There were four replicates per treatment.

The inoculated plants were placed in moist plastic bags for two days. The following data were recorded 10 days after inoculation: percentage of diseased leaf area and the percentages of infected petioles, stem internodes, peduncles and fruits.

Effect of inoculum density on the severity of BS. Six different inoculum concentrations (7.10, 3.55, 1.78, 0.89, 0.44 and 0.22 × 10^8 cfu/ml) were produced by diluting the most concentrated inoculum suspension. The number of colony forming units per milliliter of the most dense bacterial suspension was determined by the dilution plate method on 523 medium. The concentrations in cfu/ml of the other suspensions were calculated from this data.

Seedlings of the tomato varieties, Hawaii 7998 (highly resistant) and Flora-Dade (highly susceptible), were grown in plastic pots in the greenhouse. The 30-day old seedlings were inoculated with different bacterial concentrations using an airbrush with 1.5 kg/cm^2 of pressure. There were six replicates for every treatment. All seedlings were placed in a clear plastic moist chamber for two days after inoculation and then transferred outdoors.

Ten days after inoculation, the percentage of diseased leaf area, total lesion number per plant and average lesion diameter were recorded. Lesion diameters were measured under a dissecting microscope; 10 separated and well developed lesions per plant of Hawaii 7998 and 20 lesions of Flora-Dade were randomly chosen for measurement.

Effect of inoculation pressure on bacterial spot severity of tomatoes with different levels of resistance. Based on the observation of the AVRDC tomato breeder and reports in the literature, four tomato varieties with different levels of resistance to bacterial spot were selected for this experiment. Hawaii 7998, Flora-Dade and CLN 5915-153D_4-3-3-0, and CLN 363B_1F_2-167-1-0 were reported or observed to be highly resistant, highly susceptible and resistant to BS, respectively.

The bacterial suspension with 10^8 cfu/ml was used as inoculum. The 30-day old seedlings of all varieties were inoculated using an airbrush with different levels of pressure. The inoculation pressures used, 1.0, 1.5, 2.0 and 3.0 kg/cm^2, were adjusted at the air compressor. Control seedlings were sprayed with distilled water using the different inoculation pressures. There were six replicates per treatment.

All seedlings were placed in clear plastic moist chamber for two days after inoculation, and then transferred outdoors. Ten days after inoculation, the percentage of diseased leaf area, total lesion number per plant and average lesion diameter were recorded. Lesion diameter data were determined with the same method mentioned previously.

Results and Discussion

Effect of plant age on the disease severity and incidence of BS. All the aboveground parts of Hawaii 7998 and Flora-Dade could be infected by XV2. The foliar disease severity decreased with increasing plant age in both varieties (Table 1). The most severely affected plants were those that were inoculated when they were 35 and 44 days old. The disease incidences on the petiole, stem internode and peduncle of Hawaii 7998 were not significantly affected by plant age at the time of inoculation. Similarly, the disease incidences on the petiole and peduncle of Flora-Dade were not significantly affected by plant age, except for the low incidence on the peduncles of the 35-day old plants. The disease incidence on stem internodes of Flora-Dade peaked in the 55-day old plants. For

all plant ages, the disease ratings, whether foliar disease severity or disease incidence on petioles, stem internodes or peduncles, for the resistant variety Hawaii were significantly less than the susceptible Flora-Dade, with only one exception for the peduncles on 35-day old plants (Table 1). Also, the lesions on these plant tissues of Hawaii 7998 were smaller than those of Flora-Dade.

Table 1. Effect of plant age on bacterial spot severity on leaves and incidence on internodes, petioles, peduncles and fruits of resistant (R, Hawaii 7998) and susceptible (S, Flora-Dade) tomatoes.

Plant age	Leaf		Petiole		Internode		Peduncle		Fruit	
(days)	R	S	R	S	R	S	R	S	R	S
26	2.5[z]B[y]ab[x]	14.3 Ab	0.0 a	0.0 b	0.0 a	0.0 c	*[w]	*	*[w]	*
35	3.0 Ba	20.0 Aa	0.0 Ba	29.7 Aa	1.9 Ba	50.0 Ab	25.0 Aa	45.8 Ab	0.0 b	*
44	3.0 Ba	22.5 Aa	3.9 Ba	45.5 Aa	3.7 Ba	52.6 Aab	22.9 Ba	85.4 Aa	8.3 Aab	0.0 Ab
55	1.8 Bbc	13.5 Ab	1.7 Ba	38.3 Aa	4.1 Ba	67.5 Aa	50.0 Ba	100.0 Aa	21.8 Ba	75.0 Aa
65	1.5 Bbc	13.5 Ab	0.0 Ba	36.1 Aa	0.0 Ba	47.0 Ab	18.3 Ba	96.4 Aa	14.2 Aab	25.0 Aab
76	0.9 Bc	9.5 Ac	1.4 Ba	31.1 Aa	0.0 Ba	47.5 Ab	31.4 Ba	95.8 Aa	8.0 Aab	29.2 Aab

[z]Means of four replicates. [y]Means of resistant and susceptible cultivars with the same plant age and tissue organ (leaf, petiole, internode, peduncle and fruit), sharing the same upper case letter are not significantly different according to Duncan's new multiple range test, P = 5%. [x]Means in a column sharing the same lower case letter are not significantly different according to Duncan's new multiple range test, P = 5%. [w]No peduncle or fruit.

However, with respect to disease incidence on green fruit, no significant differences were observed between the two varieties in three of the four age groups tested (Table 1). Also, the symptoms and lesion size were similar on the fruit of both varieties. Apparently, the level of resistance to XCV in the fruits of Hawaii 7998 was not greater than that of Flora-Dade.

The resistance level in Hawaii 7998 was most pronounced in the data for foliar disease severity and disease incidence on petiole and internode. Therefore, future resistance screening tests, involving progeny with Hawaii 7998 in its parentage, should evaluate data recorded from these three plant tissues. The results also indicated the need to identify sources of resistance to fruit infection by XCV and higher levels of resistance to peduncle infection.

Effect of inoculum density on the severity of BS. The data for the resistant variety, Hawaii 7998, was always distinctly less than the susceptible variety, Flora-Dade, for all the disease parameters measured at all inoculum densities used. The percentage of diseased leaf area increased with increasing inoculum density in both the resistant and susceptible varieties. In Flora-Dade, total lesion number and lesion size increased with increasing inoculum density. In Hawaii 7998, only the lesion number increased with increasing inoculum density (Table 2). Not only were lesion number and size different between the resistant and susceptible varieties, but the rate of increase of both of these parameters was also distinctly greater in the susceptible variety (Fig. 1).

The optimum separation of symptom expression between resistant and susceptible varieties or progenies is necessary for selection during resistance screening. Although the highest inoculum density did provide the best separation between Hawaii 7998 and Flora-Dade (Fig. 1), it is not practical to produce this inoculum concentration in large volumes necessary for mass screening. An inoculum concentration of 10^5 cfu/ml has been commonly used by other scientists for XCV resistance screening in tomato and it also gives good separation between resistant and susceptible varieties in AVRDC tests. Therefore, the inoculum concentration of 10^5 cfu/ml is recommended for resistance screening tests.

Both BS lesion number and size on tomato are important components of disease severity. The data from this experiment indicated that both components need to be evaluated to determine the level of resistance, at least until it can be shown that these two characters are genetically linked. It appears that the resistance present in Hawaii 7998 is manifested in an overall reduction in the effectiveness of the XCV propagules to cause infections (reduced lesion number) and to extend the infection within the leaf (reduced lesion size)(Table 2). This reduced effectiveness of the XCV pathogen to cause disease

Table 2. Effect of inoculum density on bacterial spot severity (expressed as percentage of diseased leaf area, total lesion number per plant and diameter of lesion) of resistant (R, Hawaii 7998) and susceptible (S, Flora-Dade) tomatoes.

Inoculum density ($\times 10^8$ cfu/ml)	S			R		
	%	No.	Size	%	No.	Size
7.10	30.8[z] a[y]	1387 a	1.68 a	1.8 a	145 ab	0.33 a
3.55	20.7 b	934 bc	1.35 b	1.5 ab	198 a	0.33 a
1.78	17.6 bc	1116 ab	1.26 b	1.0 bc	130 ab	0.34 a
0.89	18.0 bc	718 cd	1.08 c	0.5 c	81 b	0.26 a
0.44	14.0 c	820 bcd	1.05 c	0.6 c	63 b	0.34 a
0.22	13.7 c	570 d	1.01 c	0.6 c	59 b	0.32 a

[z]Means of six replicates. [y]Means in a column sharing the same letter are not significantly different according to the Duncan's new multiple range test, P = 5%.

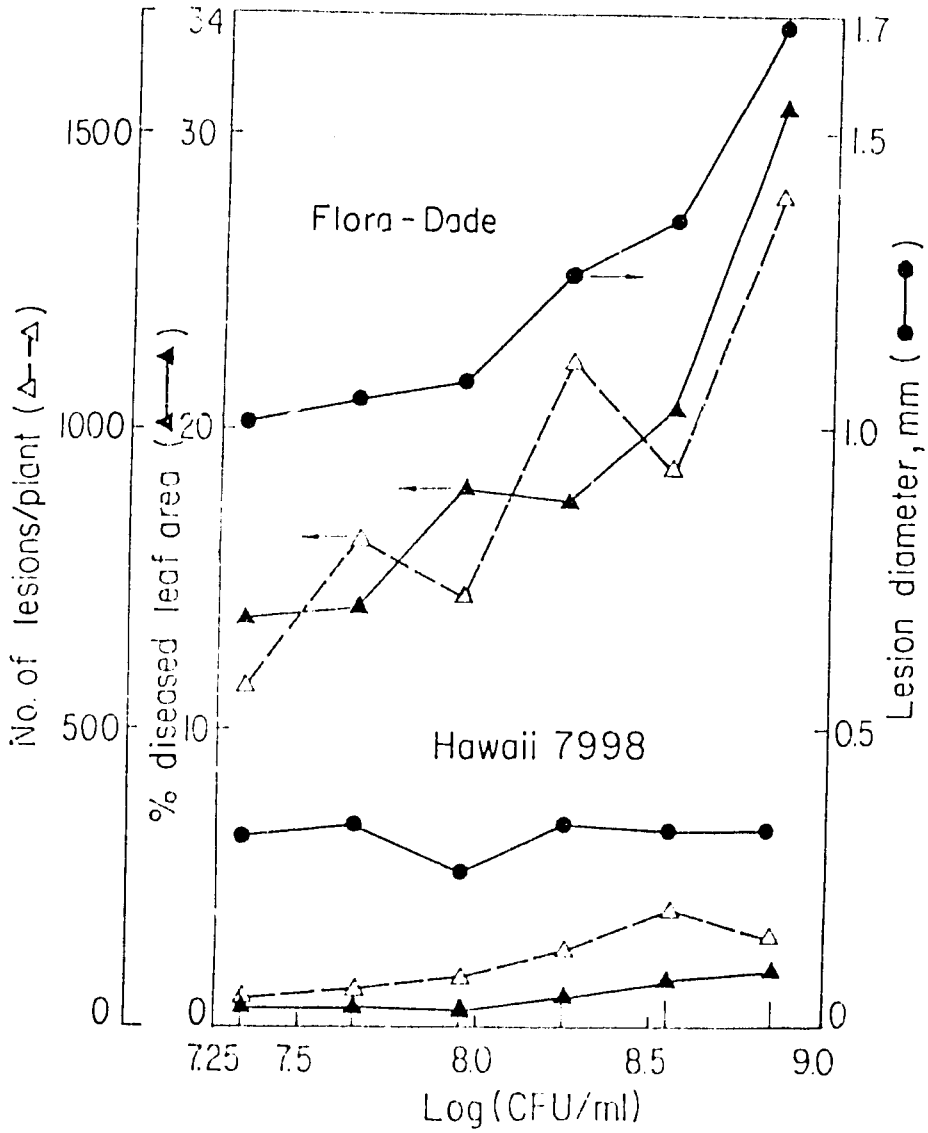

Fig. 1. The relationship between inoculum density and bacterial spot development in resistant (Hawaii 7998) and susceptible (Flora-Dade) tomatoes.

could also explain the lower increase in these disease parameters observed in response to increasing inoculum density (Fig. 1). However, other forms of resistance may also be responsible for this reduced rate of increase.

Effect of inoculation pressure on the severity of BS. Inoculation pressure had no consistent effects on any of the disease parameters across varieties. Therefore for the purpose of standardization, 1.5 kg/cm^2 was chosen as the inoculation pressure for mass-screening tests.

Two of the varieties, Flora-Dade and CLN 5915-153D$_4$-3-3-0 (CLN 5915), used in this experiment were observed to be highly susceptible in the field; the other two varieties, Hawaii 7998 and CLN 363B$_1$F$_2$-167-1-0 (CLN 363B), were highly resistant and resistant, respectively. Similar to the previous experiment, the data for the resistant variety, Hawaii 7998, was always significantly less than the susceptible variety, Flora-Dade, for all the disease parameters measured at all inoculation pressures used (Table 3).

The disease severity (percentage of diseased leaf area) of CLN 5915 was significantly less than that of Flora-Dade across all inoculation pressures and, therefore, the data in this experiment would indicate that CLN 5915 has a higher resistance level than Flora-Dade. However, the results of the field experiment that appear as the next report, indicated that CLN 5915 is more susceptible in terms of disease severity and lesion size during a field epidemic. The first set of data from this field experiment (0 days after transplanting, nine days after artificial inoculation) showed that the two varieties did not differ much with respect to disease severity or lesion size. Apparently, the symptom development resulting from artificial inoculation is not always related to symptom development under a natural epidemic. Therefore, the final quantification for the resistance level of a variety will need to be conducted under field conditions (Table 3).

Lesion sizes were similar for Flora-Dade and CLN 5915 across all inoculation pressures and they were significantly larger than the lesions of either CLN 363B or Hawaii 7998. The lesions of CLN 363B were significantly larger than that of Hawaii 7998, as were nearly all of the other disease parameters measured (Table 3). The data from the field experiment also agree with the results of this experiment. Therefore, CLN 363B can be classified as moderately resistant to XCV.

The data in this experiment indicated that lesion size is the most stable single disease parameter that reflects the field resistance level for these varieties across inoculation pressures. However, further research is necessary to confirm this observation.

Inoculation and Bacterial Spot Development in the Field

Summary

A commercially acceptable tomato cultivar, resistant to bacterial spot, has not yet been developed. Therefore, research has been undertaken to identify a suitable inoculation protocol for disease resistance screening and to identify the levels of resistance in locally adapted cultivars. Field inoculation is necessary for best epidemic development. Heavy rainfall appears to be necessary for disease development. Sprinkler irrigation, even as often as four times per day, did not have the same effect as heavy rainfall. CLN 5915-153D$_4$-3-3-0 and CLN 191B$_1$F$_2$-1-7-0 were highly susceptible; Flora-Dade and CLN 5915-206D$_4$-2-2-32-15 were moderately susceptible; CLN 363B$_1$F$_2$-167-1-0 was moderately resistant; and Hawaii 7998 was highly resistant to bacterial spot. Throughout the course of this epidemic, average lesion size was very stable and, therefore, appears to be a useful parameter for estimating the level of resistance in preliminary mass-screening tests.

Introduction

Bacterial spot (BS) is one of the main foliar diseases of tomato in tropical and subtropical areas. Currently, there are no commercially acceptable resistant cultivars available even though disease resistance screening has been in progress for about 20 years. In the past year, high priority has been given to the development of BS resistance in acceptable cultivars. Therefore, a highly efficient

Table 3. Effect of inoculation pressure on bacterial spot severity (expressed as percentage of diseased leaf area, total lesion number per plant and diameter of lesion) of tomatoes with different susceptibility.

Entry	1.0			1.5			2.0			3.0 kg/cm^2		
	%	No.	Dia.	%	No.	Dia.	%	No.	Dia.	%	No.	Dia.
CLN 5915[z]	12.0[x]b[w]AB[v]	524 aA[w]	1.2 bB[v]	10.3 bB	529 bA	1.4 aAB	13.0 bAB	481 bA	1.5 aA	15.3 bA	404 bA	1.4 aAB
Flora-Dade	15.5 aB	570 aB	1.4 aA	18.5 aB	1148 aA	1.3 bA	24.4 aA	1231 aA	1.4 aA	24.7 aA	803 aB	1.4 aA
CLN 363B$_1$F$_2$[y]	2.4 cB	171 bB	0.5 cA	7.6 bA	382 bA	0.5 cA	6.2 cA	301 bcAB	0.5 bA	7.2 cA	290 bB	0.5 bB
Hawaii 7998	0.4 cB	41 bA	0.3 dA	0.9 cA	88 cA	0.3 dA	0.8 dAB	100 cA	0.3 cA	0.7 dAB	106 bA	0.3 cA

[z]CLN 5915: CLN 5915-153D$_1$-3-3-0
[y]CLN 363B$_1$F$_2$: CLN 363B$_1$F$_2$-167-1-0
[x]Means of six replicates.
[w]Means in a column sharing the same lower case letter are not significantly different according to Duncan's new multiple range test, P = 0.05.
[v]Means of the same data set within the same variety sharing the same upper case letter are not significantly different according to Duncan's new multiple range test, P = 0.05.

screening and selection methodology has to be identified. This report presents a portion of the results necessary to accomplish this objective.

Materials and Methods

Inoculation method for BS in the field. Hawaii 7998 and Flora-Dade had been reported as being vertically resistant and highly susceptible to BS, respectively, in Florida. Seed of each variety was sown in plastic pots on 30 June, and seedlings were thinned to one plant per pot. All seedlings were grown outdoors under a shed with a clear plastic roof and transplanted to the field on 6 August.

A split-plot design with four replicates was used, with main plots as inoculation treatments and the subplots as the two varieties. The main plot inoculation treatments were: treatment 1 = seedlings were inoculated at three true-leaf stage on 28 July and reinoculated in the field on 23 September; treatment 2 = seedlings were inoculated in the field on 20 August; and treatment 3 = seedlings were inoculated with distilled water and used as control. The plot size was 3 m × 4 m. There were 20 plants per plot. Inoculum was prepared as mentioned previously. Bacterial suspension with 10^8 cfu/m^1 was sprayed to all aboveground parts of tomato by airbrush with 1.5 kg/cm^2. The percentages of disease were investigated on 1 and 14 September and 4 October.

Preliminary screening and disease development of BS. Four AVRDC breeding lines: CLN $363B_1F_2$-167-1-0, CLN $191B_1F_2$-1-7-0, CLN 5915-$206D_4$-2-2-32-15 and CLN 5915-$153D_4$-3-3-0, and Flora-Dade and Hawaii 7998 were tested in this field trial. Seeds were sown in plastic pots on 30 June. The seedlings were grown outdoors under a shed and inoculated at three true-leaf stage on 28 July. The disease severity of the seedlings was investigated on 6 August, and they were then transplanted to the field.

A randomized block design with four blocks was used. The plot size was 4 m × 4.5 m. There were 30 plants per plot. After transplanting, a flexible, plastic pipe sprinkler irrigation was used to encourage disease development. Irrigation was applied daily for a duration of 10 minutes at 0800, 1000, 1400 and 1600 hours.

Disease severity, expressed as percentage of affected foliage, was evaluated every week after transplanting. Lesion size was also evaluated at this time using the rating system found in Table 4.

Table 4. Rating on spot size of BS.

Rate	Description
0	escape or immune, no visible symptoms
1	spots very small (< 0.5 mm diameter)
2	spots small (≤ 0.5 mm diameter)
3	spots small (≤ 1.0 mm diameter)
4	spots small (≤ 1.0 mm diameter) occasionally coalescing
5	spots coalescing (≤ 2.0 mm diameter) with necrosis
6	spots coalescing (≤ 3.0 mm diameter) with considerable necrosis
7	spots and necrosis coalescing and covering much of leaf

Results and Discussion

Inoculation method for BS in the field. BS was significantly more severe on Flora-Dade than on Hawaii 7998 in the inoculated plots. Only minimal amounts of BS developed in the control plots. The susceptible plants that were inoculated after being transplanted to the field developed significantly higher levels of disease severity than those only inoculated before transplanting (Table 5, see evaluation dates 1 and 14 September). BS severity in the susceptible variety inoculated before transplanting was significantly increased after reinoculation on 23 September (Table 5). During this experiment, artificial inoculation was necessary to increase disease severity in the field.

Preliminary screening and disease development of BS. The absence of disease development during the first 25 days after transplanting, a period without rain, indicates that the sprinkle

irrigation had little effect on the development of the epidemic. Heavy rain occurred on 30-31 August and again on 7-10 September. After these rains disease severity increased rapidly, indicating that heavy rain is necessary for the development of an epidemic (Fig. 2).

Based on the percentage of diseased foliage, CLN 5915-153D_4-3-3-0 and CLN 191B_1F_2-1-7-0 were highly susceptible, Flora-Dade and CLN 5915-206D_4-2-2-32-15 were moderately susceptible, CLN 363B_1F_2-167-1-0 was moderately resistant and Hawaii 7998 was highly resistant to BS (Fig. 2). However, when the data on lesion size were evaluated, CLN 5915-153D_4-3-3-0 had the largest

Table 5. Effect of inoculation method on bacterial spot severity of resistant (R, Hawaii 7998) and susceptible (S, Flora-Dade) tomatoes in the field.[z]

Treatment	Date of evaluation					
	1 Sept.		14 Sept.		4 Oct.	
	R	S	R	S	R	S
Inoculated before transplanting[y]	0.6	7.5	1.0	9.0	2.8	22.0
Inoculated after transplanting[x]	9.0	33.0	2.3	14.8	1.0	14.8
Control	0.0	0.0	0.5	3.0	0.1	1.8
$LSD_3(0.05)^w$	2.9		1.3		1.9	
$LSD_4(0.05)^v$	3.6		1.1		2.2	

[z]All seedlings were sown on 30 June and transplanted to the field on 6 August. [y]The seedlings of this treatment were inoculated on 28 July before transplanting and on 23 September in the field. [x]The seedlings of this treatment were inoculated on 20 August in the field. [w]LSD value between means of varieties in the same treatment. [v]LSD value between means of treatment in the same or different varieties.

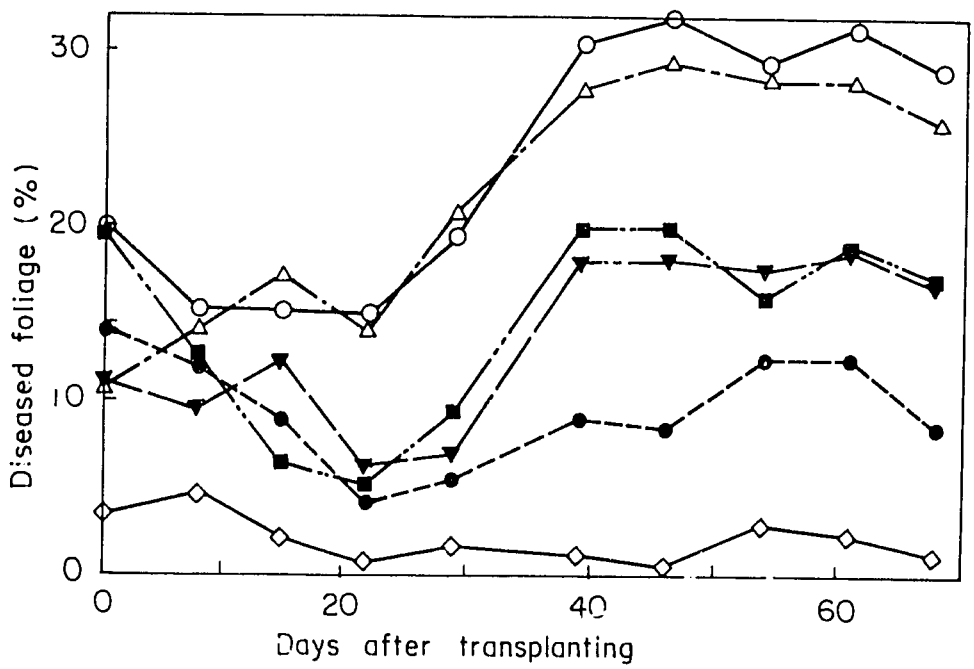

Fig. 2. The development of bacterial leaf spot on six tomato varieties: CLN 5915-153D_4-3-3-0 (○-○), CLN191B_1F_2-1-7-0 (△-△), Flora-Dade (■-■), CLN 5915-206D_4-2-2-32-15 (▼-▼), CLN 363B_1F_2-167-1-0 (●-●) and Hawaii 7998 (◇-◇).

lesions and, therefore, was presumably the most susceptible. The size of lesions in CLN $191B_1F_2$-1-7-0 and Flora-Dade was similar, although the former was more susceptible when the rating was based on the percentage of diseased foliage. The same phenomenon could be found between CLN 5915-$206D_4$-2-2-32-15 and CLN $363B_1F_2$-167-1-0. Since both lesion size and lesion number contribute to disease severity, the lesion number of CLN $191B_1F_2$-1-7-0 and CLN 5915-$206D_4$-2-2-32-15 could be more than Flora-Dade and CLN $363B_1F_2$-167-1-0 (Fig. 3). Therefore, neither lesion size nor lesion number is a completely accurate indicator of expected disease severity and disease resistance. However, lesion size of all entries was much less affected by the environment and is, therefore, a better parameter for estimating the level of resistance in preliminary mass-screening tests.

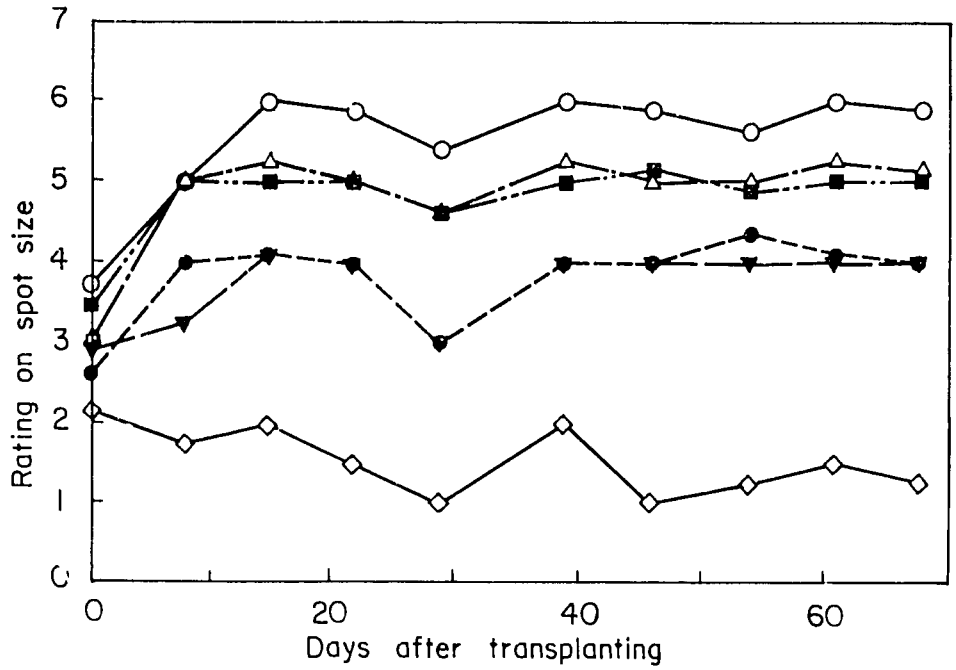

Fig. 3. The development of lesion size of bacterial leaf spot on five tomato varieties: CLN 5915-$153D_4$-3-3-0 (○-○), CLN $191B_1F_2$-1-7-0 (△-△), Flora-Dade (■-■), CLN 5915-$206D_4$-2-2-32-15 (▼-▼), CLN $363B_1F_2$-167-1-0 (●-●) and Hawaii 7998 (◇-◇).

Screening for Resistance to Cercospora Leaf Spot (*Cercospora fuligena*)

Summary

Cercospora leaf spot (CLS) (*Cercospora fuligena*) is another serious foliar disease of tomato in tropical countries. Mycological studies indicated that the best media for its rapid mycelial growth was dextrose agar with either rice, oat or corn meal added and that the optimum temperature for growth was between 24°C and 28°C. However, conidia were not produced in any of the culture conditions used in these experiments and, therefore, mycelial fragments were used for inoculum. Nearly the entire tomato germplasm collection was screened to determine the levels of resistance/susceptibility to *C. fuligena*. Thirty-nine accessions were classified as highly resistant, 546 as moderately resistant and the remaining 4,446 accessions were classified either moderately to highly susceptible.

Introduction

Cercospora leaf spot caused by *Cercospora fuligena*, also known as black leaf mold, is one of the most serious foliar diseases of tomato in tropical countries. Little research has been done,

however, on this fungus, probably because the disease is not serious in temperate countries, where a similar disease -- leaf mold caused by *Cladosporium fulvum*, is considered much more important. The present study was, therefore, undertaken to screen the AVRDC tomato germplasm collection for resistance to this important disease.

Materials and Methods

The fungus was isolated on standard PDA from infected tomato leaves collected from the AVRDC farm. Isolation was carried out by gently rubbing infected tomato leaf fragments on the surface of the growth medium. After two days of incubation, the petri dish was searched under the compound microscope for clean colonies (free of contaminants) which were transferred onto fresh medium.

As the fungus grows very slowly and does not sporulate on PDA, preliminary studies were carried out to investigate the effects of growth medium, light and temperature on fungal growth characteristics.

Twenty growth media were screened for fungal growth, 11 of which consisted of 20 g each of powdered compound (bean, soybean, mungbean, adzuki bean, lima bean, chickpea, lentil, rice, wheat, oat and corn), 10 g dextrose and 20 g agar. The remaining media were: Czapek-dox, V8-juice agar, Sabouraud, carrot juice agar, tomato leaf extract-, onion juice-, yeast extract- and malt extract dextrose agar. PDA was used as check. The fungus was incubated on each medium at 24°C in the incubator, both under continuous darkness and under continuous light from fluorescent tubes. Each treatment was replicated three times in three petri dishes.

To investigate the effect of temperature, the fungus was incubated on PDA under various temperatures ranging from 15°C to 35°C.

In both experiments, fungal growth was measured as the diameter of the fungal colony after a one-month incubation period. To assess sporulation, fragments of fungal growth were scratched off the petri dish, suspended in water and examined under the microscope for the presence of spores.

For inoculation studies, tomato seedlings were raised in the greenhouse in small plastic pots at one seedling per pot and two pots per accession and inoculated at the four to five leaf stage. Inoculation consisted of spraying the seedlings with a mycelial suspension -- one petri dish of fungal growth per liter of water, plus a few drops of Tween 20, after which they were enclosed in moistened plastic cages for 24 hours and then transferred outside. The disease was scored after full symptom expression, 12 to 18 days after inoculation, using the following scale: immune = no symptoms; highly resistant = very few spots (less than 5% leaf area) with no or very little sporulation; moderately resistant = few spots (5-15% leaf area) with light sporulation; moderately susceptible = moderate disease severity (15-30% leaf area) and sporulation; and highly susceptible = leaves extensively covered with dark abundantly sporulating spots (> 30% leaf area).

Results and Discussion

The fungus did not sporulate on any of the growth media tested, either under continuous darkness or continuous fluorescent light. Mycelial growth rate, however, varied markedly between the different media. The fastest growth occurred on rice-, oat-, and cornmeal dextrose agar; spots reached a diameter of 34 mm on each of these media after a month's incubation, as compared to 25 mm on PDA. Moreover, the mycelial colony had a smooth and woolly appearance on these media, whereas it was rather rough and crusty on PDA. Therefore, for all subsequent inoculations, the fungus was grown on ricemeal dextrose agar. However, since mycelial growth remained slow even on the best media, a method to hasten inoculum production was used which consisted of tapping small agar blocks covered with mycelial growth against the fresh medium over the whole surface of the petri dish to increase the number of resulting colonies. Inoculum could thus be obtained after five to seven days of incubation.

Growth rate was markedly influenced by temperature. No growth occurred at 15°C; growth rate then slowly increased with an optimum temperature which ranged from 24° to 28°C, then gradually decreased and was nil at 35°C. No sporulation occurred on PDA under any of these temperatures.

Out of the entire AVRDC tomato germplasm collection (5,318 listed accessions), 5,031 accessions could be grown and their disease reaction successfully scored. The remaining accessions either were no longer available in the collection or died before inoculation and disease scoring.

Disease reactions varied markedly and ranged from highly resistant to highly susceptible. No immune accessions were found. Thirty-nine accessions were classified as highly resistant (Table 6), 546 as moderately resistant and the remaining from moderately to highly susceptible.

Conclusion

This study was undertaken to screen for resistance to a very serious disease of tropical tomato and to contribute to the characterization of the AVRDC tomato germplasm. This seems especially useful in view of the very scarce documentation available about this disease.

The study revealed a wide variability in reaction to *Cercospora fuligena* within the tomato germplasm collection, and in particular, detected possible sources of resistance. Should the AVRDC tomato improvement program further address this disease problem, all accessions classified in this study as highly resistant or moderately resistant should be retested preferably with various fungus isolates from wide geographic areas. This should not only confirm the resistance of these accessions, but also eventually detect physiological races of the fungus which, if they occurred, could complicate the breeding program for resistance.

Table 6. Tomato accessions resistant to *Cercospora fuligena*.

L 733	L 2120	L 4414
L 734	L 2202	L 4455
L 1064	L 2851	L 4506
L 1065	L 2116	L 4089
L 1352	L 2119	L 4143
L 1533	L 3050	L 4815
L 1558	L 3233	L 4930
L 1666	L 4034	L 5184
L 1688	L 2888	L 4399
L 1696	L 2926	L 4405
L 1731	L 4167	L 4569
L 1777	L 4220	L 4765
L 2102	L 4253	L 5235

Occurrence of Resistance-Breaking Biotypes of *Meloidogyne incognita* on Tomato

Summary

Only one gene for resistance to root-knot nematode is known to exist in tomato. Reports in the literature indicate that 'resistance-breaking' races of *Meloidogyne incognita* can be developed in the greenhouse after repeated life cycles on the resistant cultivars. This initial study reports the development of 'resistance-breaking' races of root-knot nematode. Four root-knot nematode isolates were successively cultured through three cycles on four root-knot nematode resistant tomato cultivars. The number of galls and egg masses produced per root system at the end of the second cycle increased more than threefold. This large increase during the second and third cycles indicates that resistance-breaking biotypes of the root knot nematode had developed or were selected for during the first cycle when the nematode was cultured on the resistant plants. Additional studies are necessary to determine the occurrence and population dynamics of resistance-breaking biotypes in the field and to assess their potential damage to the tomato crop.

Introduction

Meloidogyne incognita (Chitwood), the common root-knot nematode, can seriously reduce the productivity of tomato. Numerous commercial tomato cultivars with resistance to this nematode have been developed; however, all of these carry the same single dominant gene for resistance. Repeated

cropping of cultivars with monogenic resistance in the field under natural pathogen selection pressure has often led to the development of new resistance-breaking races of the pathogen. Reports in the literature indicate that resistance-breaking races of *M. incognita* can develop in the greenhouse after repeated life cycles on the resistant cultivars. This initial report studies the development of resistance-breaking races of root-knot nematode through repeated inoculation of single egg mass cultures on four resistant tomato cultivars under greenhouse condition.

Materials and Methods

Four tomato cultivars, Healani (L 97), Kewalo (L 274), Calmart (L 345) and 72T6 (L 3890), were each inoculated with four isolates of *M. incognita*. The sources of the nematode isolates are given in Table 7. Each isolate was maintained on susceptible tomato cultivar TK 70, inoculated with a single egg mass from each infested host. The detailed procedure for culturing successive cycles of four root-knot nematode isolates on tomato cultivars is shown in Table 8.

Four-week old or about 10 cm high tomato seedlings were used in all these greenhouse tests. Plants were grown singly in 10-cm diameter clay pots containing 600 ml of potting mixture of two parts soil to one part sand and 3 g NPK1:1:1 fertilizer mixed with the media before potting. The pots and soil mix were steam-sterilized at 100°C for one hour.

M. incognita inocula were prepared by NaOCl method. The inoculum was a 3,000 egg suspension in a 1 ml aliquant of water. The inoculum was pipetted into the root zone around the plant in each pot. The treatments were laid out on the greenhouse bench in a completely randomized design with five replications. The greenhouse temperatures ranged from 25° to 35°C. Fifty days after inoculation, roots were washed free of soil, and the root galling and egg mass production per root system were

Table 7. *Meloidogyne incognita* isolated from several localities in Taiwan and purified with single egg masses on the susceptible local variety of TK 70.

Isolates assigned	Locality	Infested host	Date sampled
MI 1	Pei-Kang	Tomato	Jan. 1987
MI 2	Pei-Kang	Watermelon	Jan. 1987
MI 3	AVRDC	Tomato	Feb. 1987
MI 4	Tainan DAIS	Tomato	Nov. 1986

Table 8. Procedure for culturing successive cycles of root-knot nematode isolates on resistant tomato cultivars.

Step	Culture and inoculation	Date tested (DAT)
1	Single egg masses collected from each of the four different isolates were cultured on TK 70 for mass production of inoculum.	2/16 ~ 3/27/87 (42)
2	Testing each isolate on each resistant tomato line (L 3890, L 274, L 345, L 97) with 3000 eggs per plant. (Cycle 1).	3/28 ~ 5/17/87 (50)
3	Single egg masses of each isolate on each tested resistant tomato line were collected for mass reproduction of inoculum on TK 70.	5/18 ~ 6/28/87 (42)
4	As Step 2 (Cycle 2)	6/29 ~ 8/17/87 (50)
5	As Step 3	8/18 ~ 9/29/87 (42)
6	As Step 2 (Cycle 3), except check inoculum is from nematode stock culture which is used for tomato resistance screening.	9/30 ~ 11/18/87 (50)

evaluated. The galling/egg mass index was determined by the following scale: 0 = no gall/egg masses; 1 = 1 to 2 galls/egg masses; 2 = 3 to 10 galls/egg masses; 3 = 11 to 30 galls/egg masses; 4 = 31 to 100 galls/egg masses; 5 = >100 galls/egg masses produced on the root system.

Results and Discussion

The responses of the four resistant tomato cultivars to the culturing of successive cycles of root-knot nematode populations appear in Tables 9 and 10. In the first nematode cycle cultured on the resistant cultivars (C1), the mean number of nematode galls per root system ranged from 5.2 to 11.8 (Table 9); and the mean number of egg masses per root system ranged from 2.2 to 7.0 (Table 10). In the second cycle, the number of galls and number of egg masses per root system ranged from 15.6 to 53.8 and from 9.2 to 27.6, respectively. This represents more than a threefold increase in both the number of galls and egg masses produced at the end of the second cycle. In general, the number of galls and egg masses produced in the third cycle is similar to or represents a slight increase over the second cycle.

Table 9. Number of galls per root system and gall index of four resistant tomato cultivars inoculated with four isolates of *Meloidogyne incognita*.[z]

M. incognita		L 3890		L 274		L 345		L 97	
Cycle	Isolate	No.	Index	No.	Index	No.	Index	No.	Index
C1	MI 1	11.8	2.4	5.4	2.0	5.6	1.8	7.2	2.0
C1	MI 2	7.2	2.0	5.2	2.0	6.8	2.0	9.2	2.4
C1	MI 3	9.4	2.0	7.0	2.0	6.0	2.2	6.6	2.0
C1	MI 4	8.8	2.4	8.8	2.2	6.0	2.0	7.4	2.2
C2	MI 1	53.8	3.8	22.2	3.2	32.4	3.0	30.0	3.6
C2	MI 2	17.4	2.6	25.2	3.4	25.4	3.0	15.6	2.8
C2	MI 3	19.2	3.0	17.2	2.6	17.0	3.0	18.4	2.8
C2	MI 4	46.8	3.6	26.0	3.2	17.8	2.8	35.2	3.2
C3	MI 1	30.6	3.6	24.8	3.4	26.4	3.2	22.6	3.2
C3	MI 2	20.2	3.0	26.6	3.2	23.2	3.2	30.0	3.4
C3	MI 3	26.2	3.4	16.0	2.8	13.2	2.6	20.4	3.2
C3	MI 4	41.4	3.8	39.0	3.8	40.2	3.8	46.2	3.8

[z]Data represents the mean of five replications.

Table 10. Number of egg masses per root system and egg mass index of four resistant tomato cultivars inoculated with four isolates of *Meloidogyne incognita*.[z]

M. incognita		L 3890		L 274		L 345		L 97	
Cycle	Isolate	No.	Index	No.	Index	No.	Index	No.	Index
C1	MI 1	5.6	2.0	3.4	1.6	4.4	1.8	5.4	1.8
C1	MI 2	4.8	1.6	3.8	1.8	3.6	1.4	4.2	1.6
C1	MI 3	5.0	1.8	4.0	1.4	3.4	1.8	3.2	1.4
C1	MI 4	2.2	1.6	7.0	2.2	3.8	1.8	4.4	1.8
C2	MI 1	27.6	3.0	12.2	2.4	17.4	2.8	21.4	3.2
C2	MI 2	12.8	2.4	14.2	2.6	21.4	3.0	9.2	2.4
C2	MI 3	13.0	2.6	10.6	2.4	17.0	2.8	10.2	2.4
C2	MI 4	18.6	3.0	23.0	3.2	12.6	2.4	20.0	3.0
C3	MI 1	21.8	3.0	18.0	3.0	20.0	3.0	15.8	3.0
C3	MI 2	11.4	2.4	22.6	3.0	17.0	2.6	25.6	3.2
C3	MI 3	16.6	2.8	13.6	2.6	12.2	2.4	18.2	2.8
C3	MI 4	30.2	3.4	25.4	3.4	32.8	3.6	30.8	3.4

[z]Data represents the mean of five replications.

The large increase in the mean number of galls and egg masses produced during the second and third cycles indicates that resistance-breaking biotypes of the root-knot nematode had developed or were selected for during the first cycle when the nematode was cultured on resistant plants. Considering the procedure used for culturing the nematodes, the data also indicate that the resistance-breaking biotypes remain virulent after one or two generations on a susceptible host. This experiment showed the potential vulnerability of only one gene available in tomato for resistance to root-knot nematodes. Additional studies are necessary to determine the occurrence and population dynamics of resistance-breaking biotypes in the field and to assess their potential damage to the tomato crop.

Tomato Physiology

Cell Number and Size, and Carbohydrate Content as Related to Tomato Fruit Size

Summary

Five tomato genotypes of different fruit sizes were grown under cool season conditions to investigate the relationship of cell number and size, carbohydrate level and fruit size. Fruit size was demonstrated to be the most important yield component in determining the final fruit yield level in this cool season experiment; it was strongly related to the initial ovary size before or near anthesis. Developing ovary size from six days before to three days after anthesis was predestined by cell number rather than cell size and, hence, by cellular layer in the pericarp. Varietal difference in fruit size was also expressed in the ovary cultured under *in vitro* conditions for 30 to 40 days. *In vitro* culture developing ovaries at 32°C tended to reduce fruit size of large-fruited entries.

High soluble sugar contents in the sepal, pedicel, ovary and leaf from three days before to seven days after anthesis were desirable for high fruit set, but detrimental to ovary development of large-fruited entries. On the other hand, high starch contents in sepal, pedicel and leaf opposite the cluster were related to large fruit development. Although fruit size is predetermined genetically, its final expression may be influenced by the competition for assimilates due to the number of fruits set, position of fruits or clusters, or temperature conditions. The analysis of carbohydrates in the sepal and leaf before anthesis may serve as cues for fruit size potential.

Introduction

Fruit size is one of the important yield components determining the yield of the tomato plant. It is usually predestined by the strength of an ovary to import leaf assimilates, which is further defined by physical restraints, i.e. cell number and cell size, and physiological activities of uptake or incorporation of assimilates into the developing fruit. The present study aimed to: 1) clarify the relationship between cell number and size, and fruit size; 2) examine the varietal difference in the development of ovaries under *in vitro* conditions; and 3) investigate carbohydrate levels in the leaf, ovary, developing fruit and other floral parts as related to fruit size of different genotypes.

Materials and Methods

Seedlings of L 208, L 1488, CL 5915-153, CL 5915-206 and FMTT 14 were transplanted on 17 November 1986 in an RCB design of four replicates. Plants were pruned as a single stem with six clusters. Flower and fruit number, fruit set, fruit size, carpel number and seed number were recorded.

Floral buds and young fruits were sampled at six and three days before anthesis (DBA), at anthesis, and at 3, 7 and 14 days after anthesis (DAA). The ovaries and young fruits were excised from the sampled reproductive organs and fixed in FAA fixative. They were sectioned, examined and estimated for cell number and size, and number of cellular layer in the pericarp.

Floral buds at two DBA were sampled regardless of cluster and pedicels, and sterilized before removing the anthers and petals. Ovaries with or without sepals were cultured under *in vitro* conditions

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on MS medium supplemented with 10% sucrose. They were grown in the incubator at 18°, 25° and 32°C until maturity, and then measured for fruit weight, carpel number and seed number.

Other batches of floral buds and young fruits of the second to the fourth clusters, and the leaves opposite the third cluster were sampled at the same developmental stages for microscopic observations. The sampled reproductive organs were separated into sepals, ovaries and pedicels before they were analyzed for soluble sugar and starch along with the leaves.

Results and Discussion

Fruit yield of five diverse genotypes in terms of fruit size grown under cool season conditions was positively correlated with fruit size (r = 0.80***), but negatively correlated with fruit set (r = -0.82***). There appeared to be a compensatory effect between fruit set and fruit size, but fruit size seemed to be the predominant factor in fruit yield of tomato under cool season conditions (Table 1).

As previously reported, there was a decreasing trend in fruit yield, fruit set and fruit size with an increasing order of cluster position. This suggests that the normal fruit-setting process and fruit development at higher order cluster position might be retarded by a stronger competitiveness of lower order clusters for the assimilates. Large-fruited entries, L 208, CL 5915-206 and FMTT 14, tended to have greater reductions in fruit setting than the small-fruited entries with an increasing order of cluster position. The development of large fruits may act as stronger sinks for assimilates than the fruit-setting process.

Fruit size was related to carpel number (r = 0.91***) and seed number (r = 0.82***). Based on partial correlation and multiple regression analyses, carpel number seems more important than seed number. Carpel numbers of small-fruited L 1488 and CL 5915-153 were 2.1 and 2.3, respectively; whereas those of large-fruited L 208, CL 5915-206 and FMTT 14 were more than 4.0.

Tomato fruit size at the final harvest was strongly related to ovary sizes examined from six DBA to three DAA (r's of all examined stages >0.90***). This clearly indicates that final fruit size is predestined by the initial ovary size before or at anthesis. There were reports of cell enlargement after anthesis, the stage when cell division stops which is responsible for final fruit size. Present results, however, clearly showed that cell division in the pericarp still took place after anthesis/fertilization (Fig. 1). This increased cell number in the pericarp was also strongly related to the increased cellular layer in the pericarp. Both cell number and cellular layer number in the pericarp from six DBA to three DAA were positively correlated with developing ovaries of the respective stage (r's of all stages were > 0.51* for cell number and > 0.56* for cellular layer number). On the other hand, cell size in the pericarp at these stages was not related to the final fruit size. Results presented here, therefore, indicate that tomato fruit size relies much on the cell division in the ovary at stages before and/or near anthesis/fertilization. Cell number in the ovary before or at anthesis should be considered as an important sink size responsible for strong sink strength to drain more assimilates.

From a different approach, size variation in fruits developed from ovaries without sepals cultured under *in vitro* conditions for 30 to 40 days at 18°C (Table 2) was significantly related to that of the field-grown tomatoes (r = 0.81***). Similar results were also obtained from ovaries with sepals. However, fruit sizes of large-fruited CL 5915-206, FMTT 14 and L 208 were reduced when their ovaries without sepals were grown under *in vitro* conditions at 32°C, even though there was still a positive correlation between *in vitro* fruits and field-grown fruits. Results presented here seem to suggest that fruit size is predetermined genetically, but high temperature may have an influence on its expression.

Table 1. Comparison of growth characteristics of five tomato entries.

Entry	Fruit set (%)	Fruit wt. (kg/plant)	Fruit wt. (g/fruit)	Carpel no./fruit	Seed no./fruit
L 208	50.8 d[z]	3.02 b	152 a	5.2 a	85 a
L 1488	84.8 a	0.65 d	11 e	2.1 b	55 b
CL 5915-153	66.0 b	2.46 c	38 d	2.3 b	44 b
CL 5915-206	62.5 bc	3.50 a	113 b	5.4 a	85 a
FMTT 14	59.5 c	2.69 bc	87 c	4.9 a	78 a

[z]Mean separation within column by Duncan's multiple range test at 5% level.

Although the final fruit size is related to cell number in the ovary, the increment in cell number and size also depends on the ability to divert assimilates, i.e. carbohydrates, to the developing fruits. The analysis of carbohydrate level in the reproductive organs and leaves revealed that soluble sugar contents in the ovary, sepal and pedicel at three DBA to seven DAA were negatively related to fruit size (r's for all stages and floral parts < -0.51*), but positively related to fruit set (r's for all stages and floral parts >0.53*). It was possible that high sugar content in floral parts (Fig. 2) readily rendered carbohydrates to facilitate a rather brief process of fruit setting, which consequently created competition for assimilates, and thus, decreased its availability for the continuing process of cell division in the ovary before and near anthesis.

Starch contents in sepal and pedicel at three DBA were positively related to fruit size, r = 0.73*** and 0.62**, respectively. It was possible that the storage form of carbohydrates, i.e. starch in the pedicel and sepal (Fig. 3), was important to ensure the continuous supply of carbohydrates for the long process of fruit development. This was further supported by the fact that starch contents measured from six DBA to 14 DAA in the leaf opposite (Fig. 4) the investigated cluster were positively related to fruit size, except at anthesis where the rather fast process of fruit setting was taking place and required a ready form of carbohydrates.

It appears, therefore, that the analysis of carbohydrates in the sepal and the leaf opposite the cluster may serve as cues for predicting fruit size potential. It is worthwhile to look into varietal differences in these parameters for breeding purposes.

Table 2. Comparison of fruit size and carpel number of ovaries from five tomato entries cultured under *in vitro* conditions.

Entry	Fruit wt. (g/fruit)		Carpel no./fruit	
	18°C	32°C	18°C	32°C
L 208	1.07 a*	0.86 a	5.4 a	6.2 ab
L 1488	0.31 b	0.47 c	2.0 b	2.1 c
CL 5915-153	0.29 b	0.23 d	2.5 b	2.1 c
CL 5915-206	1.07 a	0.25 d	5.4 a	7.2 a
FMTT 14	1.05 a	0.57 b	4.6 a	5.4 b

*Mean separation within column by Duncan's multiple range test at 5% level

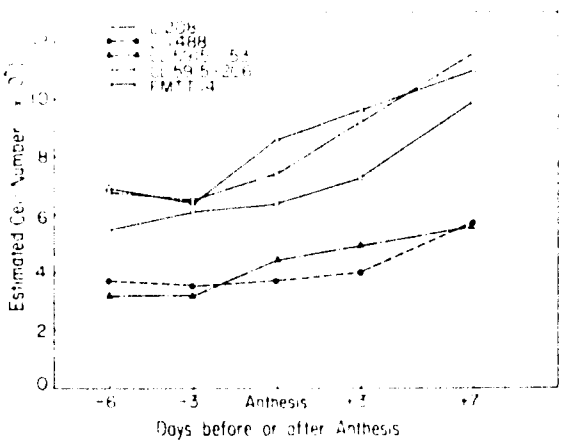

Fig. 1. Estimated cell number in the pericarp at different growth stages for five tomato varieties.

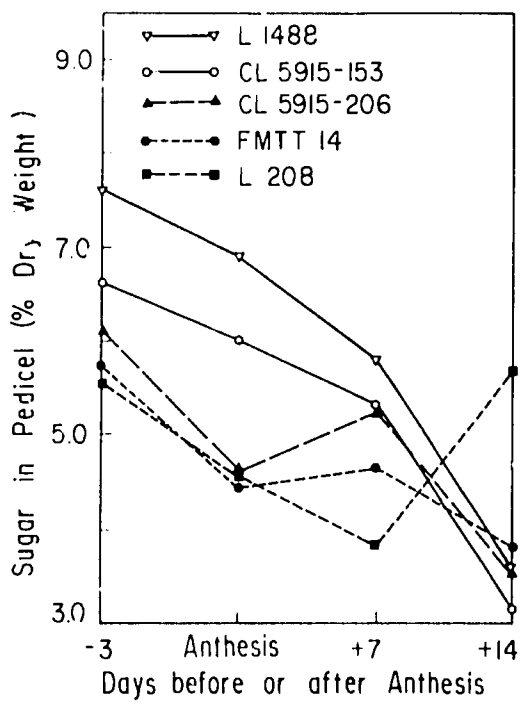

Fig. 2. Changes of soluble sugar contents in the pedicel at different growth stages for five tomato varieties.

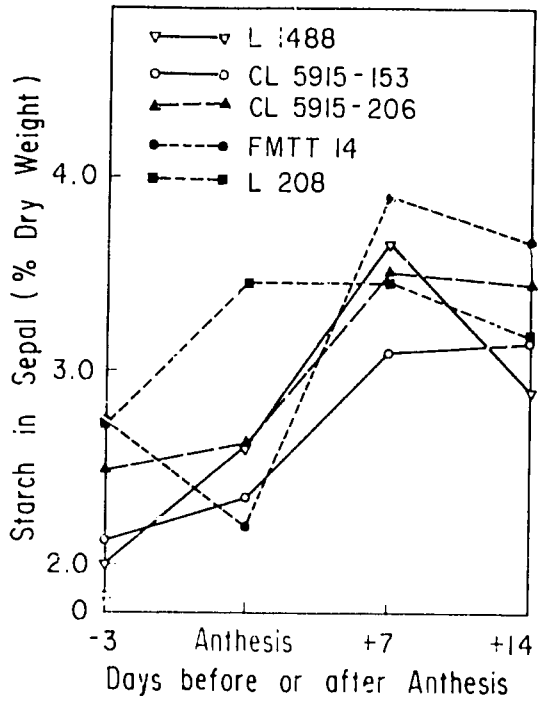

Fig. 3. Changes in starch contents in the sepal at different growth stages for five tomato varieties.

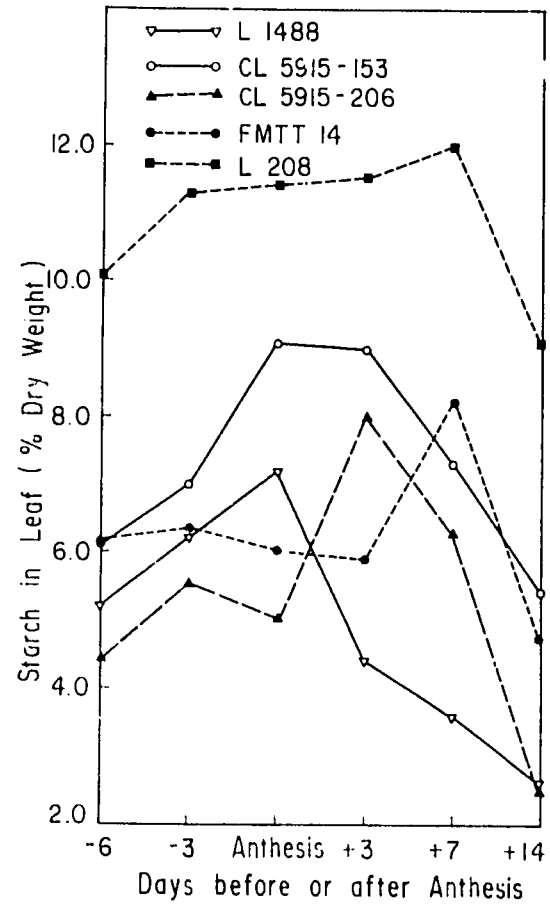

Fig. 4. Changes in starch contents in the leaf opposite the sampled cluster at different growth stages for five tomato varieties.

Hormonal Control and Carbohydrate Changes in Pedicel Abscission of Tomato

Summary

Abscission of tomato floral pedicels was examined under *in vitro* conditions, and carbohydrate contents in the reproductive organs, leaves and stems were determined. Floral pedicels of heat-tolerant CL 5915-153 and L 123 abscised much slower than the other entries. Basipetal applications of IAA at 2 ng/pedicel prevented abscission of all pedicels; acropetal and basipetal applications of ABA and ACC, on the other hand, enhanced abscission of pedicels of CL 5915-153 and L 123. High fruit-setting potential of CL 5915-153 and L 123, under either cool or hot conditions, was likely related to the ready availability of soluble sugars in the reproductive organs. The implication for plant breeding is that some initial screening of tomatoes for heat tolerance, based on *in vitro* pedicel abscission or analysis of carbohydrates with a limited number of entries, may be possible under cool season conditions.

Introduction

Earlier experiments showed that there was a varietal difference in the abscission potential of tomato flower pedicels; pedicels without reproductive organs of heat-tolerant varieties tended to have low

abscission rates. Previous works also indicated that heat stress on fruit-setting process, which involves abscission or retention of pedicels, was likely related to imbalance of endogenous-promoting and inhibitory hormones. Other researchers, on the other hand, suggested that the efficacy in the transport of assimilates to the reproductive organ is important for the fruit-setting process. This experiment continued to clarify the possible role of plant hormones, and examine carbohydrate changes in the abscission process of pedicels.

Materials and Methods

Flower buds with pedicels from seven field-grown tomato entries were collected at three to two days before or at anthesis and transplanted on 12 February 1987. They were sterilized and cut to retain 5- to 8- mm long pedicels. Pedicels were grown aseptically at 26°C in a modified MS medium containing 10% sucrose and 0.8% agar.

Growth regulators were applied to the top or bottom cut surface of cultured pedicels right before transferring them to the medium, but in some cases they were incorporated into the growing medium. There were three replicates for each treatment, and each replicate had 12 pedicels. The abscission layer formation in the pedicel was recorded daily for four days.

On a different approach, peduncles were collected from the second clusters when their first flowers reached three to two days before anthesis, at anthesis, and three days after anthesis. Pedicels and pistils of the same stages were separately collected from the second to the fourth clusters. In the meantime, internodal segments at 2 cm above or below the second cluster, and the leaf immediately below the second cluster were collected. These different plant parts were later analyzed for their soluble sugar and starch contents.

Results and Discussion

The varietal difference in the abscission of *in vitro* pedicels at anthesis obtained from the cool season was demonstrated (Fig. 5). The pattern was similar to what had been previously reported with pedicels obtained from the hot season; pedicels from heat-tolerant tomatoes, such as CL 5915-153 and L 123, tended to abscise slowly under *in vitro* conditions. This seems to suggest that the varietal difference in pedicel abscission or retention can be expressed under *in vitro* conditions regardless of the growing conditions of the plants, and may be utilized for breeding purposes.

When indole-3-acetic acid (IAA) at 2 ng/pedicel or more was applied to the top cut surface of the pedicel, pedicels of all entries did not abscise until the termination of observation at four days after culture. The trend of varietal difference in pedicel abscission or retention was completely masked with auxin application. Results clearly support the notion that auxins play an important role in the fruit setting process, and perhaps also in heat tolerance.

On the other hand, application of abscisic acid (ABA) or 1-aminocyclo-propane-1-carboxylic acid (ACC, a precursor of ethylene), tended to increase abscission of cultured pedicels. Pedicels of both L 3957 and CL 5915-153, with low pedicel abscission under conditions with no hormones, were increased with the application of ABA and ACC (Fig. 6). Since ABA is known to increase under high temperature, it may be involved in heat stress in the fruit-setting process. Furthermore, ACC also exists in tomato plant tissue and may likely play a role in the fruit-setting process.

Although the developing ovules of tomato have been suggested as sites of auxin biosynthesis during the fruit-setting process, the production site for both ABA and ACC is still not clear. Present results indicate that the basipetal application of both ABA and ACC tended to be more effective than the acropetal application. Whether this serves as an indication of the reproductive organ as production sites for ABA and ACC during the fruit setting process still needs to be further studied.

Higher abscission rates in pedicels from anthesis than those from three days before anthesis (Fig. 7) clearly support previous findings that endogenous auxins reached the lowest level at anthesis. Therefore, pedicels obtained before reaching anthesis may contain more auxins, and are thereby less prone to abscission under *in vitro* conditions.

As previously demonstrated, soluble sugar contents in the pistil and pedicel at anthesis were strongly related to the fruit-setting rate, r = 0.73*** and 0.66***, respectively. Similarly, soluble sugar contents in the pistil at two days before anthesis and three days after anthesis were related to

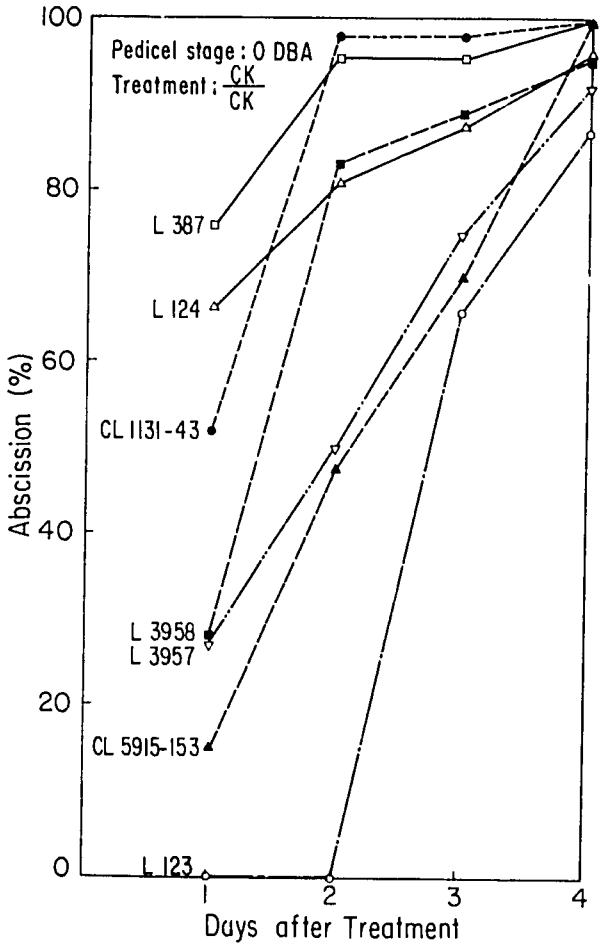

Fig. 5.
Abscissions of *in vitro* cultured pedicels.

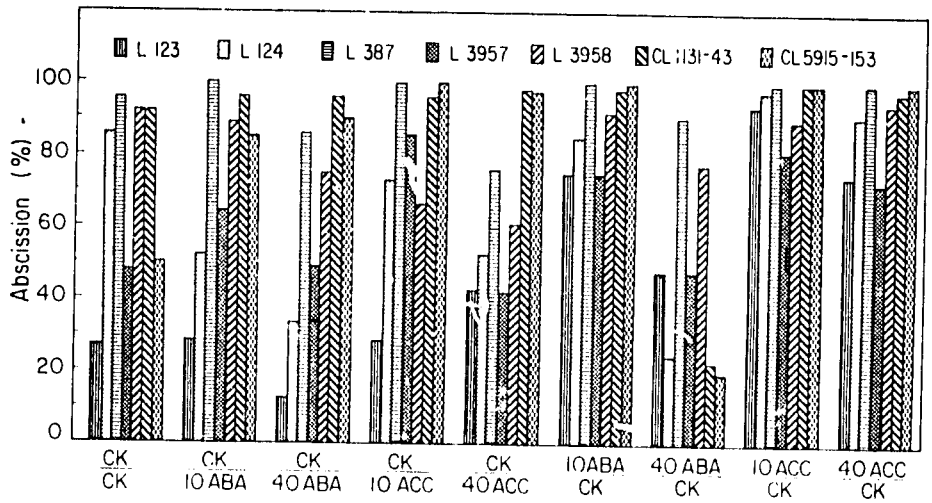

Fig. 6. Abscissions at two days after treatment of *in vitro* cultured pedicels from anthesis. Acropetal or basipetal applications of ABA or ACC were given before pedicel culture.

fruit-setting rate, r = 0.58** and 0.62***, respectively. Pistils of L 123 and CL 5915-153 at anthesis clearly had higher soluble sugar contents than the other entries; a similar trend also occurred in the hot season (Table 3). There was a reverse situation of starch contents in the leaf below the cluster; more starch was accumulated in the leaf of heat-sensitive tomatoes or tomatoes grown under hot season conditions. Results imply that high soluble sugar contents in the pistil readily render itself as available carbohydrates for the rapid fruit-setting process. Poor efficacy of translocating assimilates to the reproductive organs in heat-sensitive tomatoes may be responsible for poor fruit setting under high temperature conditions; thus, accumulating nonutilized carbohydrates in the leaf and stem as previously shown. Whether there is any relationship between the efficacy of carbohydrate translocation and the balance or level of endogenous plant hormones is still not clear.

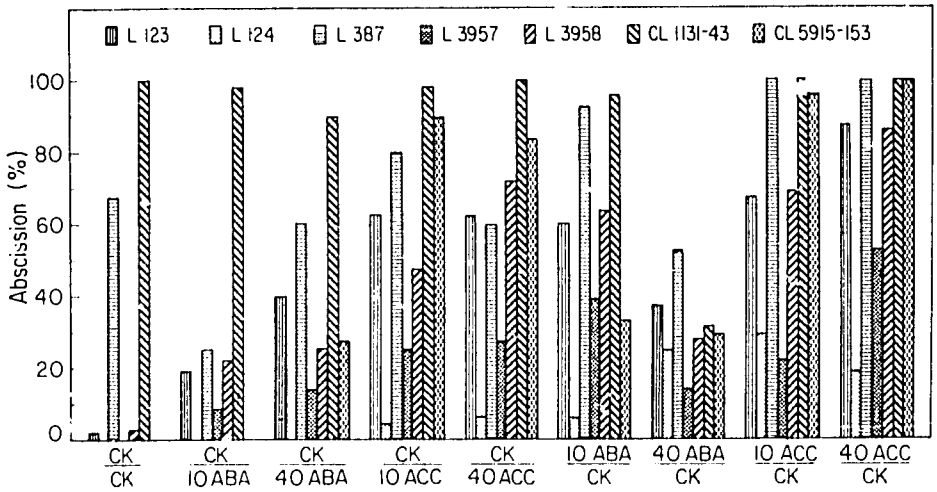

Fig. 7. Abscissions at two days after treatment of *in vitro* cultured pedicels from three days before anthesis. Acropetal or basipetal applications of ABA or ACC were given before pedicel culture.

Table 3. Comparison of carbohydrate contents (% of dry weight) in the pistil and leaf of seven tomato varieties.

Entry	Soluble sugars in pistil		Starch in leaf	
	Hot	Cool	Hot	Cool
L 123	9.63 a[z]	8.63 a	6.60 c	2.72 cd
L 124	6.30 c	6.19 c	8.75 a	5.42 b
L 387	4.59 e	6.15 c	8.43 ab	8.76 a
L 3957	5.40 d	7.11 bc	6.36 c	3.52 cd
L 3958	6.55 c	7.18 bc	7.83 b	4.09 bc
CL 1131-43	6.21 c	8.14 ab	5.99 c	2.98 cd
CL 5915-153	7.76 b	8.83 a	6.50 c	2.18 d

[z]Mean separation within column by Duncan's multiple range test at 5% level.

Comparisons of CPA, Brassinolide and BAS 112 00 W on Tomato Fruit Set

Summary

Both brassinolide and BAS 112 00 W were tested on tomato for possible improvements of fruit set and yield under high temperature conditions. No effect was observed with brassinolide; however,

BAS 112 00 W increased fruit set of heat- sensitive L 387, and fruit yield of both heat-tolerant FMTT 14 and heat-sensitive L 387. BAS 112 00 W was more potent than a commonly used growth regulator, CPA; however, it had a similar effect as CPA to cause parthenocarpic fruit set.

Introduction

A synthetic auxin, para-chloro-phenoxyacetic acid (CPA), was known to be effective in improving fruit set, development and yield of tomato under unfavorable conditions. However, this synthetic growth regulator usually causes parthenocarpic and misshapen fruits. The purpose of this experiment was to test the effects of two new growth regulators, brassinolide and BAS 112 00 W, on fruit set and yield of two tomato varieties under high temperature conditions.

Materials and Methods

Seedlings of L 387 (White Skin) and FMTT 14 were transplanted to ID 20 cm clay pots on 11 June 1987. They were staked and pruned as a single stem and grown under greenhouse conditions.

Each cluster was individually sprayed once with growth regulators in 0.02% Tween 20 when its second flower started to open. Individual plants were investigated for fruit set, fruit size, and carpel and seed number of fruits. At the termination of the experiment, dry weight of the shoot was also determined.

Results and Discussion

No apparent effects of brassinolide on fruit set and other characteristics were observed. BAS 112 00 W, however, at 0 5 ppm or higher concentrations significantly improved fruit set of heat-sensitive L 387 over the control, but not with heat-tolerant FMTT 14. FMTT 14 was able to produce fruits without chemical application under high temperature conditions. On the other hand, BAS 112 00 W concentrations at or higher than 0.5 ppm increased fruit size of both L 387 and FMTT 14; thus, the fruit yield of both entries was increased (Table 4).

Table 4. Effect of BAS11200W (BAS) and CPA on fruit yield and yield components of two tomato varieties.

Treatment (ppm)	Fruit set (%)	Fruit no./plant	Fruit size (g/fruit)	Fruit yield (g/plant)	Immature seed no./ fruit	Shoot dry wt. (g/plant)
FMTT 14						
BAS						
0.25	39 a[z]	9.8 a	21.7 d	210 bc	19 c	39 6 ab
0.50	31 ab	7.7 ab	28.5 c	217 bc	46 b	38.0 b
1.00	28 b	7.0 b	37.0 b	258 ab	55 ab	35.7 b
2.00	28 b	6.9 b	42.3 a	288 a	58 ab	32.5 c
CPA						
50.00	31 ab	7.8 ab	30.5 c	231 a-c	64 a	35.0 bc
Control	32 ab	8.0 ab	22.0 d	177 c	17 c	42.7 a
L 387						
BAS						
0.25	10 b	2.5 b	26.0 a	66 b	57 a	42.2 a
0.50	20 a	5.0 a	30.2 a	148 a	77 a	27.7 b
1.00	20 a	5.0 a	31.9 a	156 a	67 a	28.9 b
2.00	9 b	5.2 a	32.7 a	168 a	74 a	29.6 b
CPA						
50.00	11 b	2.7 b	27.5 a	67 b	86 a	43.3 a
Control	6 b	1.6 b	16.2 b	34 b	17 b	41.0 a

[z]Mean separation within column of each variety by Duncan's multiple range test at 5% level.

Low shoot dry weight of BAS 112 00 W-treated plants indicated that more dry matter was diverted to the fruits. The positive effect of BAS 112 00 W on fruit yield can be attributed to the partition of dry matter. The promotive effects of BAS 112 00 W on fruit set and size concentrated on the first two flowers of each cluster. Since the chemical was sprayed only once to the cluster when its second flower was at anthesis, it appears that further increase may be possible when the chemical is again applied or only applied at high order of flowers in bloom.

Fruits of either L 387 or FMTT 14 induced by BAS 112 00 W had comparable color, acidity and solid content as those of the control. On the other hand, fruits induced by CPA and BAS 112 00 W had more immature seeds than the control, but comparable number of mature seeds with the control. There was no apparent discrepancy of effect on seed number between CPA and BAS 112 00 W; this indicates that although BAS 112 00 W is more potent than CPA to promote fruit set at high temperature, BAS 112 00 W may have a similar mechanism as CPA to induce parthenocarpic fruit set.

Production Systems Program

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Chemistry

Nutritional and Processing Quality of Vegetable Soybean

Summary

The nutritional quality of vegetable soybean was compared with green pea. Vegetable soybean was found to be more nutritious than green pea based on the dietary pattern of Taiwan. It is an excellent source of thiamine and a good source of protein, iron, riboflavin and phosphorus based on nutritional quality index expressed as a nutrient density ratio. The postharvest properties of three vegetable soybean cultivars, Taishoshiroge (AGS 292), Tzurunoko (205) and Ryokkoh (305), were evaluated. The pod color of cultivar AGS 292 degraded faster than the other two cultivars. Frequent spraying of tap water was found to be effective in preventing color degradation of this cultivar. AGS 292 also had lower protein content. Compositional analysis revealed that carbohydrates, sugar and starch are major constituents lost after harvest.

Introduction

Vegetable soybean is a traditional commodity in East Asia. Its processing industry, however, was developed only recently in Taiwan for the Japanese market. Vegetable soybean, although only different from grain soybean in maturity, can be considered as a horticultural crop. The market value of this commodity is highly dependent on its quality. Pod size and number of seeds per pod are most important characteristics for grading purposes. Pod color, texture and flavor are associated with consumers' preference.

A Japanese cultivar, Taishoshiroge (AGS 292), was selected and released as a new cultivar in 1987. This line is high yielding with high graded pod number. Local processors reported that this new selection is less preferred in flavor and poor in postharvest property. Its chemical composition and color degradation after harvest is compared with the popular variety Tzurunoko (205) and high quality line Ryokkoh (305).

Materials and Methods

Sample preparation. All samples were obtained from the spring field trials at AVRDC. Small- or one-seeded pods were sorted out before treatment. Unless otherwise stated, samples were blanched in salt solution (5%) for 90 seconds within two hours after harvest and stored in the freezer until analysis.

Composition analysis. Conventional methods used at the Chemistry Laboratory were followed during the analysis.

Pod color rating. Right after blanching, the color of each pod per 500 g sample was rated against the Mitsubishi color chart for vegetable soybean. The overall color is expressed as the weighted average grade of the sample.

Treatments. The storage conditions for vegetable soybean samples were: 25°C, 85% RH; 30°C, 85% RH; and water spray for 30 seconds for every 30 min. Every two hours, 500 g samples from two replications were taken.

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Results and Discussion

Nutritional constituents. Selected nutritional constituents of vegetable soybean and green pea are listed in Table 1. Calculations of the nutritional quality index, expressed as nutrient density ratio, indicated that vegetable soybean is an excellent source of thiamine; good source of protein, iron, riboflavin and phosphorus; adequate source of ascorbic acid; fair source of calcium; and a poor source of vitamin A. The nutritional value of vegetable soybean, estimated from eight major nutrients and relative nutrient cost of Taiwan, is 26.5 unit which is 46% higher than green pea. The major difference in the nutritional value of these two commodities is due to energy, minerals and thiamine. Since there are no complete nutrient analysis data on the three cultivars, their nutritional value cannot be compared. But the low dry matter and protein content of AGS 292 suggested that this line is less nutritious.

Quality related properties. Although the marketable pod yield of AGS 292 is much higher than the other two cultivars, local processors reported that this line is less preferred by some Japanese consumers due to its taste and flavor. A triangle test was conducted to confirm this. Panels were not able to detect the difference between AGS 292 and the check cultivar 205. However, they were able to distinguish cultivar 305 from the other two lines only when it was served as an odd number of the test. This result suggested that the taste difference among the three cultivars is not easily detectable and it is difficult to establish a relationship with chemical compositions. Chemical analysis of the selected quality properties were conducted and are summarized in Table 2. Other properties, such as individual sugar pattern and flavor compound analysis, will be included in future studies. Biochemical properties such as lipoxygenase, β-amylase, and peroxidase had been investigated. No major difference among these three cultivars were observed.

Changes in pod color and composition after harvest. The pod color of AGS 292 degraded faster than the other two cultivars. This property was confirmed by monitoring pod color after harvest (Fig. 1). Spray water proved to be effective in prolonging color retention. This method, however, was not very effective when applied to the other two cultivars.

Analysis of the major constituents at 2, 6 and 12 hours after harvest revealed the following trends: decrease of dry matter content ($p > 0.05$); decrease of sugar content ($p > 0.01$); decrease of starch content ($p > 0.01$); increase of lipid ($p > 0.01$); and increase of fiber composition ($p > 0.01$). The changes in other constituents, such as protein, ash and individual minerals, with time were not significant. The postharvest losses on major vitamins are still under investigation.

Table 1. Some nutritional constituents of edible protein of vegetable soybean and green pea.[z]

Constituent	Vegetable soybean				Green[y]
	Market	205	AGS 292	305	pea
Energy (kcal/100 g)[x]	132.0	150.0	136.0	143.0	93.0
Moisture (%)	69.0	66.7	69.7	67.8	76.5
Protein (%)	11.2	14.3	11.4	13.6	7.4
Fat (%)	6.4	6.5	6.4	6.5	4.0
Crude fiber (%)	1.6	1.5	1.7	1.8	2.7
Ash (%)	1.5	1.6	1.9	2.1	1.0
N-free ext. (%)	9.8	9.4	8.9	8.2	12.0
Phosphorus (mg/100 g)	143.0				110.0
Calcium (mg/100g)	50.0				26.0
Iron (mg/100 g)	4.6				2.0
Vitamin A (RE)	Trace				Trace
Thiamine (mg/100 g)	0.59				0.26
Riboflavin (mg/100 g)	0.14				0.14
Ascorbic acid (mg/100 g)	8.00				24.00

[z]Source: Taiwan Food Composition Table. [y]Source: Standard Tables of Food Composition in Japan. [x]Calculated based on conversion factors of 4.0 kcal/g protein; 8.46 kcal/g of fat; and 4.07 kcal/g of N-free ext.

Table 2. Selected quality properties of three vegetable soybean cultivars.

Properties	Cultivars		
	205	AGS 292	305
Shelling (%)	47.47	45.88	42.83
No. of pod/500 g	179.00	157.00	140.00
100-seed wt. (g)	68.40	64.90	82.10
Color rating*	4.51	4.30	4.32
Seed texture			
Hardness (dye/cm^2)[z]	65113.00	64090.00	68311.00
Compressed dist. (mm)[z]	1.70	1.70	1.50
Composition (on dry wt.)			
Dry matter (%)*	33.30	30.30	32.20
Alc. Insoluble Solids (%)**	27.10	22.70	25.50
Protein (%)**	42.80	37.50	42.30
Fat (%)**	19.50	21.20	20.30
Crude fiber (%)**	4.50	5.50	5.60
Starch (%)[z]	9.30	9.50	9.50
Sugar*	11.40	10.90	10.60

[z]Not significant; *5% level; **1% level.

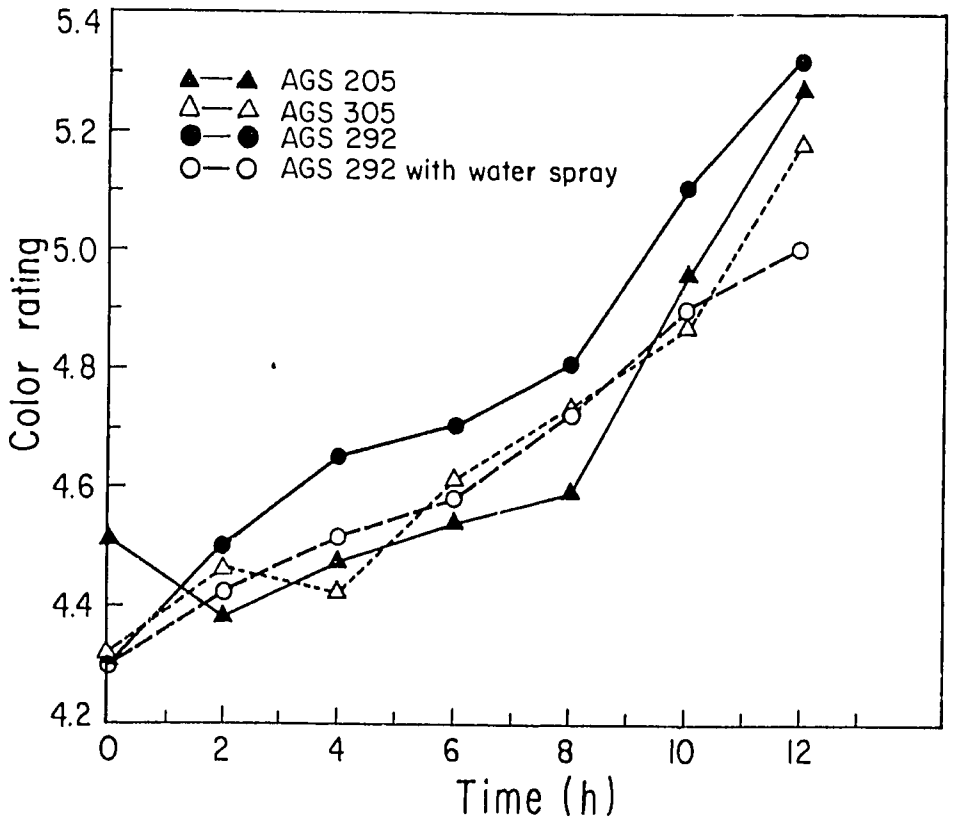

Fig. 1. Changes in pod color of three vegetable soybean cultivars after harvest under 30°C and 85% RH.

One serious problem observed in this experiment was the development of white spots on the pod surface after harvest. This problem was most severe in AGS 292. The infection rate could reach 100% under 30°C for eight hours. Water spray seemed to reduce the rate of development but was not very effective. This problem and control measures deserve further studies.

Conclusion

Vegetable soybean is a nutritious commodity with a high density of thiamine, protein, riboflavin, iron and phosphorus. It is more nutritious than green pea based on the Taiwan diet. Since it can be grown in warm environments, it has great potential in the tropics. The newly selected high-yielding cultivar, AGS 292, has slightly lower protein content and the desired pod color is more difficult to retain. Frequent water spraying after harvest could be a feasible method to improve the market quality of this cultivar.

Effect of Dietary Constituents on the Bioavailability of Provitamin A

Summary

The effects of dietary constituents, such as protein source, starch source and edible fibers as well as the contents of provitamin A, nonprovitamin A carotenoids and chlorophylls, on the bioavailability of provitamin A were studied with experiments utilizing rodents. The bioavailability of β-carotene was found to be a reciprocal function of β-carotene concentration. Nonprovitamin A carotene, lycopene, inhibited the bioavailability of α-carotene and β-carotene but not β-cryptoxanthine. Protein quality affected the bioavailability of β-carotene of sweet potato starch-based diets but this effect was not significant on corn starch-based diet. Studies on protein and starch source combinations suggested that casein-rice starch diet was the best combination tested. High edible fibers in diet reduced the bioavailability of provitamin A. Lignin was found to be a stronger inhibitor than pectin, hemicellulose and cellulose.

Introduction

Several methods can be used to estimate the biological activity of provitamin A in fruits and vegetables. The method commonly used is conversion to retinal equivalent based on contents and structures of provitamin A. The conversion rates are 6 μg β-carotene or 12 μg of other provitamin A as 1 μg retinol. This method is based on the assumption that the biological activity and digestibility of β-carotene is about 50% and 33% that of retinol, respectively, and the activity of the other provitamin A is about 50% of β-carotene. On the other hand, the biological activity of a given provitamin A, measured by bioassay method, varies according to commodity, intake level and dietary composition. The bioavailability of selected vegetables and fruits varied from 11.6% to 23.4% under controlled feeding experimental conditions. A better understanding of the effects of dietary composition on the bioavailability of provitamin A may provide useful information for commodity selection, diet designing and estimation of nutritional status, especially in regions in which vitamin A is still deficient.

Materials and Methods

Materials. Vegetables and fruits were collected from the AVRDC breeding program, garden project and the local market. The samples were freeze-dried and ground to powder, then sealed in a plastic bag and kept in a desiccator at a temperature around 4°C before they were mixed into diets for the bioassay. Carotenoid standards were prepared from vegetables and fruits through conventional procedure.

Bioassay. Twenty-one-day old male rats of Long-Evans were purchased from the Animal Center of the National Taiwan University (NTU). The rats were fed with vitamin A–free diet for four weeks for the depletion of vitamin A storage. Four rats housed in individual cages in each treatment were fed with the test diet for a 10-day period. For the test diets, isolated carotenoids or standards were dissolved in soybean oil then mixed in a vitamin A–free diet. The rats' livers were removed 48 hours after the end of the testing period, and frozen until analysis of retinol content. Livers were homogenized and extracted by methanol, following saponification to release retinol from its ester form and then determined by High Pressure Liquid Chromatograph (HPLC).

Calculation. The bioavailability of provitamin A carotenoids or vegetables and fruits were calculated by the following equation:

$$\text{Availability } \% = \frac{\text{Retinol storage in liver of treatment } (\mu g) - \text{Retinol storage in liver of control } (\mu g)}{\text{Total intake of provitamin A expressed as } \beta\text{-carotene equivalent } (\mu g)}$$

Rats in the control groups were fed with a vitamin A free diet during the testing period. Total intake of provitamin A was expressed as β-carotene equivalent. The test diet with β-carotene standard was used as the check in every experiment.

Results and Discussion

Inhibitory effect of nonprovitamin A pigments. The bioavailability of provitamin A was reported to be a dependent value of the intake level. Further studies revealed that the bioavailability of β-carotene is a reciprocal function of the β-carotene concentration of the diet. A regression equation of:

$$\text{Bioavailability} = 1/(0.0259 + 0.00223\ \beta\text{-carotene concentration})$$

can be established ($r^2 = 0.931$). The β-carotene concentration is expressed as μg per 10 g diet. A similar relationship was also observed for other provitamin A carotenoids. Studies on the interactions of plant pigments on the bioavailability of provitamin A were continued. The interactions, at a fixed provitamin A concentration, are summarized in Figure 2. Nonprovitamin A carotenoids or chlorophyll inhibited the

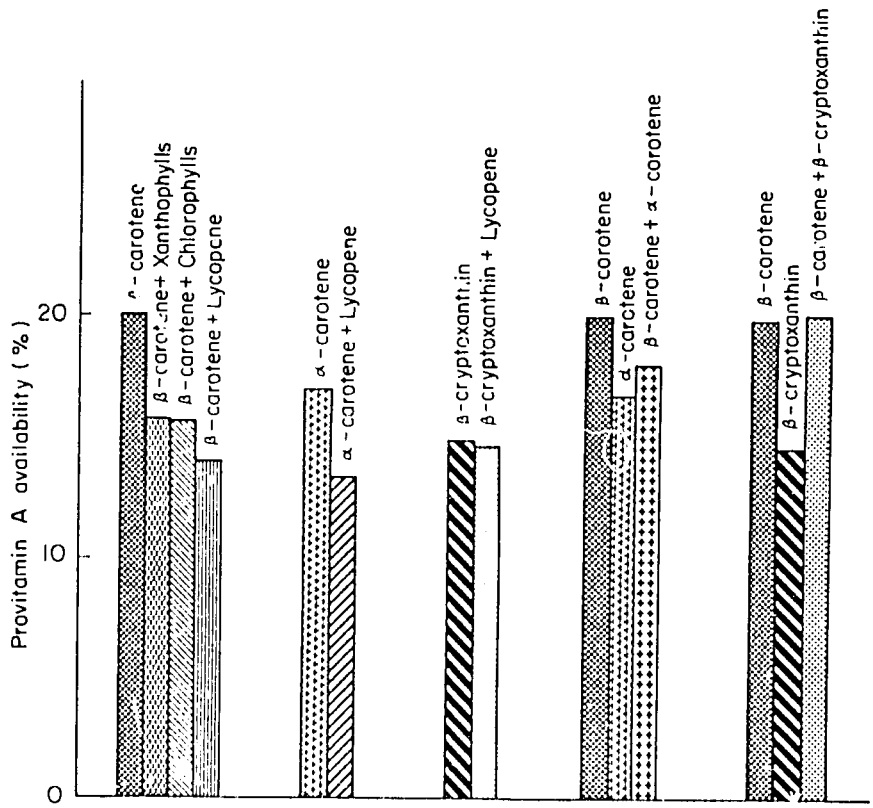

Fig. 2. Interactions of plant pigment on the bioavailability of provitamin A. Concentration of each pigment is 10 μg per g diet or 10 μg provitamin A carotenoids when more than one provitamin A carotenoid was used.

availability of the provitamin A except the tested carotenoids, which indicated that lycopene had no inhibition on β-cryptoxanthine. The quantitative data indicated that these effects may be associated with the polarity of the provitamin A compounds. In addition, nonprovitamin A pigments with higher polarity were also a weaker inhibitor.

Effects of dietary compositions. The effects of protein and starch source on the bioavailability of provitamin A are summarized in Table 3. The lower availability of provitamin A observed in this experiment was due to the low protein concentration in the diet. Statistical analysis revealed that there was no significant difference among protein sources used for corn starch-based diet; but a significant effect was observed for sweet potato starch-based diet. The effect of various starch sources on casein-based diet was found to be highly significant. Casein-rice starch diet tended to be the best among the combinations tested.

The effect of various types of edible fiber on provitamin A availability is summarized on Figure 3. All fibers tested decreased the availability of provitamin A. Lignin was found to be a stronger inhibitor for bioavailability of provitamin A.

Conclusion

Besides protein and provitamin A concentration in the diet, factors such as nonprovitamin A carotenoids, chlorophylls, fiber content and nature of protein or starch may affect the bioavailability of provitamin A. Higher provitamin A intake is recommended for diets with low protein content and high fiber concentration. The inhibitory effect of nonprovitamin A carotenoids, chlorophylls and fiber could be the major factors responsible for the low availability of provitamin A in green leafy vegetables.

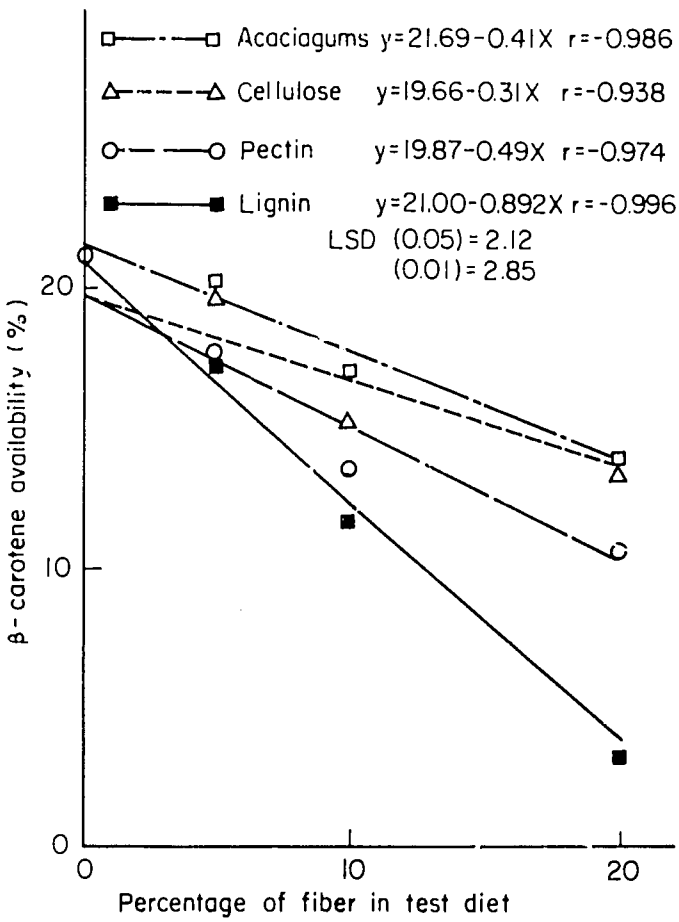

Fig. 3.
Effect of fiber source on β-carotene availability. The concentration of β-carotene was 10 μg/g diet.

Table 3. Effects of protein and starch source on provitamin A availability.

Protein source[z]	Starch source	Bioavailability of provitamin A
Casein	Corn	10.11[y]
Soybean	Corn	11.24
Gluten	Corn	11.48
Gluten	Sweet potato	8.82
Soybean	Sweet potato	13.70
Casein	Sweet potato	13.24
Casein	Potato	13.02
Casein	Wheat	12.14
Casein	Rice	14.49
Casein (22%)	Corn	19.31

[z]Protein concentration, 10%. [y]LSD (5%) = 2.0; LSD (1%) = 2.7.

Crop Management

Effect of Number of Plant/Hill and Spacing on Vegetable Soybean

Summary

The yield of vegetable soybean and its attributes were significantly affected by spacing and the number of plants/hill. Wider spacing and less number of plants/hill resulted in more pods and branches per plant but more empty pods. Conversely, yields from plots with narrow spacing and more plants/hill were higher than those with wide spacing and lesser plants/hill due to higher population density.

Introduction

The ideal vegetable soybean plants should have the following characteristics: shorter plant height, more pods per plant, large green seed size and high pod ratio, with two or more seeds. In general, pod yield and the character of the yield components can be affected by cultural management. Last year, it was found that the number of plants/hill and spacing had a significant effect on pod yield and its components. The experiment was repeated again this year to evaluate the response of the crop to different numbers of plants/hill and spacings.

Materials and Methods

The experiment was conducted using split-split-plot design with two replications, with the number of plants/hill (1 and 2) as the main plot, interrow spacing of 25, 50 and 75 cm as the subplot and intrarow spacing of 10, 15 and 20 cm as sub-subplot. The population density of the plant varied from 66,700 to 800,000 plants/ha. The sub-subplot size was 4.5 m × 6.0 m, accommodating 6 to 18 rows of soybean plants. All plots received 40 kg N/ha, 80 kg P_2O_5/ha and 100 kg K_2O/ha as basal fertilizer and were planted with soybean, G9053, on 18 February 1987. An additional 40 kg N/ha was sidedressed at flowering. The crop was harvested on 5 and 6 May. A 3 m^2 area in the center of each plot was harvested for pod yield determination. A subsample of 40 plants, taken randomly from the area, was used to determine the various characters of the yield components.

Results and Discussion

The effect of the number of plants/hill and spacing on pod character is presented in Table 1. A higher number of plants/hill gave less empty pods and tended to give less total number of pods/plant. Pods with one, two or three seeds were not affected by the number of plants/hill. More pods of all characters, except the three-seeded of the intrarow spacing, and the three- and zero-seeded of the interrow spacing, were obtained when spacing was increased. Among the interrow spacing, 75 cm gave the highest number of pods/plant (26.0) and had the highest number of pods, with one and two seeds. Among the intrarow spacing, 20 cm and 15 cm had an equal number of total pods, with one, two, three and empty seeds. All of these numbers, except the three-seeded and empty pods using 15-cm spacing, were significantly higher than those of the 10-cm spacing.

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Wider spacing, both inter- and intraspacing, increased the number of branches/plant, whereas the number of plants/hill had no effect on this character (Table 2). The lowest branch number was 1.2 from the plot with 25-cm interrow spacing and 1.6 from one using 10-cm intrarow spacing. The yield was significantly increased when the crop was planted with narrow spacing or with higher number of plants/hill. Yields from plots with 10-cm and 15-cm spacings were equally high and were higher than that with 20-cm spacing. Among the interrow spacing, plots with 25-cm interrow spacing gave the highest yield, whereas plots using 75 cm gave the lowest; plots with interrow spacing of 50 cm gave an intermediate yield.

These results clearly show that wider spacing resulted in more pods and branches per plant, but the yield was lower due to lower population density. Although plots with narrow spacing had less pods and branches per plant, they had higher population density. Yield increase due to higher population density was more than that reduced by less number of pods and branches per plant. The relationship between yield and population density and number of pods and branches had $R^2 = 0.99^{**}$, with path coefficient of 3.2 for population density, 1.4 for number of branches and 0.9 for number of pods. This resulted in higher yield in narrow space planting than in wide space planting.

Table 1. Vegetable soybean pod character as affected by spacing and number of plants per hill.[z]

Treatment	Population (no./m^2)	Pod character (no./plant) 0 seeded	1 seeded	2 seeded	3 seeded	Total
No. plants/hill						
1	17.6	3.8 a	5.8 a	13.6 a	0.8 a	24.1 a
2	35.3	2.3 b	4.8 a	11.5 a	0.8 a	19.4 a
Interrow (cm)						
25	43.3	2.4 a	3.4 b	8.5 c	0.7 a	15.1 c
50	21.7	3.6 a	6.1 a	13.7 b	0.9 a	24.2 b
75	14.4	3.1 a	6.4 a	15.5 a	0.9 a	26.0 a
Intrarow (cm)						
10	36.7	2.4 b	4.3 b	10.9 b	0.7 a	18.3 b
15	24.4	3.1 ab	5.9 a	13.1 a	0.9 a	23.0 a
20	18.3	3.6 a	5.7 a	13.7 a	0.9 a	23.9 a

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

Table 2. Number of branches, number of pods and pod yield of vegetable soybean as affected by spacing and number of plants per hill.[z]

Treatment	Pods (no./plant)	Branch (no./plant)	Yield (t/ha)
No. plant/hill			
1	17.6	2.5 a	6.3 b
2	35.3	1.6 a	8.1 a
Interrow (cm)			
25	43.3	1.2 b	8.1 a
50	21.7	2.4 a	7.3 b
75	14.4	2.6 a	6.2 c
Intrarow (cm)			
10	36.7	1.6 b	8.0 a
15	24.4	2.3 a	7.4 a
20	18.3	2.4 a	6.2 b

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

Effect of Spacing on the Growth and Yield of Bell Pepper

Summary

A field study was conducted to evaluate the effect of spacing on the growth and yield of bell pepper. The results indicated that when spacing was decreased, yield of the crop was increased. The

50-cm spacing gave the highest yield among the interrow spacings, whereas 40-cm spacing yielded the highest among the intrarow spacings. Yield difference was due to difference in number of fruits/plant and number of plant stands. The relative importance of the plant stand contribution toward the difference in yield was 2.3 times that of the number of fruits/plant.

Introduction

Spacing is one of the many factors that control plant size (vegetative growth) and eventually crop yield. Plants grown under wide spacing are generally bigger and give higher yield/plant compared to those grown under narrow spacing. However, the yield/area of plants grown under wide spacing may be less than those grown under narrow spacing due to less population density. The present study was conducted to evaluate the effect of spacing on growth and yield and yield attributes, i.e. fruit size and number of fruits/plant, of bell pepper.

Materials and Methods

Split-plot design with three replications was used in this study. The main plots used 50-, 60- and 70- cm interrow spacing, whereas the subplots used 40-, 45- and 50- cm intrarow spacing. Plot widths were 2, 2.4 and 2.8 m, respectively, for the interrow spacings of 50, 60 and 70 cm. All plots were 6-m long. Twenty-nine-day old seedlings of bell pepper cv. Blue Star, which had about five to six true leaves, were transplanted onto the plots on 6 March 1987 in four rows in each plot. Basal application of fertilizer was done at the rate of 40 kg N/ha, 80 kg P_2O_5/ha and 50 kg K_2O/ha. Sidedressing of fertilizer at 40 kg N/ha and 50 kg K_2O/ha was done twice at two and four weeks after transplanting. Furrow irrigation was done four times on 6 March, 21 and 30 April and 15 May. The crop was harvested from the two center rows seven times on 27 and 30 April, 8, 14, 21 and 28 May and 4 June. At the last harvest, fresh plant weight was determined from 10 plants/plot taken randomly from the two center rows.

Results and Discussion

Plant height, measured four, five and six weeks after transplanting, was not affected by either inter- or intrarow spacing (Table 3). Fresh plant weight at harvest tended to be reduced when both inter- and intrarow spacings were decreased (Table 3). This indicates that the minimum spacings tested were not too narrow to significantly reduce plant growth. Planting the crop closer will be tested in future trials.

Plant stand at harvest, yield and its attributes are presented in Table 4. Yield was significantly affected by spacing. When spacing was decreased, crop yield increased. The plot with 50-cm spacing gave the highest yield among the interrow spacings, whereas that with 40-cm spacing yielded the highest

Table 3. Plant height at different times and plant fresh weight at harvest of bell pepper as affected by spacing.

Spacing (cm)	Height (cm)[z] Weeks after transplanting			Plant fresh weight[z] (g/plant)
	4	5	6	
Interrow				
50	21.2	31.1	35.8	338.3
60	21.4	31.4	37.1	369.4
70	21.4	30.7	35.8	376.7
Intrarow				
40	21.6	31.6	35.9	325.6
45	21.4	31.0	36.2	370.6
50	21.1	30.7	36.6	388.3

[z]The differences were not significant.

Table 4. Yield, fruit number, fruit size and plant stand of bell pepper as affected by spacing.[z]

Spacing (cm)	Yield (t/ha)	Fruit number (no/plant)	Fruit size (g/fruit)	Plant stand (no/m^2)
Interrow				
50	41.1 a	10.0 a	94.8 a	4.4 a
60	37.6 ab	11.0 a	90.7 a	3.7 b
70	30.0 b	11.3 a	87.0 a	3.1 c
Intrarow				
40	38.8 a	10.2 b	91.1 a	4.2 a
45	36.1 ab	10.8 ab	92.6 a	3.6 b
50	33.9 b	11.3 a	88.3 a	3.4 c

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

among the intrarow spacings. Wider spacing resulted in more fruits/plant (intrarow only) but less plant among population density. Spacing had no significant effect on fruit size. Yield difference was due to differences in the number of fruits/plant and plant stand (R^2 = 0.95**). The relative effect of the plant stand toward yield difference was 2.3 times higher compared to the number of fruits/plant; path coefficient was 0.70 and 1.63, respectively, for number of fruits/plant and plant stand. This means that although the number of fruits/plant was reduced by narrow spacing, yield reduction was offset by yield increase due to high number of plant stands. This explains why narrow spacing resulted in higher yield than wide spacing.

Soft Rot Control in Chinese Cabbage Using Solarization Techniques

Summary

Soft rot is one of the most destructive diseases in Chinese cabbage. It infects the crop extensively in the hot-wet summer season. At present there is no reliable chemical control measure for this disease and not a single crop variety is resistant. By using a solarization technique, whereby the Chinese cabbage beds were covered and solarized by clear plastic sheets for 12 days, the soft rot incidence was drastically reduced from 45% to 5%. About 71% of marketable yield was saved by this technique.

Introduction

Soft rot, *Erwinia carotovora*, is one of the most destructive diseases of Chinese cabbage. It infects the crop extensively in the hot-wet summer season. So far, there is no reliable chemical control against the disease and not a single variety of the crop is resistant. Appropriate cultural management practices may help alleviate the situation. This study was conducted to evaluate the effect of solarization on disease incidence and on the growth and yield of Chinese cabbage.

Materials and Methods

The experiment was carried out using a randomized complete block design with three replications. After the field was rototilled, 1.5 × 6.0 m beds were constructed. Individual plots consisted of three beds. Only the center beds were planted with Chinese cabbage; the other two served as border blank beds. The replications were separated by 1.5-m walkways. The treatments included were: rice straw mulching at the rate of 5 t/ha, single and double layer solarizations and the check. All treatments were applied 12 days before transplanting. Solarization was done by covering the beds flat with clear plastic sheet (0.05 mm thick). In the double layer solarization treatment, another plastic sheet was placed on the beds in the shape of a tunnel. All plastic sheets from the solarization treatments were removed two hours before transplanting.

On 3 August 1987, 33-day old Chinese cabbage seedlings of the soft rot-susceptible cultivar, Fung Luh, were transplanted onto the beds with 50-cm spacing for both between and within rows. To minimize disturbance on the beds, fertilizer was applied by banding between plants at the rate of 60 kg N/ha, 80 kg P_2O_5/ha and 70 kg K_2O/ha seven days after transplanting (DAT) and 60 kg N/ha and 30 kg K_2O/ha 16 DAT. To avoid any contamination from each plot, furrow irrigation was not used; the plants instead were watered one by one from the watering can. On 28 August when the plants were big enough, they received 50 mm water from an overhead sprinkler irrigation. Heavy rain of 104 mm occurred on 30 August. Total precipitation during the growing season was 298.5 mm. The crop was harvested on 18 September and the soft rot incidence recorded. All plants were harvested, except those at both ends of each row. All clean heads were considered marketable yield; those infected by soft rot were regarded as nonmarketable.

Results and Discussion

Soil temperature at 10 cm depth was increased drastically by solarization (Table 5). The highest temperature was from the double layer solarization, 53.5°C on a clear day and 37.5°C on a cloudy day. The check temperature was 32°C on a clear day and 28°C on a cloudy day.

Plant height was significantly reduced by the solarization treatments (Table 6). At seven and 10 DAT, mulched plants were the tallest, whereas those under double layer solarization were the shortest. Solarization significantly increased soil temperature and, hence, increased evaporation from the soil. The water vapor trapped in the plastic sheet during the day time condensed and dropped off and wet the soil surface during the night. This alternate wetting and drying process during solarization caused crusting of the soil surface resulting in poor soil aeration, which is unfavorable for plant growth. The effect was more pronounced in the double layer than in the single layer since the temperature under the former was higher. This may be the reason why plants from the solarization treatments did not have as good growth as those from the other treatments at the early growth stage. However, the effect was only temporary since plant growth, as measured by total weight at harvest, of the solarization treatments was as good as the check and was better than those of the mulch treatment (Table 6). Low total weight in the mulch treatment may be due to more senesced leaves at harvest under this treatment than in the other treatments.

The effect of solarization and mulching on the percentage of soft rot incidence, yield and number and size of marketable heads are presented in Table 7. Solarization or mulching did not affect head sizes but significantly reduced soft rot incidence compared to the check. The incidence was reduced from 45% to 5% in the single layer solarization treatment. The incidence in solarization tended to

Table 5. Effect of solarization and mulching on soil temperature at 10-cm depth.

Treatment	Soil temperature at 2:00 pm (°C)	
	Clear day	Cloudy day
Check	32.0	28.0
Solarization (single layer)	49.0	34.0
Solarization (double layer)	53.5	37.5
Mulching	30.5	27.0

Table 6. Plant height and weight of Chinese cabbage as affected by solarization and rice straw mulching.[z]

Treatment	Plant height (cm)		Total weight
	7 DAT	10 DAT	(kg/plant)
Check	15.9 ab	29.7 ab	2.1 a
Solarization (single layer)	13.6 bc	27.7 bc	2.3 a
Solarization (double layer)	13.1 c	27.0 c	2.4 a
Mulching	16.4 a	30.2 a	1.7 b

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

Table 7. Effect of solarization and rice straw mulching on soft rot infection, marketable head yield, number and head size of Chinese cabbage.[z]

Treatment	Soft rot incidence (%)	Marketable head		Yield (t/ha)
		Number (no./bed)	Size (g/head)	
Check	45.0 a	9.3 c	941.7 a	11.6 c
Solarization (single layer)	5.0 b	16.7 a	894.3 a	19.8 a
Solarization (double layer)	13.3 b	14.0 ab	939.6 a	17.6 ab
Mulching	20.0 b	13.7 b	847.7 a	15.4 b

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

be less than that in mulching. Less soft rot incidence in the solarization treatments and mulching resulted in more marketable heads harvested. The highest number of 16.7 heads/bed was from the single layer solarization, whereas the lowest of 9.3 heads/bed came from the check. Yields from the solarization treatments were higher compared with those from mulching and the check. Higher yields in the solarization treatments were obviously due to higher number of marketable heads, which in turn was due to lower soft rot incidence. The relationship between yield and soft rot incidence had a correlation coefficient of -0.92**.

Solarization can effectively reduce soft rot incidence, saving as much as 71% of the Chinese cabbage yield. Based on current price and on per hectare of land, it would cost a farmer US$1,742 (67 beds × 100 m/bed × US$0.26/m), for plastic and labor and, in return, he would get an income of US$5,740 (8200 kg × US$0.70) from higher yield. Solarization is very economical and practical since the plastic can be used again for the next cropping season. Until a resistant Chinese cabbage variety can be identified and suitable chemical control measures are developed, solarization can be used by the farmers in the tropics.

Irrigation Schedule for Tomatoes

Summary

To use limited irrigation water most efficiently, a study was carried out to evaluate the effect of furrow irrigation schedule on tomato yield. The study revealed that with a proper irrigation schedule, tomato irrigated three times yielded as high as those irrigated four or five times. The most efficient and best treatment was to irrigate the crop three times at 0, 30 and 45 days after transplanting (DAT). This irrigation schedule significantly enhanced fruit setting of the crop as indicated by higher number of fruits/plant at harvest.

Introduction

In general plant water consumption increases with plant age and reaches the peak at flowering stage. Thereafter, the consumption declines during fruit setting and fruit-ripening stage. To use water efficiently, timing of irrigation is very important. This study was therefore conducted to determine the effect of furrow irrigation schedule on the yield of tomatoes.

Materials and Methods

A field experiment using randomized complete block design with four replications was conducted to evaluate the effect of irrigation schedule on tomato yield. Treatments used were irrigation at 0 and 15 DAT; 0 and 30 DAT; 0 and 45 DAT; 0 and 60 DAT; 0, 15 and 30 DAT; 0, 15 and 45 DAT; 0, 15 and 60 DAT; 0, 30 and 45 DAT; 0, 30 and 60 DAT; 0, 45 and 60 DAT; 0, 15, 30 and 45 DAT; 0, 15, 30 and 60 DAT; 0, 15, 45 and 60 DAT; 0, 15, 30, 45 and 60 DAT; and 0 DAT for the

check. The 0 DAT referred to irrigation immediately after transplanting. Individual plots consisted of four 1.5 × 4.8 m beds. The plots were separated by a blank bed and replications by a 2-m wide walkway. On 4 November 1986, 27-day old seedlings of the tomato variety, TM 103, were transplanted onto one row beds with plants spaced 40 cm apart. The crop was furrow-irrigated with approximately 720 liters of water/furrow. Fertilizer was applied basally at 40 kg N/ha, 80 kg P_2O_5/ha and 50 kg K_2O/ha and 40 kg N/ha plus 50 kg K_2O/ha as sidedress at 14 and 28 DAT. Harvesting was done six times from two center beds on 21 January, 2, 13, 19 and 26 February and 9 March 1987. Throughout the growing season, precipitation was 39.8 mm and evaporation was 515.6 mm.

Results and Discussion

The marketable yield of TM 103 and its attributes are presented in Table 8. Yields from all treatments, except those from the treatment irrigated at 0 and 15 DAT, were higher than the check. In general, yield increased with increasing number of irrigation applications. Irrigation at 0 and 30 DAT gave the highest yield of 66.7 t/ha among the treatments irrigated two times, whereas irrigation at 0, 30 and 45 DAT yielded the highest among those irrigated three times. When all treatments were compared, the treatment with three irrigations at 0, 30 and 45 DAT yielded as high as those irrigated four or five times. Yield difference was due more to difference in the number of fruits/plant than to difference in fruit size; path coefficient of the number of fruits/plant was four times higher than the fruit size, i.e. 1.2 vs 0.3. Higher yield was due to higher number of fruits/plant which is associated with small fruit size (r = -0.72**).

Therefore, with proper irrigation schedule, tomato irrigated three times yielded as high as those irrigated four or five times. To maximize the yield of treatments irrigated three times, the second and third irrigation should be applied 30 and 45 DAT (flower and fruit development stage, respectively) since this significantly enhances fruit setting of the crop as indicated by higher number of fruits/plant at harvest.

Table 8. Yield, fruit size and number of fruits of tomato following different furrow irrigation schedules.[z]

Irrigation application (DAT)	Marketable fruit		
	Yield (t/ha)	Size (g/plant)	Number (no./plant)
0, 15	52.7 ed	58.9 a-d	54.8 fg
C, 30	66.7 abc	57.0 cd	73.0 b-e
0, 45	60.2 bcd	57.1 cd	65.0 c-f
0, 60	59.4 cd	62.8 a	57.6 efg
0, 15, 30	59.1 cd	59.1 a-d	62.9 def
0, 15, 45	58.0 cd	57.2 cd	63.5 c-f
0, 15, 60	62.1 bcd	62.4 ab	59.9 ef
0, 30, 45	79.7 a	54.6 d	91.8 a
0, 30, 60	67.9 abc	60.4 abc	70.3 b-f
0, 45, 60	71.4 abc	59.4 a-d	73.4 b-e
0, 15, 30, 45	71.4 abc	54.8 d	79.5 abc
0, 15, 30, 60	66.2 a-d	58.1 a-d	71.0 b-e
0, 15, 45, 60	77.3 a	57.8 bcd	82.7 ab
0, 15, 30, 45, 60	73.8 ab	58.3 a-d	79.0 a-d
0 (check)	42.0 e	61.8 abc	42.9 g

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

Development of Low Pressure Drip Irrigation for Vegetable Crops

Summary

Drip irrigation is the most efficient and effective system of supplying water for plant growth. At present, many types of drip irrigation systems are commercially available. Unfortunately, most

of them are very expensive, very sophisticated and delicate, and require high pressure. These systems are obviously far beyond the reach of small-scale farmers who constitute the major proportion of the farming community in the tropics. To meet the needs of small-scale farmers, AVRDC developed a low-pressure drip irrigation system. The system does not require high pressure or filtration, is very inexpensive, simple and can be constructed by the farmers themselves. It consists of PVC pipes which serve as laterals, holes (5.0 mm in diameter) on the laterals, sponges (2.0 cm long, 1.0 cm wide and 0.7 cm thick) which serve as drippers, and a water tank of 200 liter capacity. Results of a trial on Chinese cabbage indicated that the system performed satisfactorily and saved from 65.8% to 77.2% water compared to furrow irrigation.

Introduction

Drip irrigation is the most efficient and effective water supply system for plant growth. The system is essential especially in dry areas where water supply is scarce. Numerous researches showed that crop yields were increased significantly by the use of drip irrigation. Also, the quality of the drip-irrigated crops was improved. Increased yield and quality under drip irrigation have been attributed to better water utilization, less salt and higher oxygen concentration in the root zone.

Many types of drip irrigation systems are commercially available. Unfortunately, most of them are very expensive, very sophisticated and delicate, and require high pressure, about 1 atmosphere. The systems cannot be afforded by small-scale farmers who make up the major proportion of the farming community in the tropics.

AVRDC therefore developed a drip irrigation system which is practical and can be afforded by small-scale farmers using locally available materials.

Experiment I

Materials and Methods

Materials used were 200 liter orange plastic tanks, which gave a pressure head of 0.07 atm when filled with water, faucets, cotton and PVC pipes (1.5 cm ID, 3.0 mm thick wall) used as laterals in the drip irrigation system. Holes of 2 mm diameter were drilled 50 cm apart along the pipes. The holes served as emitters to deliver water to the plants grown at the same distance as the holes. To slow down water discharge rate, the holes were plugged loosely with cotton. By varying the amount of cotton used, the discharge rate was adjusted to 11 ml/min per hole, with a range of 8 to 13 ml/min per hole at a pressure head of 0.08 atm. The faucets were placed close to the bottom of the tanks.

The system was assembled in the field where 8-m long pipes with cotton inserts were connected to the faucets using rubber tubing. Rubber stoppers were used at the other end of the pipes (closed system). Two irrigation systems were tested, i.e. underground system in which the pipes were burried 15 cm below the soil surface and aboveground system in which the pipes were laid on the soil surface along planting beds. Individual beds accommodated two rows of Chinese cabbage which were provided with two lateral lines of the drip irrigation system. The tanks were filled with water so that they had maximum pressure head of 0.07 atm. By turning on the faucet, water was delivered into the system. The crop was irrigated everyday.

Results and Discussion

The results of this experiment were not satisfactory and the crop was not harvested due to some difficulties in the system:

1. Hole size of 2 mm diameter was too small; the holes did not deliver sufficient amount of water for plant growth, especially during later growth stages.
2. Due to the low elasticity of cotton when wet, it was pushed off from the holes and, hence, broke down the system.

3. Water discharge rate of the underground system was much slower than the aboveground system since roots grew into the holes and obstructed water discharge.
4. Since this design was a closed drip irrigation system and operated under very low pressure, it was rather difficult to expel air bubbles which were trapped inside the laterals.

Experiment II

Materials and Methods

Based on the results of Experiment I, the following changes and modifications were made: (1) the underground system was dropped; (2) hole size was made bigger from 2 mm to 5 mm diameter; and (3) artificial sponge with good water absorbing quality was used in addition to cotton. The other materials used were the same as those used in Experiment I.

An open system was developed in this experiment. In this system, rubber tubing was attached to the end of the laterals and the other end was left open. To prevent water from flowing out through the open end, the rubber tubing was raised vertically so that its open end was higher than the water level in the water tank.

This system was compared with furrow irrigation using sweet pepper as a test crop. The experiment was conducted using a randomized complete block design with two replications. The treatments included were: sponge drip system (sponge size was 1.0 cm wide, 2.0 cm long and 1.2 cm thick), which delivered 20 to 28 ml of water/minute per hole at 0.08 atm pressure head; cotton drip system, which delivered 18 to 20 ml of water/minute per hole at 0.08 atm pressure head; furrow irrigation; and check. Bed size was 1.5 × 8.0 m^2. Seedlings of sweet pepper cv. Blue Star, with about six true leaves, were transplanted onto the beds on 20 March 1987 with 50 cm space between rows and 40 cm within rows forming two rows/bed. The drip irrigation treatments were turned on everyday and closed when sufficient amount of water was delivered.

Results and Discussion

Yield of sweet pepper and its attributes are presented in Table 9. Although none of the characters measured were significantly affected by the different irrigation systems, yield and fruit size from the sponge drip system tended to be higher than those from the furrow and cotton treatment. The obvious benefit from drip irrigation was water saving. Water used for furrow irrigation was 2.9 to 4.8 times more than drip irrigation. Since the time of operation for both drip irrigation systems was the same, the sponge drip system discharged more water than the cotton system (829.0 vs 501.5 l/bed).

Throughout the growing period, water under the drip irrigation system was delivered at the rate of 250 to 375 ml/plant per day. Although it would be logical to increase the amount of water delivered in accordance with increased plant age, it was difficult to do so because of the extremely slow discharge rate of the system at later dates, probably due to the expansion of the sponge and cotton. Sometimes, it took three to seven hours to deliver 10 to 15 liters of water/bed. The problem was more serious with the cotton drip system.

Another problem encountered was the development of algae on the sponge and in the water tank after fertilizer application. Due to its good absorbing quality, the sponge stayed moist all the time even if the system was turned off, which was favorable for the growth of algae. Adding 25 ml of Chlorox solution per 200 liters of water in the tank helped alleviate the problem significantly.

Table 9. Yield and yield attributes of sweet pepper as affected by different irrigation systems.[z]

Irrigation	Yield (g/plant)	Fruit size (g/fruit)	Fruit no. (no./plant)	Water irrigated (l/bed)
Furrow	414.4	59.6	7.3	2400.0
Sponge drip	489.5	82.8	6.0	829.0
Cotton drip	390.6	66.2	5.9	501.5

[z]Yield and its attributes were not significantly affected by irrigation systems.

Experiment III

Materials and Methods

The modification made in this experiment was the use of a poor absorbing quality sponge (packing material) instead of a good absorbing one. The size of the sponge was 1 cm wide, 2 cm long and 1.0 cm thick instead of 1.2 cm. The thickness of the sponge under this experiment was lessened to increase and facilitate the discharge rate. Due to low elasticity and low discharge rate, the cotton drip system was discontinued. The other materials and methods used were the same as those in Experiment II.

The effectiveness of this system was compared with furrow irrigation using Chinese cabbage as a test crop. On 9 April 1987, 25-day old Chinese cabbage seedlings, cv. Bing Luh, were transplanted onto beds with two rows/bed using a 50-cm spacing between and within rows. Beds were 1.5 m wide and 16 m long. All beds received 40 kg N/ha, 80 kg P_2O_5/ha and 50 kg K_2O/ha as basal application. The furrow irrigation treatment received an additional 138 g urea/bed and 133 g KCl/bed as sidedress application at 18 DAT, whereas the drip irrigation treatment received 30 g each of urea and KCl/bed four times through the water tanks at 1, 11, 18 and 21 DAT. The experiment was conducted using a randomized complete block design with three replications. The crop was harvested on 17 May 1987.

Results and Discussion

Throughout the growing season, the check was furrow irrigated once immediately after transplanting, whereas the furrow irrigation treatment received water three times, i.e. immediately after transplanting, and two and four weeks after transplanting. The amount of irrigation water used and growth and yield of Chinese cabbage are presented in Table 10. Furrow irrigation gave the biggest plant and highest yield due to good water supply throughout the growing season, resulting in high heading rate and large head size. Although the drip irrigation treatment resulted in as high a heading rate as furrow irrigation, the Chinese cabbage had smaller heads, and hence lower yield. This indicated that either the distribution of water under the drip irrigation was not good throughout the growing season or the amount of water supplied by the system was not sufficient. Water discharge rate from the drip system was significantly reduced as time elapsed. Since no algae developed on the system, the reduction in discharge rate could be due to the very big size of the sponge and very thick pipes (wall thickness of 3 mm).

Table 10. Growth and yield of Chinese cabbage and amount of water irrigated under different irrigation systems.

Irrigation	Plant wt[z] (kg/plant)	Yield[z] (kg/bed)	Head size[z] (g/head)	Heading[z] rate (%)	Water irrigated (l/bed)
Check	1.5 b	10.5 c	523.3 b	64.9 b	780
Furrow	1.8 a	17.7 a	636.7 a	93.5 a	2340
Drip	1.5 b	16.3 b	543.3 b	95.8 a	1040

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

Experiment IV

Materials and Methods

The experiment was conducted to compare the effect of sponge and lateral thickness on the discharge rate and pressure head loss of the system. Materials used were the same as those used in Experiment III. The treatments included were: sponge (1 cm wide, 2 cm long) of different thickness, 0.6, 0.7 and 0.8 cm; and pipes with two thickness, 1.5 mm (1.8 cm ID) and 3.0 mm (1.5 cm ID). The laterals were 16 and 32 m long and had 32 and 64 emitters, respectively. Discharge rate was measured at pressure head of 0.07 atm. Pressure head loss was measured at the end of the laterals which had wall thickness of 1.5 mm.

Results and Discussion

The sponge and lateral thickness had a significant effect on water discharge rate (Table 11). The rate was reduced from 32.4 to 26.5 l/30 min per bed when the thickness of the lateral was increased from 1.5 mm to 3.0 mm. A similar effect was also obtained when sponge thickness was increased from 0.6 cm to 0.8 cm. There was no difference between the discharge rate of the sponge thickness of 0.6 and 0.7 cm.

Pressure head loss and discharge rate were obviously affected by sponge thickness and length of laterals (Table 12). The pressure loss was reduced when thickness of the sponge was increased; the loss was higher when the lateral length was increased. The loss of the pressure head in the system affected the water discharge rate from various emitters. Due to higher pressure loss, the differences in discharge rate between the first and the last emitter of the 0.6-cm thick sponge system (1.7 liter/bed for the 16 m lateral and 5.8 liter/bed for the 32 m lateral) were greater than those of the system with thicker sponge size, i.e. 0.7 and 0.8 cm.

Based on the results of the above experiments, it is concluded that the low pressure drip irrigation system should have the following specifications for satisfactory operations: (1) laterals should be 1.5 mm thick with 1.8 cm inside diameter; (2) hole size should be 5 mm; (3) the sponge must be nonabsorbing type (packing material), 1.0 cm wide, 0.7 or 0.8 cm thick and 2.0 cm long; (4) aboveground and open system; and (5) pressure head must not be high; the system works well with pressure head of about 0.07 atm.

Table 11. Discharge rate as affected by sponge and lateral thickness measured at different weeks.

Thickness (cm)		Discharge rate (l/30 min/bed)				
Lateral	Sponge	3	4	5 (WAI)[z]	Average	Grand mean
0.3	0.6	26.5	34.0	31.5	30.7	
	0.7	32.5	32.5	31.0	32.0	
	0.8	14.0	18.5	17.5	16.7	26.5
0.15	0.6	46.0	34.5	32.5	37.7	
	0.7	49.5	33.0	37.5	40.0	
	0.8	26.0	16.0	16.5	19.5	32.4

[z]WAI = weeks after installation.

Table 12. Pressure head loss at the end of the lateral and discharge rate of the first and last emitters as affected by lateral length and sponge size.[z]

Lateral length (m)	Sponge thickness (cm)	Pressure loss (atm x 10^{-3})	Discharge rate (l/hr)		
			First	Last	Difference
16	0.6	9.0	7.9	6.2	1.7
16	0.7	6.8	6.2	5.3	0.9
16	0.8	5.0	4.7	4.0	1.7
32	0.6	30.0	8.7	2.9	5.8
32	0.7	28.0	5.7	2.7	3.0
32	0.8	24.7	4.7	2.5	2.2

[z]The system was operated under pressure head of 0.07 atmosphere.

Experiment V

Materials and Methods

The drip system was further modified and improved. In this study the drip irrigation was tested for its effectiveness and efficiency on Chinese cabbage in comparison to furrow irrigation. Chinese cabbage seedlings were transplanted on 21 September onto 1.5-m wide and 8.0-m long beds at a spacing of 50 cm between plants and between rows, forming two rows per bed.

The experiment was conducted using a randomized complete block design with three replications. The treatments were: furrow irrigation two times (T_1), furrow irrigation three times (T_2), and low-pressure drip irrigation (T_3). The drip system consisted of 200-liter plastic tank, which gave pressure head of 0.07 atmosphere when filled with water, and PVC pipes (laterals) of 2.0 mm wall thickness and 1.6 cm inside diameter. The sponge was 0.7 cm thick, 1.0 cm wide and 2.0 cm long. Hole size was 5.0 mm in diameter. Each drip-irrigated bed had two laterals lying on the soil surface and providing one dripper per plant.

The crop was given basal fertilizers of 50 kg N/ha, 80 kg P_2O_5/ha and 50 kg K_2O/ha. In addition, the furrow-irrigated treatments were sidedressed with 40 kg N/ha and 50 kg K_2O/ha twice at 8 and 28 DAT, whereas the drip-irrigated plants were fertilized with 20 kg N/ha and 25 kg K_2O/ha thrice at 8, 18 and 25 DAT. Furrow irrigation was applied 0 and 20 DAT for T_1 and 0, 10 and 20 DAT for T_2. Drip irrigation was regulated to deliver 10 liters of water/bed per day for the first 12 days, 20 liters/bed per day from 13 to 26 DAT, 30 liters/bed per day at 27 DAT, and 40 liters/bed per day from 28 to 45 DAT. The crop was harvested on 9 November at 46 DAT.

During the course of the study, mean maximum and minimum temperature were 29.2°C and 21.6°C, respectively. Total precipitation was 42.5 mm, whereas total evaporation was 207.0 mm.

Results and Discussion

Plant height was not affected by the different irrigation systems at two weeks after transplanting (WAT). At three WAT, plants under the drip irrigation and the furrow irrigation (3 times) treatments were the tallest (Table 13). There was no height difference at four WAT. Although there was no obvious average height difference, growth in the drip-irrigated treatment was more uniform, as indicated by lower standard deviation, compared to the furrow-irrigated treatment (Table 14). The high uniformity of plant growth under drip irrigation may be due to good soil structure which was least disturbed and, hence, provided better soil aeration for plant growth. On the other hand, soil aeration under furrow irrigation was impaired due to surface crusting caused by alternate wetting and drying of the soil.

Total plant weight, head size and yield are presented in Table 15. Although there were no significant differences in any of these characters, total weight, head size and yield of plants under drip irrigation and furrow irrigation (3 times) tended to be higher than those under furrow irrigation (2 times). Unlike the results of Experiment III in which the yield of the drip-irrigated plants was lower than the furrow-irrigated ones, in this study the Chinese cabbage yield from the drip irrigation treatment was as high as that of the treatment receiving furrow irrigation three times. This shows that low-pressure drip irrigation worked satisfactorily and delivered a sufficient amount of water for plant growth throughout the growing season.

Table 13. Plant height of Chinese cabbage at various growth stages as affected by furrow and drip irrigation.

Irrigation	Height (cm)		
	2 WAT	3 WAT	4 WAT
Furrow (2 times)	20.2 a	25.6 b	30.7 a
Furrow (3 times)	21.3 a	28.8 a	32.0 a
Drip	20.1 a	28.2 a	32.0 a

Means within a column followed by the same letter are not significantly different at the 5% level by DMRT.

Table 14. Uniformity of plant height of Chinese cabbage as affected by furrow and drip irrigation.

Irrigation	Standard deviation of plant height (cm/plant)		
	2 WAT	3 WAT	4 WAT
Furrow (2 times)	0.36	0.35	0.51
Furrow (3 times)	0.41	0.25	0.47
Drip	0.36	0.28	0.35

The most obvious benefit from drip irrigation under this study was water use efficiency and soil compaction (Table 16). Drip irrigation saved water by as much as 65.8% to 77.2% compared to furrow irrigation. The water use efficiency (WUE) under drip irrigation was 3.3 to 4.2 times higher than in furrow irrigation. Due to less soil structure disturbance, soil compaction as indicated by soil penetration resistance of the drip irrigation treatment was much lower than in furrow irrigation. Soil compaction in the furrow-irrigated treatment increased with increasing number of applications; 1.5 kg/cm^2 and 2.4 kg/cm^2, respectively, for irrigation two and three times. Other benefits observed, although no data were recorded, were less weed problem and labor savings on fertilizer application under drip irrigation.

Conclusion

The low-pressure drip irrigation system can be adopted by farmers in their fields. The system is inexpensive, simple and can be constructed by the farmers themselves. Due to big hole sizes, clogging of drippers is unlikely. The system is suitable for the vegetable field and should be able to irrigate a land area of 0.1 to 0.2 ha.

Table 15. Total plant weight, head size and yield of Chinese cabbage as affected by furrow and drip irrigation.

Irrigation	Total weight (kg/plant)	Head size (kg/head)	Yield (t/ha)
Furrow (2 times)	2.05	1.00	26.15
Furrow (3 times)	2.12	1.13	30.12
Drip	2.20	1.12	29.75

Table 16. Soil compaction, amount of water applied and water use efficiency under furrow and drip irrigation.

Irrigation	Soil compaction resistance (kg/cm^2)	WUE (g/l)	Water irrigated (l/bed)
Furrow (2 times)	1.5	13.1	2400
Furrow (3 times)	2.4	10.4	3600
Drip	0.4	43.5	820

Cropping Systems

Collecting and Testing the Second Set of 'New Vegetables'

Summary

This study aimed to gather more information on tropical vegetables for AVRDC's nutrition garden project and bilateral programs, and for the Center's cooperators. The second set of 15 new vegetables was selected in 1986. A total of 566 varieties of these crops had been collected until December 1987. Observational and advanced trials of some of these crops were conducted during 1987. Results showed that three entries of malabar spinach, four of yardlong bean, and two of kangkong outperformed other entries. These entries will be included in advanced yield trials for further confirmation and nutritional studies.

Introduction

This study was conducted to gather more information on tropical vegetables for AVRDC's nutrition garden project and bilateral programs, and for its cooperators. The second set of new vegetables was selected in 1986. Commercially available cultivars of these 15 crops were collected to evaluate their yields, horticultural characteristics and nutrient contents under tropical environments. There were 33 varieties of these crops; hence, a total of 566 varieties were collected in 1987 (Table 1). Observational and advanced trials of some of these crops were conducted during 1987.

Table 1. Collection of new vegetable crops.

Vegetables	Scientific name	No. of varieties received
Broccoli	*Brassica oleracea* var. *italica*	48
Carrot	*Daucus sativa*	81
Cucumber	*Cucumis sativus*	84
Eggplant	*Solanum melongena*	30
Hyacinth bean	*Dolichos lablab*	4
Kangkong	*Ipomoea aquatica*	24
Leaf amaranth	*Amaranthus* spp.	12
Leaf lettuce	*Lactuca sativa*	95
Malabar spinach	*Basella alba* and *rubra*	11
Nonheading Brassica		
Chinese kale	*Brassica oleracea* var. *acephala*	18
Paitsai	*Brassica campestris* var. *chinensis*	20
Rape green	*Brassica napus*	14
Onion	*Allium cepa*	60
Spinach	*Spinacia oleracea*	49
Yardlong bean	*Vigna unguiculata* var. *sesquipedalis*	16
Total		566

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Materials and Methods

A randomized complete block design with replications was used in all trials. A total of 9 and 13 varieties of malabar spinach and yardlong bean, respectively, were evaluated for their performances and nutrient contents. Nutrient contents of amaranth and kangkong from the 1986 trials were analyzed.

Results and Discussion

Amaranth. Amaranth had relatively high leaf growing rates during summer without significant differences among entries last year. Results of nutrient analysis showed that their contents were similar (Table 2). Differences in some nutrients among entries were correlated to differences in dry matter contents, which might be related to different maturing stages, since leaves were sampled on the same day.

Malabar spinach. A much higher yield was obtained this year since seedlings were transplanted earlier (16 April) compared to last year (25 July) (Table 3). This vegetable can be grown and harvested for a long period, as long as the temperature is high enough for it to stay in vegetative phase. Among entries, White, Green Malabar Spinach, Green Leaf and Green Stem (big leaf) outyielded the other entries. Green Leaf had the highest calcium content, while White and Green Stem had higher vitamin C compared to the other entries (Table 3).

Yardlong bean. Three new entries, namely: Golden Mountain, Green Tail and White Lip outyielded the other entries during the summer planting season, while most entries in the autumn planting season performed well, except Local Red Seed, Green Tail and White Lip (Table 4). The dramatic difference in yield of white Lip between two seasons was mainly due to the number of pod set, showing a sensitive response to environments. The differences in fiber, protein and iron contents among entries

Table 2. Yield and nutrient contents of amaranth in observational trial, summer 1986.

Entry	Yield (t/ha)	Dry matter (%)	Protein (%)	Fiber (%)	Ca	Fe	Vit. C	β-carotene
					mg/100 g			
White leaf	4.4	11.5	2.49	1.19	259	15.9	29.2	1.85
Local white	4.0	11.9	2.68	1.16	261	23.3	38.9	1.15
Local red	4.2	11.6	2.46	1.18	269	13.1	35.5	1.98
White amaranth	3.8	10.4	2.45	1.03	230	19.9	23.4	1.22
Red amaranth	5.2	10.6	2.34	1.10	250	13.8	30.4	2.46
Yellow leaf	3.3	10.2	2.33	0.96	236	19.0	23.6	1.53
Red amaranth	4.4	11.2	2.61	1.08	272	17.6	19.9	2.26
White amaranth	4.2	11.5	2.64	1.09	250	17.3	32.0	1.49
LSD (0.05)		0.7		0.09				

Date sown: 24 July 1986. Date harvested: 25 August 1986.

Table 3. Yield and nutrient contents of Malabar spinach in observational trial, summer 1987.

Entry	Yield (t/ha)	Dry matter (%)	Protein (%)	Fiber (%)	Ca	Fe	Vit. C	β-carotene
					mg/100 g			
White	79	10.1	1.22	0.94	153	5.29	145	1.70
Green stem (big leaf)	70	10.5	1.20	0.81	164	4.53	130	2.42
Red stem	61	9.2	1.29	0.90	131	4.28	88	2.17
Green stem (small leaf)	56	10.9	1.56	1.08	131	5.48	126	2.68
Green leaf	68	10.3	1.60	0.91	197	5.40	118	2.66
Green leaf	55	11.4	2.28	1.26	128	4.87	122	2.43
Sakada	59	10.6	1.18	0.93	104	4.60	105	1.98
Purple	56	8.9	1.15	0.85	120	3.70	83	1.69
Green	73	8.9	1.18	0.91	136	4.21	114	2.18
LSD (0.05)		1.0		0.19	28		26	

Date sown: 12 March 1987; Date transplanted: 16 April 1987. Date harvested: 11 May to 4 September 1987.

were correlated to their dry matter contents (r = 0.926**, 0.962** and 0.916**, respectively). In general, Green Kaohsiung and Soft Pod Red Seed had higher nutrient contents than the other entries. Among the high-yielding entries, Golden Mountain and Green Tail contained more nutrients.

Kangkong. It was reported last year that kangkong should be harvested more than once to obtain a higher yield; however, the fiber content could have increased as the number of harvests was increased. Results of nutrient analysis showed that the dry matter contents increased in the second harvest (9.13%), compared to the first harvest (7.59%); but the fiber contents were similar in the two harvests (1.03% and 0.96%, respectively). There was no significant difference in nutrient, except the dry matter contents among entries in the first harvest. In the second harvest, Cheng Chang and Taichung Wong had lower fiber contents compared to the other entries (Table 5).

Table 4. Yield and nutrient contents of yardlong bean in observational trials, 1987.

Entry	Yield (t/ha)		Dry matter	Protein	Fiber	Ca	Fe	Vit. C
	Summer	Autumn	(%)	(%)	(%)	mg/100 g		
Green pod Kaohsiung	3.2	12.1	11.6	2.59	1.16	38.5	3.01	26.9
Green arrow	10.5	13.1	8.2	1.93	0.89	40.6	2.19	21.5
Soft pod red seed	11.5	9.9	12.0	2.78	1.26	48.9	2.78	25.1
Local black	7.6	10.7	9.0	2.05	0.95	40.7	2.19	22.8
Local red seed	11.4	8.4	9.7	2.28	1.08	40.8	2.63	23.8
White seed	10.2	12.6	8.4	2.02	0.97	36.3	2.02	20.1
White seed-2	11.4	11.8	8.8	2.07	0.96	39.9	2.18	23.9
Black seed green pod	3.2	12.2	10.2	2.28	1.07	36.3	2.79	22.2
White seed white pod	12.0	12.2	8.6	2.13	0.97	38.3	2.23	20.2
White pod	11.5	11.5	9.7	2.27	1.08	40.0	2.42	21.9
Golden mountain	16.8	11.3	10.0	2.41	1.09	46.8	2.47	21.9
Green tail	17.3	9.3	10.7	2.49	1.04	47.4	2.75	21.3
White lip	23.7	5.5	8.7	2.21	0.99	36.3	2.26	25.1
LSD (0.05)	4.0	2.7	0.9	0.26	0.13		0.38	

Date sown: Summer 6 May; Autumn 11 August. Date harvested: Summer 23 June to 10 August; Autumn 5 October to 2 November.

Table 5. Yield and nutrient contents of kangkong in observational trial, summer 1986.

Entry	Yield (t/ha)	Dry matter (%)	Protein (%)	Fiber (%)	Ca	Fe	Vit. C	β-carotene
					mg/100 g			
Large leaf	15.7	10.0	2.87	1.02	110	8.62	40.0	2.23
Common variety	18.4	8.9	2.45	0.90	120	5.96	30.8	2.39
Chu-Yieh-Ching	15.6	9.0	2.48	0.92	114	6.45	30.8	2.03
Local white stem	20.8	8.8	2.45	0.95	120	5.38	33.0	1.88
Yuan Lin	19.8	9.5	2.45	0.96	119	7.79	33.3	2.30
Long leaf	19.9	8.8	2.73	0.91	123	5.78	37.3	2.45
Chu Yieh	15.2	9.0	2.29	0.94	111	4.96	37.5	2.72
Chung Yieh	20.3	8.6	2.37	0.94	124	6.07	27.4	2.14
Chu-Tzu Yieh	20.0	8.8	2.89	0.96	104	6.62	30.0	2.47
Shuie Wong	18.5	9.4	2.46	0.96	133	6.49	34.2	1.95
Cheng Chang Yieh	19.3	8.8	2.52	0.84	110	4.90	35.7	2.37
Taichung Wong	18.5	8.7	2.46	0.88	106	6.05	32.5	1.88
C variety	12.5	9.1	2.69	1.05	100	5.73	30.5	1.39
Ching-Ku-Jan-Yieh	20.2	9.8	2.64	1.11	111	7.54	34.2	1.54
Pai-Ku-Jan-Yieh	19.3	8.7	2.45	0.94	126	5.41	38.1	1.70
White	4.1	8.9	2.36	0.98	117	7.01	36.6	1.32
Green	17.7	9.5	2.54	1.02	105	6.32	37.9	1.76
Ching-Yieh-Chin-Keng	17.2	9.7	2.50	0.95	130	6.31	32.4	2.39
Ching-Yieh-Pai-Keng	14.5	9.4	2.49	1.06	99	6.13	39.8	1.26
LSD (0.05)		0.7		0.13				

Date sown: 25 July 1986; Date sampled: 12 September 1986 (second harvest).

Garden Program

Summary

Garden research during 1987 focused on information on individual crops and possible interactions between crops. The characteristics which might be used in the garden design from 43 varieties of 16 vegetables had been recorded from the school and home gardens and placed in the Tropical Vegetable Data File (TVDF). The AVRDC noncirculating hydroponic system was adopted as an urban home garden, and seven out of eight leafy vegetables were found to be suitable for this system. Deep plowing and compost application were found to be suitable management techniques in gardening.

Introduction

The AVRDC garden program initiated in 1981 aimed to increase the nutritional status and income of people in the tropics. Researches in the first phase of the program had demonstrated that a 4 × 4 m garden can supplement the nutritional needs of a family of five significantly on a year-round basis. Hence, studies in the second phase, which started in 1987, are being focused on garden designing and management. Since information on vegetable production in the tropics is often lacking and hardly accessible, a data base is being built up using data obtained from garden studies. In the meantime, the key characteristics of vegetables needed for garden planning in the tropics are being identified by testing the productivity (weight of edible part, vitamin, or mineral) of a garden designed based on the information from the data base.

Materials and Methods

Home and school gardens. Also used for demonstration purposes, four home gardens, each containing 18 1.2 × 0.7 m plots and a school garden containing 96 1.2 × 1.5 m plots were planted continuously with different vegetables. Since vegetable production on a garden basis had been clearly demonstrated, these gardens were mainly used for collecting data on individual crops, and the possible interaction between crops, i.e. effects of inter- and sequential cropping during 1987. Different vegetable varieties collected locally were grown in such a way that each variety can be planted in different seasons. Each plot in the garden had a code number.The data collected were all keyed into the computer, analyzed and then stored in a data base. The data collected are shown in Table 6.

Urban home garden. The AVRDC noncirculating hydroponic system was adopted for urban home gardens. Studies were focused on the evaluation of suitability of different leafy vegetables under this system. Figure 1 shows the setup of the hydroponic system:

- Polystyrene container for nutrient solution, which also served as insulator from heat and light to increase the oxygen in the solution and to prevent the occurrence of moss under tropical conditions.
- Plastic basket to support the medium and plants; the medium used in the present study was smoked rice husk.
- Nutrient solution. The stock solution developed by AVRDC in 1986 was prepared by the Taiwan Fertilizer Company.

Garden management techniques. Two experiments on the improvement of garden management techniques, deep plowing and compost application were carried out by comparing the yields of different vegetables grown in school garden plots with or without deep plowing and with or without compost application.The nutrient contents of amaranth and kangkong from the compost trial were analyzed by the Chemistry Department.

Table 6. Data on vegetables collected from gardens and stored in data base.

From gardens	In data base
Code of plot	Code of plot
Name of crop	Name of previous crop
Name of variety	Name of crop
Date sown	Name of variety
Data transplanted	Date sown
Date of each harvest	Date transplanted
Number of plants harvested	Period from sowing (or transplanting) to first harvest and C.V.
Weight of plants harvested	
Date of fertilizer applied	
Amount of fertilizer applied	Period of harvesting and C.V.
Date of chemical sprayed	Number of harvests and C.V.
Name and dosage of chemical sprayed	Plants/m^2 harvested and C.V.
Insect and damage found	Yield (kg/m^2/day) and C.V.
Disease infection	Vitamin A (μg/m^2/day)
Protein Content*	Vitamin C (mg/m^2/day)
Vitamin A Content*	Protein (g/m^2/day)
Vitamin C Content*	Iron (mg/m^2/day)
Calcium Content*	Calcium (mg/m^2/day)
Iron Content*	Mean temperature during growth
	Total rainfall during growth
	Total solar radiation during growth

*Analyzed by the Chemistry Department, AVRDC.

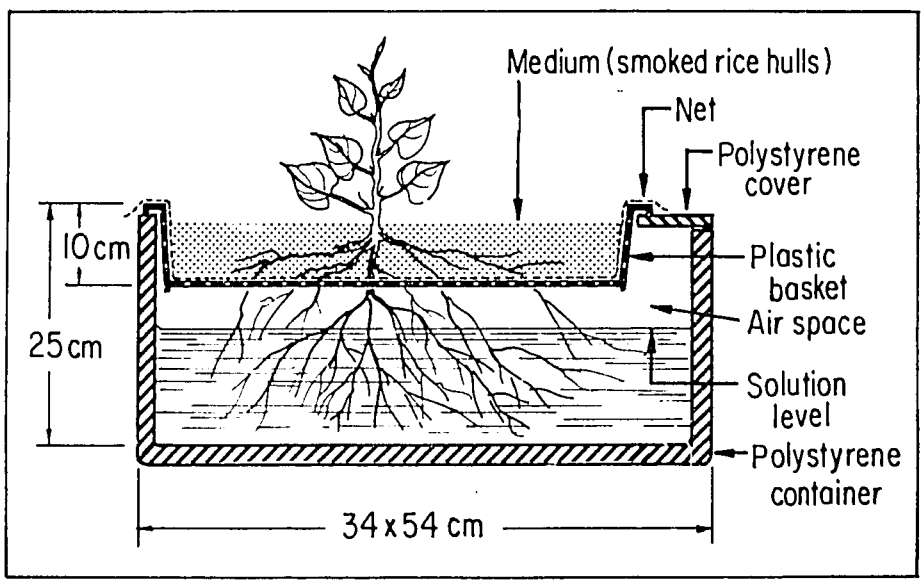

Fig. 1. Section of noncirculating hydroponic growing unit.

Results and Discussion

Home and school gardens. Data on the characteristics of 43 varieties of 16 vegetables which might be used in garden designing had been collected (Tables 7 and 8). The coefficient of variation for each character of a variety and a crop was also calculated to estimate the possible variation among or within crops. With these information, the possible yield level can be estimated for a chosen group of vegetables in a certain garden size. These data were collected during the hot season only (from May to October), and no significant relationship between yields of a particular variety or crop and

climatic conditions was found. However, it is expected that the reverse may be true when more data are obtained on a year round basis. These yield data were also transferred to the production of nutrients of different vegetables, by calculating their nutrient contents (Tables 9 and 10). These data can be used for selecting vegetables or even varieties for a garden, with specific nutrient requirements.

Urban home garden. The AVRDC hydroponic growing unit could save a lot of time for the daily cultivation in most of the leafy vegetables tested. The labor needed was only during sowing and harvesting. The nutrient solution in the container was enough for the whole growth duration of most of the leafy vegetables tested; hence, no watering was needed. The growing units were covered by a screen net from sowing until harvesting; therefore, there was hardly any insect problem and no pesticide was applied. Several vegetables had higher yields than those from garden plots (Fig. 2), except lettuce which had a germination problem under the system.

Table 7. Yield, growing and harvesting period of short growth duration vegetables in gardens, 1987.

Crop	Variety	No. of plantings	Yield (g/day/m^2)	CV (%)	Growth period (days)	CV (%)	Harvest period (days)	CV (%)	HP/GP (%)
Amaranth	Softgreen	16	26.3	38.7	30.8	11.0	3.0	119	9.7
	Tigerspot	16	30.3	39.7	32.7	19.0	6.1	52	18.8
	Whitelien	4	17.0	33.5	36.3	7.0	3.3	77	8.7
		Mean*	24.5	22.7	33.3	12.3	4.1	83	12.4
Chingchiang	Ching-Hi	9	29.7	51.8	36.9	22.3	1.4	66	3.9
	Known You	10	28.3	41.6	38.1	28.0	2.2	136	5.7
		Mean	29.0	2.5	37.5	25.2	1.8	101	4.8
Kale	Goldenround	10	11.5	40.5	59.2	18.5	3.8	147	6.4
	Sie Su	7	16.0	38.8	56.1	16.2	4.6	130	7.3
	White Flower Point	2	9.7	28.6	73.0	21.9	11.5	91	13.2
	White Flower Round	4	5.5	38.7	55.3	20.4	1.0	0	1.9
		Mean	10.7	35.1	60.9	19.3	5.2	92	7.2
Kangkong	Largeleaf	3	97.1	47.1	40.3	29.2	8.3	13	15.5
	New Big Leaf	7	54.3	24.6	38.4	27.4	10.4	106	21.5
	Ping Tung	10	74.4	29.2	36.2	21.7	8.5	103	19.9
	White Cane H.K.	4	47.8	45.9	38.0	29.4	8.0	152	15.1
		Mean	66.4	28.2	38.2	26.9	8.8	93	18.0
Lettuce	Celtuce	4	38.3	46.0	34.5	24.0	3.0	41	9.7
	Grandrapid	10	29.1	65.4	38.2	32.0	1.0	0	2.9
	Kangtung	8	32.2	66.6	39.4	11.0	1.00	0	2.6
		Mean	33.2	11.6	37.4	22.3	1.7	14	5.1
Mustard	Chicken Heart	3	44.8	89.7	30.0	23.6	1.0	0	28.3
	Hsi Lou	11	42.4	41.7	46.1	16.0	6.5	89	13.0
	Gisilba	1	21.3		28.0		1.0		3.6
	Tendergreen	1	17.2		38.0		1.0		2.6
		Mean	31.4		35.5		2.4		11.9
Paitsai	Fengshan	8	25.4	47.9	36.9	23.1	3.3	124	7.6
	Golden	3	29.3	45.2	37.7	8.5	1.0	0	3.6
	Singapore	4	34.1	17.1	35.5	12.7	2.8	110	7.7
	South Asia	5	15.8	30.3	37.2	5.2	1.0	0	2.7
		Mean	26.1	25.8	34.3	12.4	2.0	59	5.4
Rapegreen	40 Days Edible	4	30.6	17.5	31.3	14.6	2.0	61	6.0
	Knownyou Rape	9	21.9	71.3	31.4	14.7	1.1	28	3.6
		Mean	26.2	16.6	31.3	14.6	1.6	45	4.8

*Mean = mean across varieties.

Table 8. Yield, growing and harvesting period of long growth duration vegetables in gardens, 1987.

Crop	Variety	No. of plantings	Yield (g/day/m^2)	CV (%)	Growth period (days)	CV (%)	Harvest period (days)	CV (%)	HP/GP (%)
Cowpea	Local	7	14.8	13.2	102	3.5	55	27.5	54.0
Cucumber	Joy	5	90.5	13.9	90	3.0	6	23.0	69.0
Chinese leek (flower)	Local	5	2.9	52.3	200	3.0	27	11.0	13.4
Chinese leek (leaf)	Local	5	14.7	63.5	207	3.0	130	4.0	62.6
Eggplant	Bride	6	56.9	24.5	129	17.0	83	20.0	64.3
	Earlybeauty	6	90.4	44.7	137	18.0	92	28.0	65.9
	Extralong	4	43.4	29.2	127	14.0	84	16.0	66.2
	Farmslong	3	26.3	14.9	111	4.0	61	23.0	55.0
	Mean*		54.3	43.3	126	13.3	80	21.8	62.9
Malabar spinach	Green	1	34.4		147		112		76.2
	Greenstem	1	48.4		141		114		80.9
	Greenstem (Big)	1	56.4		141		114		80.9
	Redstem	1	17.3		156		103		66.0
	Sakada	3	54.1	18.2	156	2.4	135		86.8
	White	4	32.4	53.3	110	28.0	83	38.0	71.0
	Mean		40.5		142		110		77.0
Okra	Ladyfinger	8	37.0	41.9	134	12.5	101	12.3	75.6
	Luckfive	4	53.4	80.2	135	19.7	97	24.6	71.6
	Mean		45.2	18.1	134	16.1	99	18.5	73.6
Sweet potato (tips)	Five Fingers	4	19.8	0.7	84	39.0	67	55.0	73.6
Vegetable soybean	AGS 292	4	17.8	21.5	68	3.8	1		1.5

*Mean = mean across varieties.

Table 9. Nutrient contents of short growth duration vegetables in gardens, 1987.

Crop	Variety	Vitamin A (μg/day/m^2)	Vitamin C (mg/day/m^2)	Protein (g/day/m^2)	Iron (mg/day/m^2)	Calcium (mg/day/m^2)
Amaranth	Softgreen	71.7	13.9	0.79	1.24	76.5
	Tigerspot	82.6	16.0	0.91	1.42	88.1
	Whitelien	46.3	9.0	0.51	0.80	49.4
	Mean*	66.9	13.0	0.74	1.15	71.3
Chingchiang	Ching-Hi	118.2	25.5	0.74	1.01	61.8
	Known You	112.5	24.2	0.71	0.96	58.8
	Mean	115.4	24.8	0.73	0.99	60.3
Kale	Goldenround	28.8	13.3	0.28	0.38	26.9
	Sie Su	40.1	18.4	0.38	0.53	37.3
	White Flower Point	24.4	11.2	0.23	0.32	22.7
	White Flower Round	13.8	6.4	0.13	0.18	12.9
	Mean	26.8	12.3	0.26	0.35	24.9
Kangkong	Largeleaf	317.5	46.6	2.91	5.83	112.6
	New Big Leaf	177.5	26.1	1.63	3.26	63.0
	Pingtung	243.4	35.7	2.23	4.47	86.3
	White Cane H.K.	156.3	22.9	1.43	2.87	55.4
	Mean	223.7	32.8	2.05	4.11	79.3

Table 9. Continued.

Crop	Variety	Vitamin A ($\mu g/day/m^2$)	Vitamin C ($mg/day/m^2$)	Protein ($g/day/m^2$)	Iron ($mg/day/m^2$)	Calcium ($mg/day/m^2$)
Lettuce	Celtuce	171.3	9.2	0.65	2.62	35.3
	Grandrapid	130.0	7.0	0.49	1.98	26.5
	Kangtung	143.8	7.7	0.55	2.19	29.6
	Mean	148.4	8.0	0.56	2.26	30.4
Mustard	Chicken Heart	141.3	51.1	1.08	0.90	79.8
	Hsi Lou	133.5	48.3	1.02	0.85	75.4
	Gisilba	67.0	24.2	0.51	0.43	37.8
	Tendergreen	54.3	19.6	0.41	0.34	30.7
	Mean	99.0	35.8	0.76	0.63	55.9
Paitsai	Fengshan	45.1	18.8	0.46	1.22	37.5
	Golden	52.1	21.7	0.53	1.41	43.4
	Singapore	60.7	25.2	0.61	1.64	50.5
	South Asia	28.1	11.7	0.28	0.76	23.3
	Mean	46.5	19.3	0.47	1.26	38.7
Rapegreen	40 Days Edible	126.4	14.7	0.64	1.77	44.1
	Knownyou Rape	90.4	10.5	0.46	1.27	31.5
	Mean	108.4	12.6	0.55	1.52	37.8

*Mean = mean across varieties.

Table 10. Nutrient contents of long growth duration vegetables in gardens, 1987.

Crop	Variety	Vitamin A ($\mu g/day/m^2$)	Vitamin C ($mg/day/m^2$)	Protein ($g/day/m^2$)	Iron ($mg/day/m^2$)	Calcium ($mg/day/m^2$)
Cowpea	Local	0.3	0.2	3.37	0.96	16.3
Cucumber	Joy	2.3	6.2	0.36	0.27	12.7
Chinese leek (flower)	Local	5.8	1.1	0.07	0.06	0.7
Chinese leek (leaf)	Local	63.5	5.1	0.44	0.32	12.8
Eggplant	Bride	47.3	6.7	0.80	0.40	3.2
	Earlybeauty	75.0	10.7	1.27	0.63	5.4
	Extralong	36.0	5.1	0.61	0.30	2.6
	Farmslong	21.9	3.1	0.37	0.18	1.6
	Mean*	45.0	6.4	0.76	0.38	3.2
Malabar spinach	Green	176.1	32.2	0.57	0.68	15.1
	Greenstem	247.0	45.3	0.80	0.96	21.2
	Greenstem (Big)	288.7	52.9	0.93	1.12	24.8
	Redstem	88.7	16.2	0.29	0.34	7.6
	Sakada	276.6	50.6	0.89	1.07	23.7
	White	165.7	30.3	0.53	0.64	14.2
	Mean	207.1	37.9	0.67	0.80	17.8
Okra	Ladyfinger	4.3	2.9	0.57	0.76	39.9
	Luckfive	6.2	4.2	0.82	1.09	57.4
	Mean	5.3	3.6	0.70	0.93	48.6
Sweet potato	Five Fingers	42.0	7.4	0.44	2.18	29.9
Vegetable soybean	AGS 292	6.8	2.9	2.61	0.91	2.8

*Mean = mean across varieties

Garden management techniques. One-half of the school garden area was plowed 30 cm deep, while the other half was plowed 15 cm deep. Vegetables grown in the deep-plowed plots performed better, except lettuce which had similar performance in both treatments (Fig. 3). The application of compost not only increased the yield of vegetables, but also maintained the productivity of the soils. Results of the compost application trials showed that except for calcium content both yield and nutrient content of amaranth and kangkong increased with the application of 2 kg/m^2 compost (Figs. 4 and 5). It appears that both deep plowing and compost application are good practices in garden management.

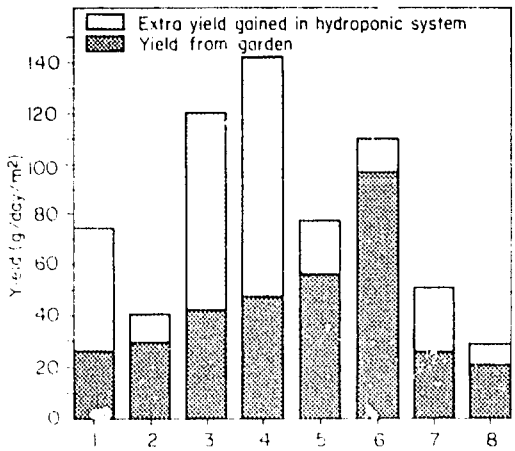

Fig. 2. Yield of leafy vegetables grown in gardens and noncirculating hydroponic systems. Legend: 1 = Paitsai; 2 = Chinese cabbage; 3 = Mustard; 4 = Sweet potato tip; 5 = Malabar spinach; 6 = Kangkong; 7 = Amaranth; 8 = lettuce.

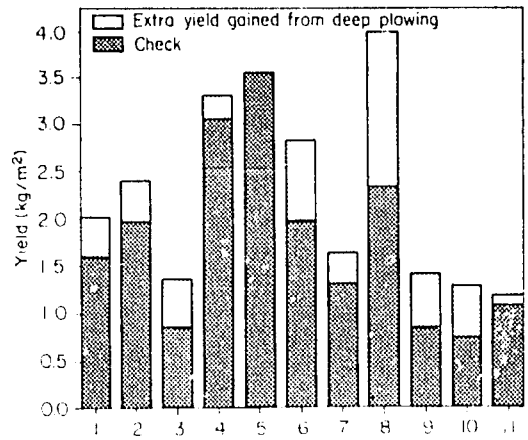

Fig. 3. Yield of vegetables grown in plots with and without deep plowing. Legend: 1 = Amaranth; 2 = Chinese cabbage; 3 = Kale; 4 = Kangkong; 5 = Lettuce; 6 = Mustard; 7 = Paitsai; 8 = Radish; 9 = Rape green; 10 = Spinach; 11 = Vegetable soybean.

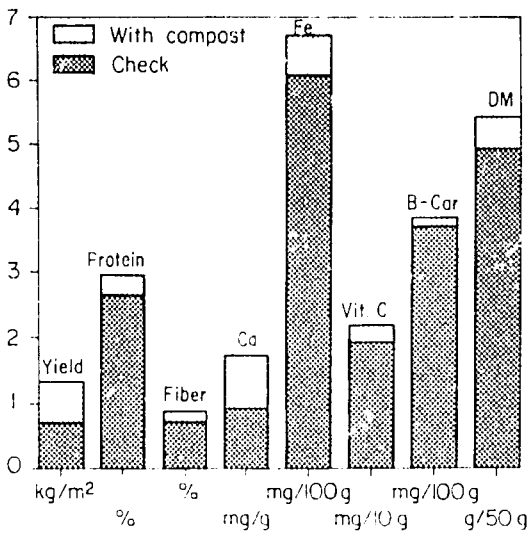

Fig. 4. Yield and nutrient contents of Amaranth with and without compost application.

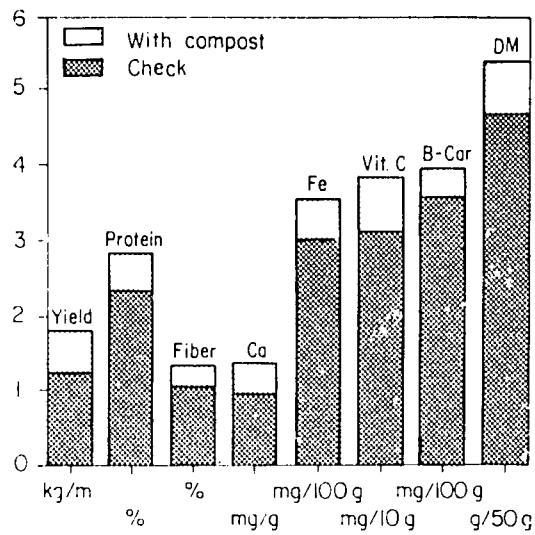

Fig. 5. Yield and nutrient contents of Kangkong with and without compost application.

Effects of High Population Density on the Earliness and Uniformity of Mungbean

Summary

Early and uniform maturity are needed for mungbean to easily fit into various cropping systems and to reduce the labor requirement for harvesting. Management techniques, i.e. high population

densities and harvest once-over, were tried in this study to achieve both objectives. Mungbean lines VC 3738A and VC 2764A were sown in three spacings at a rate of 400,000 and 800,000 plants/ha, respectively, during three seasons to compare their first harvest and total yields. It was concluded that it is feasible to harvest AVRDC-improved mungbean lines once-over to reduce growth duration and save on labor cost. However, a high population density of more than 400,000 plants/ha should be maintained.

Introduction

Early and uniform maturity are two of the primary objectives of the mungbean breeding program in AVRDC. From the cropping system's point of view, both characteristics are important because early maturity will easily fit mungbean into various cropping systems and uniform maturity will reduce the labor requirement for harvesting, which is one of the major limiting factors for mungbean production. Furthermore, if mungbean yield during the first harvest is high enough to be harvested once-over, then it is possible to be harvested by machines. In vegetable fruit crops like tomato, increased population density enhanced fruit yields during the early-harvesting period. This project, therefore, aimed to study the possibility of using management techniques, i.e. high population densities and harvest once-over, to achieve both early and uniform maturity of mungbean.

Materials and Methods

Uniform-maturing line VC 3738A and high-yielding VC 2764A were sown on 16 February (spring season), 3 June (summer season) and 20 August (autumn season) 1987 at a rate of 400,000 and 800,000 plants/ha with a spacing of 50 × 10 cm (two plants/hill), 50 × 5 cm (one plant/hill) and 50 × 5 cm (two plants/hill). An RCB design with three replications was used. The plot size was 4 × 6 m. Total seed yield and seed yield in the first harvest were compared.

Results and Discussion

Results showed that a relatively high mungbean yield of 1.5 to 2.0 t/ha was obtained at first harvest in a much shorter growth duration than when it was harvested for a second time. The yield of VC 3738A was significantly higher than VC 2764A in summer and autumn planting seasons (Table 11).

Table 11. The first harvest and total yields of mungbean under different population densities during three seasons, 1987.

Season	Entry	Plant density (no./m^2)	Days to harvest 1st	Days to harvest 2nd	Yield at 1st harvest (t/ha)^z	Total yield (t/ha)^z	1st/total yield (%)^z
Spring							
	VC 3738A	36.4	86	103	1.8	2.2	81.3 b
	VC 3738A	55.3	86	103	2.1	2.3	88.8 a
	VC 2764A	38.1	86	103	1.9	2.3	81.7 b
	VC 2764A	63.5	86	103	1.9	2.4	81.9 b
Summer							
	VC 3738A	32.0	67	106	1.6 b	1.9	86.7 b
	VC 3738A	56.1	67	106	1.7 a	1.9	92.6 a
	VC 2764A	34.1	67	106	1.5 c	1.8	83.5 c
	VC 2764A	57.8	67	106	1.5 c	1.7	87.4 b
Autumn							
	VC 3738A	36.9	68	95	1.7 a	2.1 a	84.1
	VC 3738A	67.2	68	95	1.8 a	2.2 a	83.6
	VC 2764A	37.3	68	95	1.5 b	1.8 b	86.4
	VC 2764A	64.0	68	95	1.6 b	1.8 b	88.4

^{z}Means with different letters are significantly different at 5% level.

Increasing population density tended to increase the yield at first harvest for VC 3738A only (Figs. 6 and 7). Generally, the ratio of the first harvest to total yield was high in all treatments during all three seasons. It was significantly increased by the rise in population density in both entries during summer. This was mainly attributed to a lower yield in the second harvest.

It appears that harvesting of mungbean once-over to reduce growth duration and save labor cost is feasible with the AVRDC improved lines. However, a population density of more than 400,000 plants/ha should be maintained.

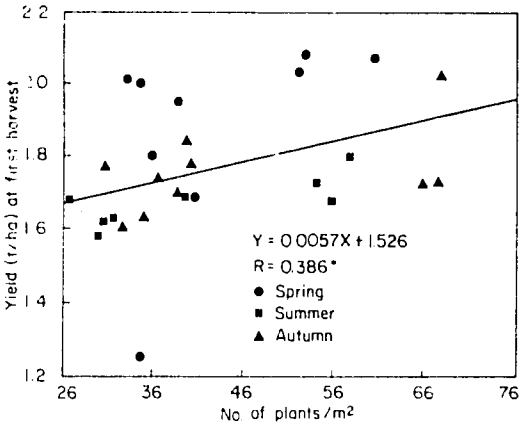

Fig. 6. Relationship of yield and population densities of mungbean VC 3738A.

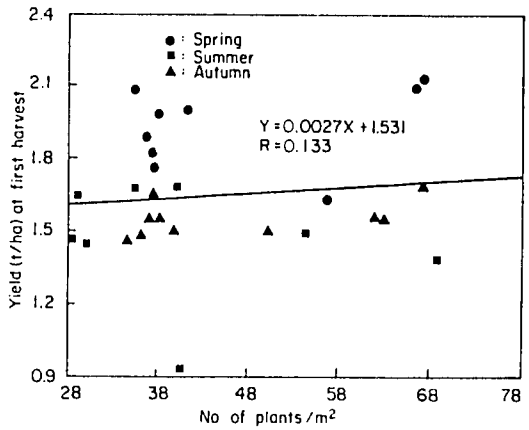

Fig. 7. Relationship of yield and population densities of mungbean VC 2764A.

Sweet Potato/Soybean Intercropping

Intercropping has long been an important practice in the tropics and subtropics because it can reduce failure depending on a single crop. Research work has also shown recently that it can give a higher combined yield than sole cropping because of the better use of growth resources, i.e. sunlight, moisture and soil nutrients (Willey 1979)[1].

In tropical Asia, more than 60% of the cultivated land is rainfed. There is only one cropping season per year in most of these areas due to the uneven distribution of rainfall. It appears that intercropping may be the only viable multiple cropping scheme to increase crop productivity in these areas.

Soybean, which is a leguminous crop with the ability to fix nitrogen may excrete it during its growth and leave a large amount of residues as well as nodules after harvesting. These can be beneficial to an associated nonlegume (Wilson and Burton 1938)[2], particularly when the nonlegume has a long growing duration (Willey 1979). The production of sweet potato during the wet-warm summer often results in high shoot growth and low storage root yield. It was found that early-maturing soybean reduced cassava shoot growth, but not tuber yield in cassava/soybean intercropping under fertile soil with irrigation (Tsay 1985)[3]. On the other hand, soybean growth was not affected by the associated cassava, and a seed yield of 2 t/ha was obtained. If the same principle applies, it would appear that sweet potato/soybean intercropping could be a potentially good combination to increase sweet potato production as well as total productivity in the humid tropics. Furthermore, this combination should provide a better balanced nutrition with respect to protein and carbohydrate.

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[1]Willey, R.W. 1979. Intercropping – Its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abst. 32:1-10.

[2]Wilson, P.W. and Burton, J.C. 1938. Excretion of nitrogen by leguminous plants. J. Agric. Sci. 28:307-323.

[3]Tsay, J.J.S. 1985. Physiological Studies of Cassava-Soybean Intercropping. Ph.D. thesis. Univ. of Queensland. Australia. 212 pp.

Yield Responses of Intercropped Sweet Potato and Soybean Cultivars with Different Spatial Arrangements and Planting Dates

Summary

Intercropping has been shown to result in higher combined yield than sole cropping because of the better use of growth resources. It may be the only viable multiple-cropping scheme to increase crop productivity in rainfed areas. Sweet potato/soybean intercropping could be a good combination to increase total productivity as well as better balanced nutrition. This study examined the effects of genotype, spatial arrangement and relative planting of sweet potato and soybean on the competition of these two crops in intercropping to minimize this competition and to increase the intercrop productivity. It was found that sweet potato TN 67 and soybean AGS 66 were more suitable genotypes for intercropping than other entries. Two rows of soybean per bed were a better arrangement than one row for this particular combination. Soybeans seemed to dominate in this intercropping system in the summer planting season.

Introduction

Two component crops usually compete with each other for growth resources, such as light, nutrients and water in intercropping. It is important to minimize this competition to increase the intercrop production by manipulating cultural practices, such as choice of genotypes, plant populations and spatial arrangements, and relative planting time.This study investigated the effects of these factors and their interactions on yields of sweet potato and soybean in intercropping.

Materials and Methods

There were 16 intercropping treatments (a 2^4 factorial experiment with two replications), including two soybean genotypes (broad leaflet and early-maturing AGS 66 and narrow leaflet and late-maturing AGS 129), two sweet potato genotypes (semierect type TN 66 and spreading type TN 67), two soybean spacings (50 × 10 cm with one plant/hill, and 100 × 10 cm with two plants/hill), and two soybean sowing times (eight days earlier and the same day as sweet potato planting). Four sole treatments, two sweet potato and two soybean cultivars, were repeated twice in each replication and planted on the same day. The spacing used for sweet potato was 100 × 25 cm. Yield of soybean, and yield and fresh weights of different parts of sweet potato at maturation were recorded.

Results and Discussion

Soybean yields were different between entries and between cropping systems. AGS 66 had a significantly higher yield than AGS 129 in both cropping systems (Table 12). This was mainly due to the severe lodging caused by heavy rains during flowering and pod filling stages of the latter. Among cropping systems, AGS 66 had 83% yield as in sole cropping when intercropped with sweet potato cultivars, while AGS 129 had 92% and 58% yield when associated with TN 66 and TN 67, respectively.

Sweet potato yields were relatively low in this summer planting, and were significantly affected by cropping systems (Table 12). Both entries of sweet potato had about 60% yields as in sole cropping when intercropped with AGS 66, whereas they were only about 30% to 40% with AGS 129.

The yield advantage in intercropping indicated by Land Equivalent Ratio (LER), defined as the relative land area required by sole crops to produce the same yield as in intercropping (Mead and Willey 1980)[4] , showed that both sweet potato entries intercropped with soybean AGS 66 produced a relative advantage of 40% over sole cropping. On the other hand, only TN 66, but not TN 67, had an advantage of 23% with AGS 129. Results of light interception also showed that intercropping

[4]Mead, R. and R.W. Willey. 1980. The concept of a 'Land Equivalent Ratio' and advantages in yields from intercropping. Exp. Agric. 16:217-228

had higher percentage of light intercepted during the early growth stage up to 45 days after planting (Figs. 8 and 9). Sweet potato intercropped with AGS 129 had significantly lower percentage of light intercepted when soybean was harvested, and the recovery was not as good as those intercropped with AGS 66.

Intercropped soybean was taller than in sole cropping, which showed the competition for light between these two crops (Table 13). Most of the soybean yield components were reduced when intercropped with sweet potato (Table 13), indicating that soybean growth was affected throughout its whole growing period.

Soybeans had higher yield when grown in two rows than in one row per bed although their population densities were similar (Table 14).

The growth of sweet potato was affected when intercropped with soybean, except the leaf growth of TN 67 during late stages (Table 15). The stem was the most affected part and the leaf was the least. However, due to unsuitable climatic conditions, i.e. heavy rains, during the late-growing stages of sweet potato, the storage roots did not have a chance to catch up. The growth curve of the storage roots showed that TN 66 was an early-maturing cultivar, and it appeared unsuitable for intercropping (Fig. 10). TN 67 increased its storage root weight mainly during the late-growing stages, and it seemed more suitable for intercropping than TN 66 (Fig. 11). Yield responses and other agronomic characteristics also showed similar trends (Table 16).

Within intercropping treatments, the yield and growth of both sweet potato entries were affected more by the associated soybean AGS 129 than by AGS 66 (Figs. 9 and 10 and Table 16), and tended

Table 12. Yield and land equivalent ratio (LER) of sweet potato and soybean under intercropping.

Sweet potato/Soybean		AGS 66 (t/ha)		AGS 129 (t/ha)	
		Sweet potato	Soybean	Sweet potato	Soybean
TN 66	Sole cropping	16.5	3.1	16.5	1.2
	Intercropping	9.2	2.6	5.2	1.1
	I/S	0.6	0.8	0.3	0.9
	LER	1.4		1.2	
TN 67	Sole cropping	16.1	3.1	16.1	1.2
	Intercropping	9.3	2.6	6.8	0.7
	I/S	0.6	0.8	0.4	0.6
	LER	1.4		1.0	

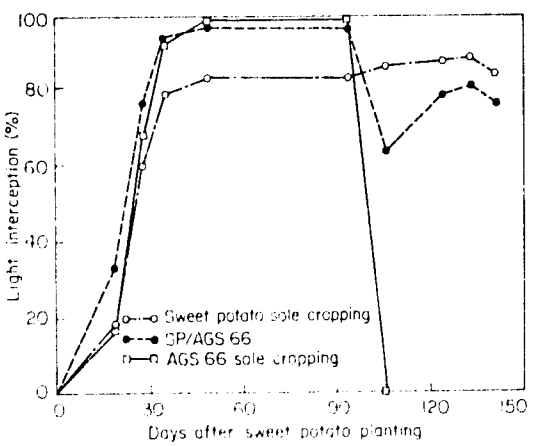

Fig. 8. Light interception of sole soybean, AGS 66, sole sweet potato, and sweet potato/AGS 66 intercropping.

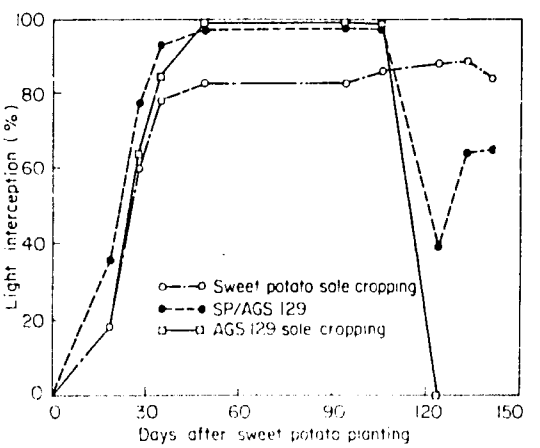

Fig. 9. Light interception of sole soybean, AGS 129, sole sweet potato and sweet potato/AGS 129 intercropping.

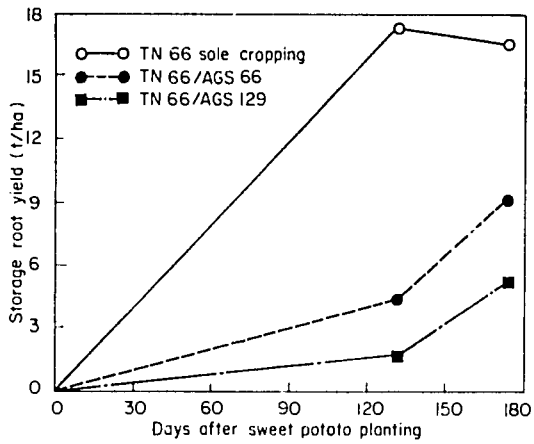

Fig. 10. Yields of storage roots of sweet potato, TN 66, in sole cropping and intercropped with soybean, AGS 66 and AGS 129.

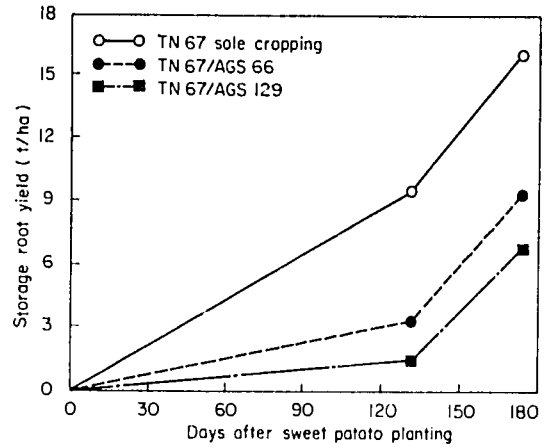

Fig. 11. Yields of storage roots of sweet potato, TN 67 in sole cropping and intercropped with soybean, AGS 66 and AGS 129.

Table 13. Agronomic characters of soybean in sole cropping and intercropping with sweet potato.[z]

Variety	Cropping	Plant ht. at flowering (cm)	Node no./plant	Plant no./m^2	Pod no./plant	Seed no./pot	100-seed wt. (g)
AGS 66	Sole cropping	46.8 b	13.0	21.4 a	72.5 a	1.86 a	11.0
	Intercropping	50.7 a	12.8	20.2 b	59.3 b	1.63 b	11.0
	I/S (%)	108.3	98.5	94.4	81.8	87.60	100.0
AGS 129	Sole cropping	47.0	27.0 a	21.1 a	34.8	0.89	14.3 a
	Intercropping	49.0	24.6 b	19.7 b	28.4	0.83	11.4 b
	I/S (%)	104.3	91.1	93.4	81.6	93.30	79.7

[z]Means with different letters are significantly different at 5% level.

Table 14. Effect of number of rows per bed on yield and agronomic characters of soybean intercropped with sweet potato.[z]

Variety	No. of rows	Yield (t/ha)	Plant ht. at flowering (cm)	Node no./plant	Plant no./m^2	Pod no./plant	Seed no./pod	100-Seed wt. (g)
AGS 66	1	2.35 b	51.0	12.7	22.0	58.3	1.60	10.9
	2	2.91 a	50.4	12.9	22.9	60.3	1.66	11.1
AGS 129	1	0.76	50.2	23.8 b	20.3	27.0	0.79	10.6
	2	1.03	47.8	25.4 a	21.1	29.9	0.86	12.2

[z]Means with different letters are significantly different at 5% level.

Table 15. Agronomic characters of sweet potato in sole cropping and intercropping with soybean.

Variety	Cropping	Leaf wt. (t/ha)	Stem wt. (t/ha)	Total wt. (t/ha)	No. of storage root (1/m^2)
TN 66	Sole cropping	5.5	15.6	37.6	34.2
	Intercropping	4.8	6.9	18.9	23.5
	I/S (%)	87.3	44.2	50.3	68.7
TN 67	Sole cropping	5.1	16.2	37.4	44.3
	Intercropping	6.1	7.3	21.5	23.6
	I/S (%)	119.6	45.1	57.5	53.3

to have larger reductions in the two-row arrangement than by one row of soybean per bed (Table 17), but not by the relative planting time of soybean.

It is concluded that sweet potato TN 67 and soybean AGS 66 were more suitable genotypes for intercropping than other entries. Two rows of soybean per bed was a better arrangement than one row for this particular combination. It seemed that soybean was dominant in this intercropping system during the summer planting season, hence, the earlier planting of soybean than the associated sweet potato did not have a significant effect on the sweet potato growth.

Table 16. Effect of associated soybean varieties under intercropping on yield and agronomic characters of sweet potato.[z]

Variety	Variety of associated soybean	Yield (t/ha)	Leaf wt. (t/ha)	Stem wt. (t/ha)	Total wt. (t/ha)	No. of storage roots/m^2
TN 66	AGS 66	9.2 a	5.1	8.6 a	22.9 a	29.5 a
TN 66	AGS 129	5.2 b	4.4	5.1 b	14.7 b	17.5 b
TN 67	AGS 66	9.3 a	5.5	7.7	22.5	27.7 a
TN 67	AGS 129	6.8 b	6.6	6.8	20.2	19.4 b

[z]Means with different letters are significantly different at 5% level.

Table 17. Effect of number of rows per bed of associated soybean under intercropping on yield and agronomic characters of sweet potato.[z]

Variety	Number of soybean rows	Yield (t/ha)	Leaf wt. (t/ha)	Stem wt. (t/ha)	Total wt. (t/ha)	No. of storage roots/m^2
TN 66	1	7.6	4.9	7.6	20.1	25.2
TN 66	2	6.8	4.6	6.0	17.4	21.8
TN 67	1	8.8	6.5	8.8 a	24.1	24.9
TN 67	2	7.4	5.6	5.7 b	18.7	22.2

[z]Means with different letters are significantly different at 5% level.

Effects of Previous Crops and 'SH' Mixture on Growth and Yield of Chinese Cabbage

Summary

This study examined the effects of rotating Chinese cabbage with rice and application of an 'SH' soil improvement mixture to alleviate continuous cropping hazards. Chinese cabbage Hybrid 62 was grown after rice and after other vegetables with and without 'SH' treatment, and their yields were compared. Results implied that rotation with paddy rice can be an effective method to mitigate continuous cropping hazards caused by intensive vegetable production. 'SH' can reduce some of the hazards but was not as effective as rotation with rice on soil with high pH values.

Introduction

One of the main production constraints in intensive vegetable production systems is the presence of continuous cropping hazards, i.e. accumulation of pest population, destruction of the physical structure of the soil, decreasing soil fertility, and hence, reducing soil productivity. Farmers in Taiwan have been rotating a crop of paddy rice after some crops of vegetables to mitigate these problems. Sun and Huang (1986)[5] reported that a soil improving mixture 'SH' can improve soil properties and

[5]Sun S.K. and C.W. Huang. 1986. The development and application of 'SH' soil improving mixture. Shing Nung Farm Magazine. 217.68-72.

reduce soilborne diseases. Hence, this experiment aimed to study the effects of previous crops, i.e. paddy rice and other vegetables, and 'SH' mixture on the growth and yield of Chinese cabbage.

Materials and Methods

Chinese cabbage Hybrid 62 was sown on 16 June and transplanted on 7 July 1987 on a piece of land, which was continuously grown with vegetables for five years, after paddy rice and other vegetables. There were two treatments in each cropping pattern, i.e. 1.0 t/ha 'SH mixture' and the control. A complete randomized design was used with three replications. The plot size was 3 × 5 m and the spacing was 75 × 40 cm.

A basal fertilizer of 10 t compost, 60 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha, and two sidedressings of 40 kg N/ha each were applied.

Chinese cabbage was harvested on 11 August 1987, and the gross weight, head yield, number of heads harvested, and rate of internal rot in heads were recorded. Heading efficiency was then calculated by the ratio of head weight over nonwrapped leaf weight. Soil samples were taken before and after the trial for estimation of their organic matter contents, P and K, and their pH value.

Results and Discussion

There was no interaction of treatments of the 'SH mixture' and previous crop on any of the investigated characters. Water content of Chinese cabbage was not affected by either treatment, and was about 94%. The EC, total nitrogen and available P and K in soil before, during and after Chinese cabbage's growth did not respond significantly to treatments.

Between two previous crop treatments, the Chinese cabbage preceded by paddy rice did not only have a significantly higher gross weight, but also higher heading efficiency and, hence, higher head yield than those after other vegetables (Table 18). These results seemed to agree with those found last year that Chinese cabbage had a higher heading efficiency and yield after paddy rice than after tomato. Sugiyama (1968)[6] suggested that physical structure and water content of soil, and plant hormone might affect the heading efficiency of Chinese cabbage. Hence, the growing of paddy rice might have improved some of these factors; however, it warrants further studies. Since no plant was lost and the same number of heads in all plots was harvested, therefore, the effect of treatments on average head weight was the same as on head yield (Table 18). A drastic difference in the rate of internal rot was found between these two treatments (Table 18). All heads sampled from plots previously growing other vegetables showed the symptom of internal rot, although it was not severe. No sampled head grown after paddy rice showed this symptom. It was reported that this disorder might be related to calcium deficiency (Kuo et al. 1981)[7]; calcium availability was reduced when soil pH was lower than 7.0 (Hanna and Hutcheson 1968)[8]. In this study, the plots previously grown with paddy rice had higher pH values than those preceded by vegetables (Fig. 12). Although these pH values decreased after the growing of Chinese cabbage, and had a smaller difference between two previous crop treatments, the differences might have been attributed to the occurrence of internal rot in Chinese cabbage.

Table 18. Effects of previous crops on yield and other horticultural characters of Chinese cabbage.[z]

Previous crop	Gross wt. (t/ha)	Yield (t/ha)	Head wt. (kg/head)	Heading efficiency	Internal rot (%)
Rice	34.3 a	19.2 a	0.74 a	1.27 a	0 a
Vegetables	30.9 b	16.0 b	0.60 b	1.08 b	100 b

[z]Means with different letters are significantly different at 5% level.

[6]Sugiyama, T. 1968. Nutritional physiology and fertilizing technology of vegetables. 405 p. Seibundo, Tokyo, Japan.

[7]Kuo, C.G., J.S. Tsay and C.L. Tsai. 1981. Tipburn of Chinese cabbage in relation to calcium nutrition and distribution. Scientia Hortic. 14:131-138.

[8]Hanna, W.J. and T.B. Hutcheson. 1968. Soil Plant Relationships. *In* L.B. Nelson, ed. Changing Patterns in Fertility Use. Soil Sci. Soc. of Am. Inc. Madison, Wisconsin, U.S.A.

The 'SH' treatment increased gross weight and head yield, but not the heading efficiency of Chinese cabbage, and it did not reduce the rate of internal rot (Table 19). Sun and Huang (1986) pointed out that 'SH' worked more effectively under lower pH condition. The pH value (about 6.5) of soil previously grown with other vegetables was relatively high and was not increased by 'SH'.

These results imply that rotation with paddy rice is a good cropping system for intensive vegetable production in terms of maintaining soil productivity. It appears that rotation with aquatic crops could have similar effects, but warrants further research. Although 'SH' could partially improve the hazards due to continuous vegetable cultivation, it did not have similar effects as rice rotation on soil with high pH values.

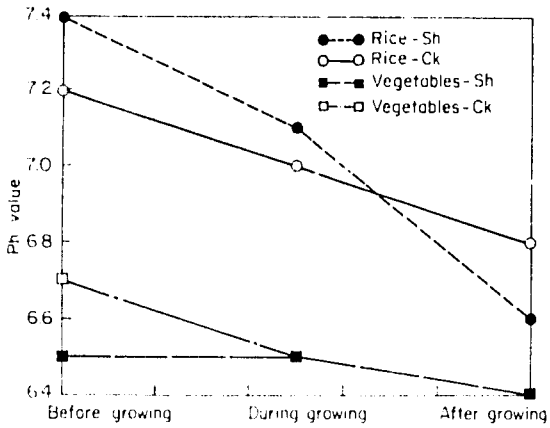

Fig. 12.
Changes in soil pH before, during and after Chinese cabbage growing under different treatments.

Table 19. Effects of 'SH' on yield and other horticultural characters of Chinese cabbage.[z]

Treatment	Gross wt. (t/ha)	Yield (t/ha)	Head wt. (t/ha)	Heading efficiency
SH	34.3 a	18.6 a	0.72 a	1.18
Control	30.9 b	16.6 b	0.64 b	1.17

[z]Means with different letters are significantly different at 5% level.

Onion as a New AVRDC Crop — Feasibility Review

Background Information

In the preestablishment stage of the AVRDC in 1968, onion was considered among the 26 vegetables under Category II — good shipping and keeping quality group. When AVRDC launched its research program in 1972, it was technically feasible for the Center to work on only 12 vegetables, and onion was one of them. However, in late 1972, when the number of crops seemed excessive, onion was one crop that was dropped. When AVRDC evaluated crops for secondary vegetables in 1982, it was considered under priority III. The AVRDC staff conducted a library study in 1983-84 and they found that onion was the most popular vegetable in developing countries based on hectarage of production (highest at 771,000 ha followed by pepper at 411,000 ha).

In 1986, AVRDC selected pepper as the new principal crop and during the selection process onion ranked number 5. In addition to pepper to supplement Chinese cabbage and mungbean, three vegetables were recognized by AVRDC as potential candidates for research, and onion was one of these. In the overall evaluation, the significant factors which hindered selection of onion as a new AVRDC crop were: 1) comparatively high capital investment necessary for storage and seed production, and 2) relatively long time needed to solve a problem or to develop an improved cultivar. However, if resources were not limited, onion would have been one of AVRDC's principal crops long ago.

Detailed Analysis on Onion (*Allium cepa*) as an AVRDC Crop

Positive aspects. Onion is an important and widely known vegetable worldwide and is commonly cultivated in more than 100 countries. It ranks second to tomato in annual world production. However, the cultivated area devoted to it and its total production in the Asian and Pacific region are higher than those of tomato according to the 1985 FAO report (Table 20). Nutritionally, onion is relatively high in calcium (Ca) and iron (Fe) (Table 21). Onion is consumed either as fresh or in dehydrated form. It is very popular in Asia because in 12 out of 19 Asian countries, the total annual consumption is more than that of tomato (Table 22). Dehydrated bulb onion powders which reduce transport cost and storage losses are in great demand in developed countries. Onion is one of the few vegetables that can be stored for a long period and safely withstand the hazards of rough handling including long distance transport. Therefore, it is an important world trade crop which can increase farmers' income in the Asian region.

Sufficient quantities (both Asiatic and global) of onion genetic resources which could be readily utilized in crop improvement are available from many sources, such as the National Seed Storage Laboratory (Fort Collins, Colorado, USA), the National Vegetable Research Station (UK), the Institute for Horticultural Plant Breeding (Netherlands) and the National Institute of Agricultural Sciences (Japan). There is a great need for varietal improvement in onion, especially because the national programs are mainly dependent on introduced cultivars which are not fully adaptable in the Asian tropics for commercial cultivation. Furthermore, there are few breeding programs currently underway to improve shallot onion which is also very popular in many Asian countries. In the last two decades, tropically-adapted onion cultivars with a yield potential of 35 t/ha, which was highest in the tropics, were developed in Taiwan. This changed Taiwan from an importer to an exporter status. Therefore, AVRDC has a comparative advantage over many other tropical countries from which to launch an onion improvement program. Based on Taiwan's successful experience in onion improvement, onion could be considered as a suitable candidate for AVRDC's mandate crop if financial resources and manpower are given appropriate priority.

Negative aspects. Onion, a biennial bulb crop, is rather new to many AVRDC researchers, and this may initially delay the research progress of the breeding program. Onion breeding may be relatively slow since one advance generation needs two years to complete, compared to only six months for other AVRDC crops. Specific climatic requirements (long days, cooler temperature) necessary

Table 20. Tomato and onion production statistics in the Asian and Pacific developing countries.

Country	Production in 1985 ('000 t)		Area harvested in 1985 ('000 ha)	
	Tomato	Onion	Tomato	Onion
Bangladesh	75	136	10	33
Burma	–	181	–	23
China	5,260	3,240	333	231
DPR, Korea	56	37	4	3
Fiji	3	1	–	–
India	802	2,855	82	269
Indonesia	115	210	23	49
Laos	15	39	3	22
Malaysia	25	–	5	–
Pakistan	–	500	–	47
Philippines	130	40	14	6
Rep. of Korea	34	362	1	11
Sri Lanka	28	97	5	10
Thailand	33	153	7	19
Vietnam	–	152	–	47
Total	6,577	8,003	487	770
World total	60,825	24,517	2,588	1,693

Table 21. Nutrient content of onion bulb (amount/100 g).

Name	Water (%)	Energy (Cal)	Protein (g)	Fat (g)	Carbohydrate (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Vitamin A (μg/re)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
Onion	89	38	1.5	0.2	8.7	30	44	1.0	10	157	tr	0.03	0.04	0.2	10

Table 22. Vegetable consumption (kg) per person in Asia.[2]

Country	Cabbage	Lettuce	Spinach	Tomato	Cauliflower	Pumpkin/Squash	Cucumber	Egg-plant	Green chili-pepper	Green onion	Dry onion	Garlic	Green bean	String bean	Carrot	Other fresh vege.	Total
Bangladesh	0.5	0.5	0.1	0.7	0.4	1.0	0.1	–	–	–	1.3	0.4	0.3	–	–	4.5	9.8
Brunei	3.4	–	–	1.0	–	–	–	–	–	–	3.8	–	–	–	–	18.6	26.8
Burma	–	–	–	–	–	–	–	–	–	–	2.8	0.7	–	–	–	44.0	47.5
China	4.9	–	–	3.7	0.6	0.8	2.4	1.4	1.3	1.0	2.4	0.4	0.3	1.6	–	44.5	65.3
Hong Kong	15.4	5.3	1.6	2.4	–	1.7	0.5	0.2	–	1.9	1.4	–	0.4	–	–	49.1	79.9
India	0.6	–	–	1.0	0.9	–	–	–	–	–	3.3	0.3	0.1	–	–	51.9	58.1
Indonesia	1.9	0.6	–	–	–	–	1.0	–	1.3	–	1.3	1.0	–	–	–	4.7	11.8
Japan	27.9	2.9	2.0	7.4	0.7	1.9	8.2	5.0	1.3	4.2	10.3	–	0.7	–	4.6	25.3	103.2
D.R. Korea	15.3	–	–	1.7	–	2.4	1.9	1.2	1.8	1.4	1.3	1.6	–	–	–	75.4	104.0
R.O. Korea	74.8	–	1.7	1.4	–	0.9	2.6	0.8	2.8	10.0	7.0	5.6	–	–	1.7	75.0	184.3
Macau	–	–	–	10.7	–	–	–	–	–	–	–	0.1	–	–	–	60.3	71.1
Malaysia	0.8	–	–	2.0	–	0.1	0.1	–	–	–	5.0	0.7	–	–	–	23.0	31.7
Mongolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14.4	14.4
Nepal	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.0	11.0
Pakistan	–	–	–	–	–	–	–	–	1.2	–	4.0	0.4	–	–	–	15.5	21.1
Philippines	1.3	–	–	2.9	–	–	–	2.1	–	–	0.8	0.3	–	–	–	26.8	34.2
Singapore	3.6	1.0	–	3.4	1.4	4.4	6.5	–	0.1	–	6.3	2.4	4.9	–	1.4	19.7	55.1
Sri Lanka	2.4	–	–	1.5	–	1.4	1.3	–	2.6	–	4.4	0.3	1.1	–	0.3	1.7	17.0
Thailand	1.7	–	–	0.6	0.5	1.4	1.3	1.1	–	–	2.5	3.6	0.8	–	–	31.3	44.8
Average	8.13	0.54	0.32	2.12	0.23	0.84	1.36	0.62	0.65	0.97	3.04	0.93	0.45	0.08	0.42	31.4	52.16

[2]Food Balance Sheets. 1979-1981.

for bulb development and seed production may restrict the wide adaptability of onion. A very large capital investment is necessary for storing large amounts of breeding materials in cold and ambient conditions and for construction of isolation cages and net houses needed in crossing and seed production. Crossing and seed production depend on insects, especially honeybees and flies. Due to the difficulty of onion seed production, national programs may totally depend on AVRDC for continuous supply of seeds, which would impose a severe burden on the Center's budget. Because onion seeds have a relatively short shelf life compared to many other seeds, additional seed storage facilities might be needed. Onion is also a favorable candidate for production by the private seed companies, and the impact of AVRDC's crop improvement may be overshadowed by the profit-oriented private seed companies.

Constraints in Tropical Onion Production

Cultivation: **(1) Abiotic factors.** Climatic restriction is imposed on bulb initiation and development. For vegetative growth, lower temperature (13-20°C) and short photoperiod are required while relatively higher temperature (16-25°C) and long photoperiod (>12 h) are needed for bulb development. Onion is a shallow-rooted crop; therefore, careful water and nutrient management is necessary for good productivity.

(2) Biotic factors. The following diseases and pests cause severe yield loss in the tropics: purple blotch (*Alternaria* spp.), basal rot (*Fusarium* spp.), smut (*Urocystis* spp.), and bacterial soft rot (*Erwinia* spp.), and Yellow dwarf virus, diseases; and thrips (*Thrips tabaci*), onion maggot (*Hylemya antigua*), and *Heliothis armigera*, pests.

Postharvest problems: **Sprouting and rotting.** In the tropical and subtropical countries, the crop is harvested in early summer and stored for four to six months in ambient conditions of high temperature and high humidity due to monsoon rains. During this period, the bulbs sprout very easily, and rots develop readily due to diseases such as bulb mold (*Aspergillum* sp.) and *Penicillium* rot. Sprout inhibiting chemical are used in Western countries and such may be useful in tropical storage, but would certainly need careful study.

Seed production constraints. In many countries, major difficulties exist in producing economically viable domestic seeds under tropical condition. Imported seed is expensive. Thus, domestic seed production is important.

Vernalization of onion bulbs is required for flower induction in onion seed production. High temperature throughout the year and short daylength during the growing season limit the area suitable for seed production. Artificial vernalization (< 10°C) is required to induce flowering in the tropics. Temperatures ranging from 7.5° to 14°C with an optimum of about 12°C is the best for storage of mother bulbs, which are to be planted for seed production. Poor storage quality of bulbs and seed deterioration due to high humidity prior to harvest have constrained seed production.

Constraints in cultivar improvement. Onion flowers are protandrous in nature and, therefore, the plant is predominantly a cross-pollinated one. Selfing beyond two generations results in inbreeding depression and low yield. Synchronous flowering among cultivars, efficient bee management, and isolation cages are essential in successful seed production.

Onion hybrids produce higher yield, uniformity in appearance, size and maturity than the open-pollinated cultivars; thus, they are more suitable for the tropics. However, unavailability of locally adaptable male-sterile lines is a severe restriction in hybrid breeding in the Asian tropics. Onion seeds are vulnerable to high temperature and high humidity in the tropics and lose viability within a year. Thus, a fresh supply of good quality seeds is necessary in the tropics.

In the case of shallot, vegetative propagation is a common practice because an open-pollinated crop is not uniform maturing and is usually low yielding. The potential hazards of transmitting yellow dwarf virus via vegetative propagules will impose restriction on international transfer of superior bulbs. Breeding efforts should be focused on improvement of the seed-propagated shallot crop.

Possible Research Thrusts for Onion at AVRDC

Varietal improvement. AVRDC research thrusts for varietal improvement of onion include the following: development of both open-pollinated and hybrid short-day group varieties that are adaptable and can produce bulbs in the tropical environment; resistance to diseases such as purple blotch (*Alternaria spp.*), basal rot (*Fusarium* spp.), smut (*Urocystis* spp.); good storability and shipping quality under hot and humid environment; and suitability for fresh market (sweet and mildly pungent), for processing and export (highly pungent and high solids).

AVRDC needs to develop an improved, seed-propagated shallot onion which should be high yielding, uniform in maturity, shape and size.

Overcome the seed production constraints in the tropics. AVRDC should also develop methods to improve onion seed production in the tropics by manipulating both genetic and management factors during the storage period and in vernalization treatment to induce synchronous flowering among cultivars, efficient insect pollinator management and the utilization of cytoplasmic male sterility or gametocides in hybrid seed production.

Crop management. In the southern, tropical part of Taiwan, the locally developed cultivars produce a yield of 35 t/ha compared to only 10 t/ha in other tropical countries. By investigating the factors responsible for the low yield and transferring the Taiwan technology to those countries, a means of increasing their yield level could be achieved.

Cultural practices to improve the yield potential of tropically adapted cultivars and postharvest management to enhance the storage potential of bulbs in the tropics are also essential. Sprout inhibition through application of growth regulating chemicals and appropriate storage conditions should also be investigated.

Germplasm activities. Germplasm activities should include collection, multiplication, conservation, characterization and utilization of tropically adapted onion germplasm.

Cross-Commodities Physiology

Estimation of Heat Tolerance in Vegetables by Conductivity Tests

Summary

Different vegetable species were examined for heat tolerance by measuring electrolyte leakage of leaf tissue with a conductivity meter. Twenty vegetables were assessed for the optimum incubation temperature for leaf tissue heat injury (HI). Incubation at 50°C of 59 vegetables grown under three distinct seasons in the year showed that species of Monocotyledoneae and Convolvulaceae were heat-tolerant, and Cruciferae and Umbelliferae were heat-sensitive.

A regression analysis of stability showed that low leaf tissue HIs tended to be less influenced by environmental factors (high temperature) under different growing seasons; the hardening process probably was not required in heat-tolerant vegetables. High leaf tissue HIs, on the other hand, tended to be less stable under different growing seasons; the hardening process might take place among some of these vegetables to ameliorate stress effects under high temperature conditions.

Introduction

Information on physiological traits of heat tolerance among vegetables may be useful for horticulture and cropping systems research. However, it is generally difficult to adequately define heat tolerance in vegetables because of differences in species, responses, thermal adaptation (hardening), duration of exposure, growth stage, etc. Based on controlled heating of excised leaf tissue at 50°C, comparisons of heat tolerance in terms of degree of the cell membrane damage among vegetables have already been initiated with a limited number of vegetables in different seasons. For the evaluation of heat tolerance 50°C was arbitrarily selected; it, however, likely surpasses the optimum growing temperature. Hence, this study aimed to: 1) reexamine the optimum temperature for leaf tissue heat injury (HI), 2) further evaluate relative heat tolerance in terms of leaf tissue HI at 50°C for 59 vegetables grown in the same season, and 3) assess the stability of HI values in three distinct growing seasons.

Materials and Methods

Fully expanded leaves of 20 vegetable species were sampled from the field on 16 November 1987. Mean maximum/minimum temperatures during the 10-day period before sampling were 27.8°/19.2°C. The leaves of each species were separated into five groups, each with four replicates. Twenty leaf disks of 10-mm diameter were punched out from each group. Leaf tissues were placed in a test tube (2 × 15 cm) and 10 ml of deionized water was added. They were incubated in a thermostated, reciprocal shaker at a frequency of 40 cycles/min at 25°, 30°, 35°, 40° and 50°C for an hour. After incubation, the test tubes were cooled to room temperature and measured for electrolyte conductivities with a YSI Model 32 Conductance Meter. After initial readings, these test tubes were then boiled for 30 minutes, cooled to room temperature, and again measured for electrolyte conductivities. The heat injury (%) of the leaf tissue was measured by the following equation:

$$\text{Heat injury (\%)} = \{1-[1-(T_n/T_{100})]/[1-(C_{25}/C_{100})]\} \times 100\%$$

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where: T = initial conductivity at 30°, 35°, 40° or 50°C;

T_{100} = final conductivity of T_n group after boiling at 100°C;

C_{25} = initial conductivity at 25°C, i.e. control group;

and

C_{100} = final conductivity of C_{25} after boiling at 100°C.

Fifty-nine vegetable species and varieties were planted in the experimental farm in different weeks of March, June and October 1987, to be harvested at about the same time, usually at the midstage of producing the economic part, for sampling and measuring of leaf tissue HI at 50°C for all vegetables. Three measurements, each with four replicates for March and June plantings, and one measurement for the October planting were made. An analysis of stability using the method proposed by Eberhart and Russell (1966) was conducted for HI values of vegetables which had been totally measured seven times in three seasons.

Results and Discussion

Differential responses of field-grown vegetables on leaf tissue HI after exposing to four incubation temperatures were noticeable (Fig. 1), albeit these vegetables were grown under cool-season conditions, and thus, probably not in hardened conditions. Although the greater degree of heat injury occurred at 40° to 50°C, the relative heat injuries of various vegetables were similar at 35°, 40° and 50°C. Less than 15% of the leaf tissue HI occurred at 30°C; therefore, it would be difficult to assess the degree of HI at or below this temperature.

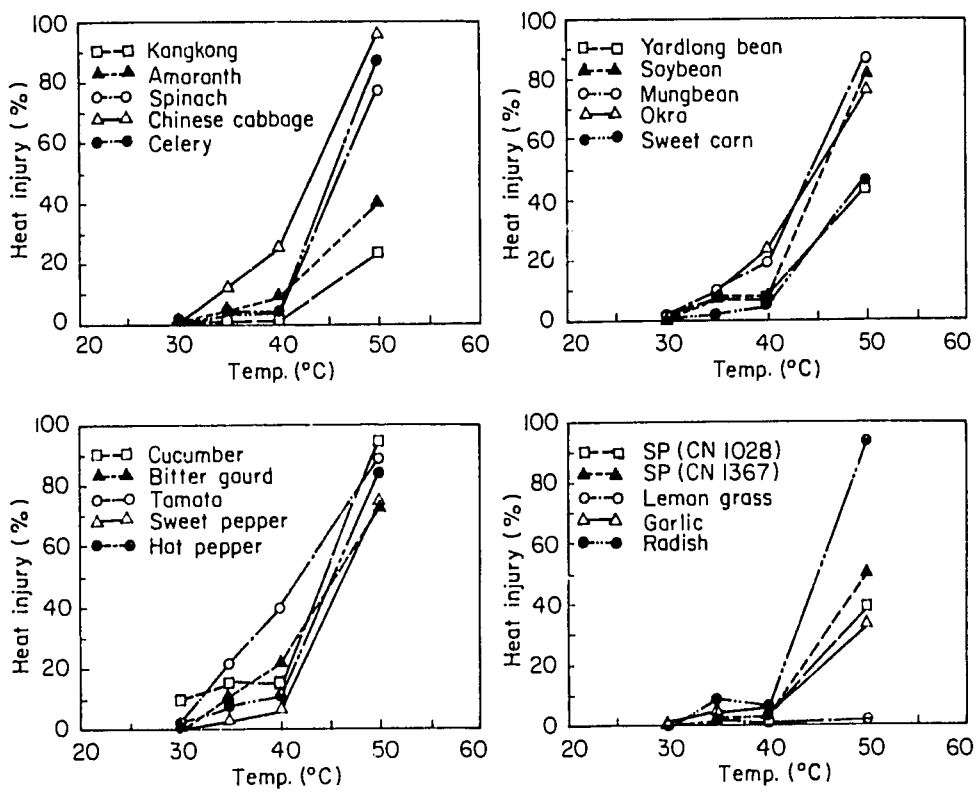

Fig. 1. Heat injury of leaf tissue of 20 vegetables obtained by measuring the conductivity of electrolyte leakage after incubation at different temperatures.

Sweet potato, kangkong and lemon grass previously showed low leaf tissue HIs at 50°C. The present experiment confirmed this finding. However, amaranth, garlic and sweet corn, which were previously characterized as moderately heat-tolerant, also had comparable HIs (less than 50%) as the heat-tolerant sweet potato and kangkong. It is possible that the 20 vegetables investigated in this experiment had not been subjected to heat because of the prevailing low temperatures during field-growing conditions; thus, the leaf tissues were not probably damaged before the test.

Among the rest of the vegetables which had more than 70% leaf tissue HI at 50°C, soybean, spinach, peppers, celery and radish had less than 15% leaf tissue HI at 40°C; thus, they may be considered as moderately heat-tolerant.

Based on the relative HI of leaf tissue at 35°C, both cucumber and tomato appeared to be most sensitive to high temperature. Since these two vegetables were able to grow under high temperature conditions, heat injury of leaf tissue may not completely block the development of reproductive organs under field-growing conditions.

The present observations indicate that the differential HIs of leaf tissues were exhibited at 30° to 40°C. However, the best differential responses among different vegetables were still better expressed at 50°C; thus, this incubation temperature is recommended for the assessment of leaf tissue HI.

Assessment of leaf tissue HI at 50°C for 59 vegetables grown in three distinct seasons revealed that there was a wide range of leaf tissue HI, 7.2 to 96.9, 7.9 to 97.4, and 7.0 to 98.1 for March, June and October plantings, respectively (Table 1). Among all vegetables the leaf tissue HIs of Gramineae (lemon grass, sweet corn), Araceae (taro), Liliaceae (asparagus, day lily), Zingiberaceae (ginger), Amaryllidaceae (garlic, shallot, bunching onion, Chinese chive) and Dioscoreaceae (yam) of Monocotyledoneae were less than that of Dicotyledoneae.

Table 1. Heat injury (%) of leaf tissue as measured by the conductivity of electrolyte leakage for 59 vegetables grown in three distinct growing seasons in 1987.

Vegetable	April	July	November
Pumpkin	69.1 l-o[z]	58.9 m-o	73.4 b-h
Luffa	78.9 h-j	67.8 k-m	78.5 a-h
Hyacinth bean	87.1 c-g	80.6 e-i	88.6 a-e
Calabash gourd	70.0 l-n	62.8 l-n	70.7 c-i
Wax gourd	57.9 p-r	51.1 op	70.5 c-i
Yam	56.4 q-s	45.2 pq	38.3 l-o
Asparagus	7.2 z	15.6 v-x	7.0 q
Bitter gourd	59.0 p-r	70.1 j-l	69.9 c-j
Yardlong bean	68.1 l-o	53.8 n-p	64.3 e-j
Snap bean	84.6 d-h	73.8 g-k	85.9 a-g
Cucumber	81.9 gh	82.9 e-h	88.0 a-f
Lima bean	84.7 d-h	82.4 e-h	86.0 a-g
Tomato	80.4 g-i	86.7 a-e	88.0 a-f
Eggplant	63.9 n-p	70.3 j-l	80.8 a-g
Malabar spinach	50.1 st	38.5 q-s	49.2 i-n
Cassava	27.4 w	26.5 tu	36.8 l-o
Lemon grass	13 5 y	12.4 wx	7.9 q
Okra	71.5 k-m	73.5 g-k	73.5 b-h
Sweet corn	54.1 rs	39.0 q-s	46.9 j-n
Sesame	62.3 o-q	71.8 i-l	79.8 a-g
Rice bean	54.2 rs	57.5 no	81.7 a-g
Adzuki bean	62.8 o-q	74.1 g-k	85.1 a-g
Mungbean	79.5 hi	78.4 e-j	92.7 a-c
Soybean	56.7 q-s	62.3 l-n	90.4 a-o
Peanut	24.4 wx	20.7 u-w	39.7 l-o
Sweet potato CN 1367-2	43.7 tu	39.6 qr	66.2 d-j
Sweet potato CN 1028-15	28.5 w	40.8 qr	41.2 o
Sweet pepper	62.4 o-q	54.9 no	68.4 c-j
Kohlrabi	74.2 i-l	75.4 f-k	85.4 a-g
Chinese cabbage	92.9 a-c	83.5 b-g	96.3 ab

Table 1. Continued.

Vegetable	April	July	November
Lettuce	80.0 g-i	72.9 h-k	87.4 a-g
Amaranth	46.8 tu	39.8 qr	39.6 l-o
Kangkong	22.3 wx	25.4 tu	23.2 o-q
Shallot	44.6 tu	33.1 r-t	39.4 l-o
Bunching onion	42.3 u	29.8 s-u	55.4 h-l
Chinese chive	19.6 xy	23.4 uv	22.9 o-q
Radish	95.8 ab	93.1 a-c	98.1 a
Carrot	83.2 e-h	94.6 a	77.0 a-h
Mustard	91.1 a-d	92.5 a-d	95.9 ab
Ching-chiang	78.3 h-k	85.1 a-f	83.3 a-g
Broccoli	81.1 g-i	80.6 e-i	91.7 a-c
Basil	78.0 h-k	82.9 e-g	83.9 a-g
Hot pepper	72.1 j-m	93.8 a	80.8 a-g
Nightshade	80.5 g-i	66.8 lm	81.2 a-g
Garlic	36.0 v	–	32.4 m-p
Cabbage	64.2 n-p	62.7 l-n	81.4 a-g
Spinach	44.3 tu	–	83.8 a-g
Cherry radish	96.9 a	97.4 a	
Chinese kale	72.2 j-m	–	89.1 a-d
Garland chrysanthemum	66.9 m-o	–	–
Coriander	92.0 a-c	–	–
Cauliflower	82.5 f-h	–	83.3 a-g
Rape green	90.0 a-e	–	83.2 a-g
Paitsai	89.5 b-f	93.1 ab	89.1 a-d
Day lily	–	8.8 x	14.5 pq
Snake gourd	–	50.9 op	71.8 b-i
Taro	–	7.9 x	4.9 q
Celery	–	77.9 e-j	–
Ginger	–	12.2 wx	–
Mean in each season	62.5 ab[y]	59.2 b	67.2 a
Mean max. temp. (°C)	28.4	33.3	27.9
Mean temp. (°C)	19.5	24.1	19.9

[z]Mean separation in column by Duncan's multiple range test at 5% level. [y]Mean separation in three seasons by Duncan's multiple range test at 5% level.

Among Dicotyledoneae, species of Convolvulaceae (sweet potato, kangkong) and Euphorbiaceae (cassava) had lower leaf tissue HIs, whereas Cruciferae and Umbelliferae had higher leaf tissue HIs.

Arbitrary classification of heat sensitivity among the 59 vegetables, as measured by the conductivity test of electrolytes leakage, is listed as follows:

- Heat tolerant (HI × 25%): asparagus, Chinese chive, day lily, ginger, kangkong, lemon grass and taro.
- Moderately heat tolerant (25% × HI × 50%): amaranth, bunching onion, cassava, garlic, Malabar spinach, peanut, shallot, sweet corn, sweet potato and yam.
- Slightly heat tolerant (50% × HI × 75%): bitter gourd, cabbage, calabash gourd, eggplant, garland chrysanthemum, luffa, okra, pumpkin, rice bean, sesame, snake gourd, soybean, sweet pepper, wax gourd and yardlong bean.
- Heat sensitive (HI 75%): adzuki bean, basil, broccoli, carrot, cauliflower, celery, cherry radish, Chinese cabbage, Chinese kale, ching-chiang, coriander, cucumber, hot pepper, hyacinth bean, kohlrabi, lettuce, lima bean, mungbean, mustard, nightshade, paitsai, radish, rape green, snap bean, spinach and tomato.

Some of the heat-tolerant and moderately heat-tolerant vegetables in the above list are usually grown under hot season conditions and are expected to adapt well to high temperature conditions. However, there are cases of moderately or slightly heat-tolerant vegetables, e.g. garlic and garland chrysanthemum, in terms of leaf tissue HI, which would be expected to grow poorly under hot season conditions. It is possible that other physiological processes, such as photosynthesis, morphogenesis, and other growth and developmental processes, would be limited by high temperature stress.

The above classification confirms the findings of last year for vegetables tested again this year; however, there were cases of interchanges within categories for two years' results. It seems that environmental factors (temperature) have some effect on the stability of leaf tissue HI. To estimate the stability of leaf tissue HI, regressions of leaf tissue HIs stabilities were calculated for 41 vegetables. By definition, a stable HI should have the smallest possible regression coefficients (b) and deviation from regression (S^2d). Regression coefficients of these 41 vegetables ranged from -0.63 to 2.75 (Fig. 2). Vegetables such as pumpkin, wax gourd, yam, snap bean, soybean, sweet potato (CN 1367-2), kohlrabi, lettuce and broccoli had high regression coefficients, which implies that the leaf tissue of these vegetables may not be stable. The lower leaf tissue HIs of pumpkin, wax gourd, snap bean, soybean, kohlrabi, lettuce and broccoli in the hot season than in cool season seemed to indicate that the adaptation process (hardening) to high temperature functioned in the hot season, which would render them heat tolerant and thus reduce leaf tissue HIs. However, the hardening process of these vegetables under hot season conditions needs to be further examined under controlled growth temperature conditions.

On the other hand, vegetables such as bitter gourd, tomato, lemon grass, asparagus, cucumber, sweet potato (CN 1028-15), kangkong, shallot, radish, yardlong bean, Malabar spinach and mustard had low regression coefficients regardless of specific injury levels of individual vegetables, which indicates that the leaf tissue of these vegetables is quite stable under different growing seasons. Results suggest that the hardening process of these vegetables under hot season conditions may not accrue enough to cause any significant effect on leaf tissue HI.

In conclusion, an analysis of stability for leaf tissue HI showed that low leaf tissue HIs tended to be more stable under different growing seasons, which seems to indicate that the innate heat tolerance

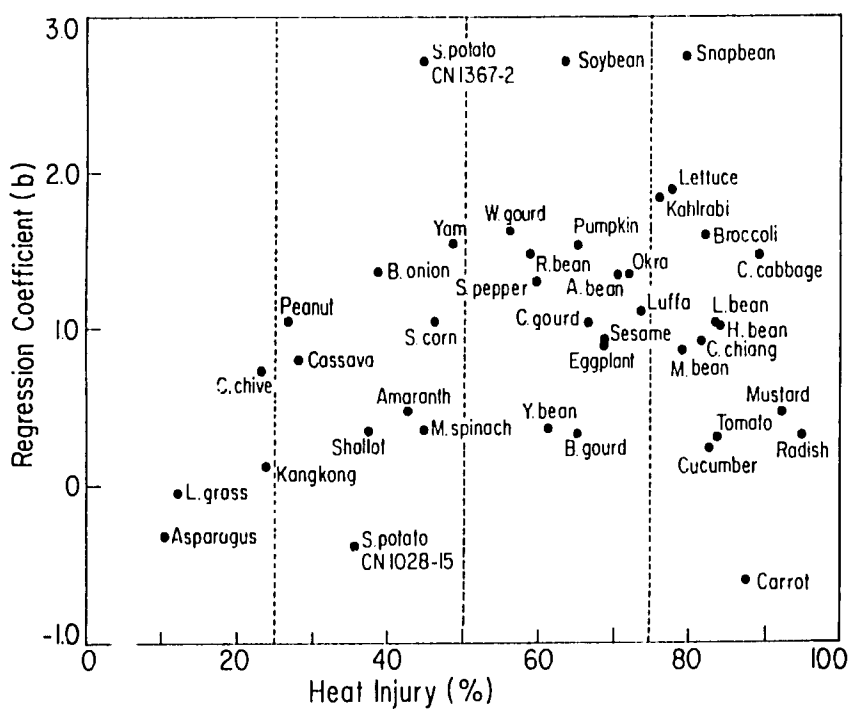

Fig. 2. Relationship of the average leaf tissue heat injury and stability of 41 vegetables grown in three distinct seasons at AVRDC, 1987.

of these vegetables would be adequate to overcome heat stress encountered under different environmental conditions. The increasing trend in regression coefficients with increasing leaf tissue HI, on the other hand, seems to suggest that the adaptation mechanism may be required in vegetables with high leaf tissue HI to overcome heat stress. More detailed studies, however, are needed to examine the adaptation (hardening) process as affected by high temperature and its effect on the overall plant performance under high temperature conditions.

On-Station Testing

Cooperative Projects with Local Institutes

Summary

Promising AVRDC lines and selected varieties of new vegetables, including sweet and hot peppers, cauliflower, Chinese radish, mustard and snap bean were tested under different environments in Taiwan through RYT. Vegetable soybean variety AGS 292 was released in 1987 because of its outstanding performances during these trials. Entries which outperformed the check entries in RYT during 1986 and 1987 are: GS 208 and AGS 215 of soybean; AGS 190 and AGS 292 of vegetable soybean; VC 3738A and VC 3890A of mungbean; FMTT 22 of fresh market tomato; AVRDC 85-216 and AVRDC 82-156 of Chinese cabbage; CN 1345-8 of sweet potato; Gypsy of sweet pepper; Passion of hot pepper; Chu Pei Kan Zuyi and Tung Shih Kan Zu of Chinese radish; Chinhsingly and Tender Green of mustard; and Witsa of snapbean.

Introduction

Promising AVRDC lines and selected varieties of new vegetables, including sweet and hot peppers, cauliflower, Chinese radish, mustard, and snap bean, were tested under different environments in Taiwan through the regional yield trials (RYT) and the district trials (DT). These trials were supported and mainly conducted by Taiwan's national programs in farmers' fields.

Materials and Methods

The locations, number of entries, sowing and harvesting dates in regional yield trials are shown in Table 1. Trials were conducted in a randomized complete block design with four replications. The plant spacings are listed in Table 2.

District trials of soybean were conducted in summer and autumn 1986, and spring 1987 at seven, three and seven locations, respectively. There were five entries including one AVRDC line, AGS 157. The same experimental design and plant spacings as in RYT were used.

Results and Discussion

A. Release of AVRDC Line in Taiwan During 1987

An AVRDC-introduced vegetable soybean line, AGS 292 (Taishoshiroge), was released in Taiwan as Kaohsiung Selection No. 1 (KS 1) on 23 April 1987 after its outstanding performance in RYT. Its acreage in autumn 1987 planting season in Taiwan was nearly 800 ha, which was 19% of the total acreage for vegetable soybean during that season. A total of 40 ha had been planted to this variety by the Taiwan Seed Service for seed multiplication during the same season. It was estimated that 100 t of seeds for growing in 1,000 ha will be produced in the 1988 spring season.

Table 1. Number of locations, number of entries, sowing and harvesting dates of regional yield trials including AVRDC material in Taiwan.

Year	Season	No. of locations	No. of entries	Sowing dates	Harvesting dates
Soybean[z]					
1986	Summer	10	11	[illegible] June - 29 Aug.	21 Sept. - 30 Dec.
1986	Autumn	3	11	10 Sept. - 9 Oct.	6 Dec. - 16 Jan.
1987	Spring	11	11	21 Jan. - 23 Feb.	24 Apr. - 20 June
Vegetable soybean[z]					
1986	Autumn	3	8	10 Sept. - 3 Oct.	17 Nov. - 17 Dec.
Mungbean[y]					
1987	Spring	5	10	16 Feb. - 22 Mar.	12 May - 7 June
1987	Summer	4	10	3 July - 25 Aug.	7 Sept. - 3 Nov.
Processing tomato[y]					
1986	Autumn	3	10	*22 Oct. - 23 Oct.	14 Jan. - 20 Mar.
1986	Winter	3	10	*25 Nov. - 27 Nov.	7 Mar. - 8 Apr.
Fresh market tomato[x]					
1987	Summer	7	11	*25 Feb. - 3 Aug.	2 Apr. - 23 Nov.
Chinese cabbage[x]					
1987	Summer	8	5	9 May - 4 Sept.	26 June - 4 Nov.
Sweet potato[w]					
1987	Summer	5	11	1 Apr. - 29 Apr.	25 Aug. - 29 Oct.
Snap bean[x]					
1986	Autumn	3	9	6 Sept. - 30 Sept.	30 Oct. - 29 Dec.
1987	Spring	3	9	17 Feb. - 5 Mar.	15 Apr. - 2 June
Sweet pepper[v]					
1986	Autumn	3	8	*1 Sept. - 30 Oct.	3 Nov. - 24 Mar.
1987	Spring	4	8	*3 Jan. - 21 Apr.	12 Mar. - 7 Aug.
Chinese radish[u]					
1986	Autumn	2	6	1 Sept. - 30 Sept.	15 Oct. - 24 Nov.
1987	Spring	1	6	Apr. 9	26 May - 4 June
Hot pepper					
1986	Autumn	1	6	*26 Sept.	7 Nov. - 4 Feb.
1987	Spring	1	6	*2 Apr.	16 June - 18 Sept.
Cauliflower					
1986	Autumn	1	4	*26 Sept.	3 Nov. - 24 Nov.
1987	Spring	1	4	*6 May	15 June - 29 June
Mustard					
1986	Autumn	1	3	*25 Sept.	17 Oct. - 3 Nov.
1987	Spring	1	4	9 Apr.	5 May

*Transplanting [z]Coordinated by Kaohsiung DAIS; [y]Coordinated by Tainan DAIS; [x]Coordinated by Taichung DAIS; [w]Coordinated by Chiayi TARI; [v]Coordinated by TSIPS; and [u]Coordinated by Taoyuan DAIS.

B. Regional Yield Trials and District Trials

1. Soybean

Regional yield trials. Two AVRDC lines, AGS 208 and AGS 215, were used in RYT in summer and autumn 1986, and spring 1987. Generally, these two lines yielded as high as the check variety, KS 8 (Table 3); however, there were seasonal effects. Compared to the check, these two lines tended to have higher yields in summer, but lower in autumn planting. These two lines were more stable than KS 8 under different environments in Taiwan (Figs.1 & 2).

District trials. All five entries had similar mean yields across locations in each planting season, and had the highest yield in spring planting season (Table 4). The AVRDC line, AGS 157 had similar responses to different environments as the check variety, KS 8, but had a little higher stability (Fig. 3).

Table 2. Plant spacings used in regional yield trials.

Crops	Space between rows (cm)	Space between plants (cm)		Plant no./hill (cm)
		Spring & Summer	Autumn	
Soybean	50	15	10	2
Vegetable soybean	50	10	10	2
Mungbean	50	10	–	2
Processing tomato	150	–	40	1
Fresh market tomato	75	50	–	1
Chinese cabbage	75	35	–	1
Sweet pepper	75	40	40	1
Hot pepper	75	40	40	1
Snap bean	75	50	50	1
Chinese radish	50	25	25	1
Cauliflower	75	50	50	1
Mustard	75	50	50	1

Table 3. Yield of entries in the Taiwan soybean regional yield trials in summer and autumn 1986 and spring 1987.

Entry	Yield (t/ha)			Mean	Index
	1986		1987		
	Summer	Autumn	Spring		
TARI 6	1.83 bc	2.07	2.28 c	2.07 b	90
TARI 7	2.09 a	2.06	2.48 abc	2.27 a	98
AGS 208	2.01 ab	2.20	2.35 abc	2.19 ab	95
AGS 215	1.99 ab	2.03	2.59 a	2.27 a	99
Hualien 71-27	1.97 abc	2.46	2.20 c	2.14 ab	93
Hualien 71-30	1.93 abc	2.36	2.26 c	2.14 ab	93
KSS 22	1.87 bc	2.27	2.34 abc	2.13 ab	93
KSS 72	2.04 ab	2.18	2.52 ab	2.28 a	99
KS 1372	1.77 c	2.06	2.35 abc	2.07 b	90
KS 1397	1.77 c	2.32	2.53 ab	2.19 ab	95
KS 8	1.84 bc	2.82	2.58 a	2.30 a	100

Table 4. Yield of entries in the Taiwan soybean district yield trials in summer and autumn 1986 and spring 1987.

Entry	Yield (t/ha)			Mean	Index
	1986		1987		
	Summer	Autumn	Spring		
KS 1266	1.73	1.78	2.73	2.17	97
AGS 157	1.78	1.91	2.81	2.25	100
TARI 4	1.80	1.75	2.77	2.22	99
Hualien 70-40	1.83	1.77	2.72	2.21	99
KS 8	1.76	1.86	2.84	2.25	100

2. Vegetable soybean

Six promising AVRDC lines and two checks were used in the vegetable soybean RYT. Their relative performances were consistent during 1985 and 1986 (r^2 = 0.88**). The mean marketable yields of AGS 190 and AGS 292 were significantly higher than the check varieties, 205 (Tzurunoko) and Ryokkoh (Table 5). In general, both AGS 190 and AGS 292 had similar responses to the environment compared to the average yield of the checks (Figs. 4 & 5). AGS 190 was more stable than the checks in spring planting, but less stable in summer. Furthermore, AGS 190 had relatively smaller pods than the checks. Therefore, only AGS 292 was recommended and released for growing in Taiwan.

3. Mungbean

The mungbean breeding programs in Taiwan aim to develop high and stable-yielding genotypes with the following attributes: a) dull seeds with 100-seed weight of more than 6 g, b) uniform maturity

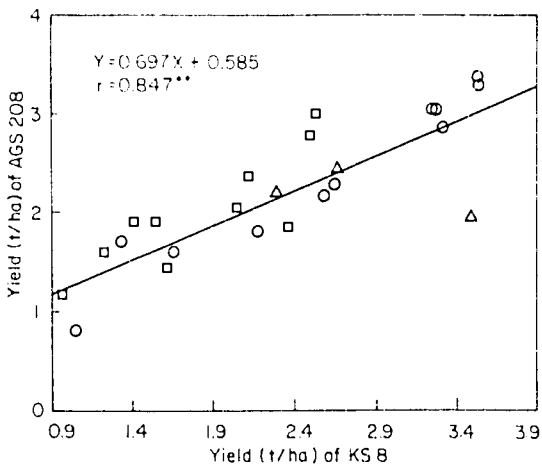

Fig. 1. The relationship of seed yield of AGS 208 and KS 8 at different locations in summer (□) and autumn (△) 1986, and spring (○) 1987.

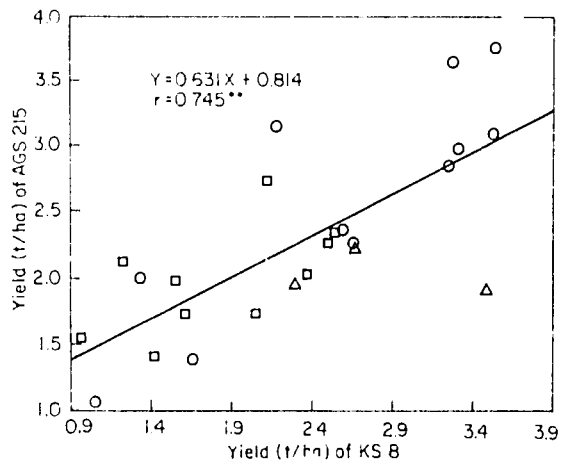

Fig. 2. The relationship of seed yield of AGS 215 and KS 8 at different locations in summer (□) and autumn (△) 1986, and spring (○) 1987.

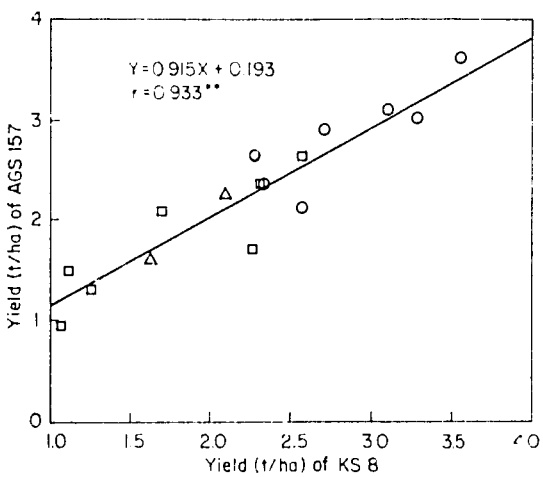

Fig. 3. The relationship of seed yield of AGS 157 and KS 8 at different locations in summer (□) and autumn (△) 1986, and spring (○) 1987.

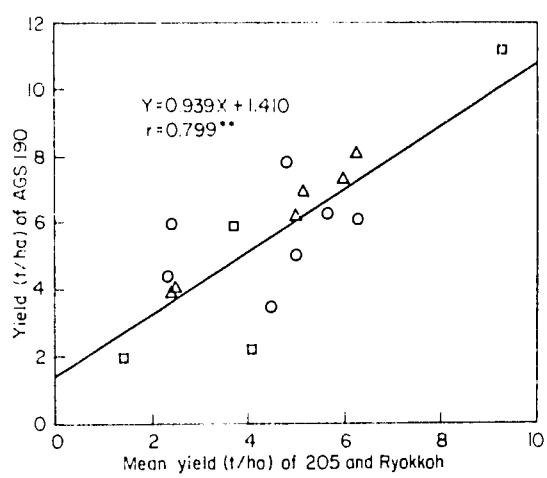

Fig. 4. The relationship of seed yield of AGS 190 and the average yield of 205 and Ryokkoh at different locations in spring (○), summer (□) and autumn (△) 1985 and 1986.

for mechanical harvest, c) resistance to pests, and d) early maturity. Due to the shortage and high cost of labor in Taiwan, mungbean had to be harvested by machine to reduce production cost. Therefore, the uniform-maturing lines developed by AVRDC are particularly suitable for Taiwan's condition.

Eight dull seed types of AVRDC mungbean lines and two check varieties were used in RYT 1987. V 2010 was used as the check variety for seed size, while TN 3 (VC 1628A) with lustrous seeds was used for yield. All AVRDC lines as well as TN 3 showed good performance in both spring and summer plantings, except VC 3857A which had lower yield than TN 3 in summer planting (Table 6). VC 3738A and VC 3890A did not only have the highest yields in both planting seasons but also similar or higher stability than TN 3 under different environments (Figs. 6 & 7). There was no significant difference in maturity among the entries, and mungbean had a shorter growth duration in summer than in spring planting (Table 6). However, due to the small seed size of VC 3738A, only VC 3890A was recommended to be released in Taiwan during 1988.

Table 5. Yield of entries in the Taiwan vegetable soybean regional yield trials in 1985 and 1986.

Entry	Marketable yield (t/ha)										Index
	Spring			Summer			Autumn			Mean	
	1985	1986	Mean	1985	1986	Mean	1985	1986	Mean		
AGS 190	5.8	5.2 ab	5.5	8.5 a	2.0	5.3	7.4 c	4.7 a	6.1	5.7 a	120
AGS 291	3.9	3.5 c	3.7	3.6 d	2.9	3.3	4.0 c	3.3 b	3.6	3.6 c	76
AGS 292	5.6	5.7 a	5.6	7.4 ab	3.2	5.3	7.3 a	3.5 a	5.4	5.5 a	117
AGS 293	3.9	4.3 abc	4.1	5.5 c	2.2	3.8	5.2 b	3.3 b	4.2	4.1 bc	87
AGS 294	5.4	5.1 ab	5.2	6.8 abc	3.0	4.9	4.0 c	2.9 b	3.4	4.5 b	96
AGS 295	4.0	4.2 bc	4.1	6.5 bc	2.8	4.6	5.3 b	3.0 b	4.2	4.2 bc	90
205	5.0	4.7 abc	4.8	6.9 abc	3.0	5.0	6.0 b	3.2 b	4.4	4.7 b	100
Ryokkoh	4.0	4.0 bc	4.0	6.1 bc	2.6	4.3	6.0 b	3.4 b	4.7	4.3 b	92

Table 6. Yield and agronomic characters of entries in the Taiwan mungbean regional yield trials, spring and summer 1987.

Entry	Mean yield (t/ha)	Index	Days to maturity	100-seed wt. (g)	Plant height (cm)	Pod/plant	Seed/pod
Spring 1987							
VC 3004A	1.3 bcde	91	78.6	5.42	43.6	15.3	10.1
VC 3116A	1.3 cde	86	80.5	5.63	49.4	13.2	10.6
VC 3543A	1.3 bcde	91	79.7	5.67	45.0	13.4	10.2
VC 3580A	1.2 de	84	79.9	5.10	50.3	14.5	10.7
VC 3678A	1.4 abc	102	77.6	4.97	47.7	14.9	11.2
VC 3738A	1.5 ab	107	79.2	5.43	45.3	14.6	11.1
VC 3857A	1.3 bcde	93	78.8	5.60	51.8	11.9	11.0
VC 3890A	1.6 a	111	77.3	5.91	46.0	14.5	11.2
V 2010	1.1 e	77	79.6	5.86	54.7	9.5	10.8
TN 3	1.5 abcd	100	78.1	5.61	53.5	14.6	10.9
Summer 1987							
VC 3004A	1.5 ab	101	68.6	6.01	66.6	12.6	11.9
VC 3116A	1.3 bc	88	68.9	6.12	63.5	11.1	11.4
VC 3543A	1.4 ab	100	68.0	6.26	59.2	12.0	10.8
VC 3580A	1.3 bc	87	70.9	5.41	66.5	12.7	11.4
VC 3678A	1.4 abc	95	70.6	5.44	63.0	12.8	12.4
VC 3738A	1.6 a	112	69.7	5.84	62.6	13.4	12.3
VC 3857A	1.1 cd	77	71.3	6.42	67.8	11.0	12.2
VC 3890A	1.5 ab	101	65.4	6.35	53.7	11.2	11.1
V 2010	0.9 d	61	69.6	6.56	65.6	10.1	11.1
TN 3	1.4 ab	100	67.9	6.22	64.0	11.9	11.2

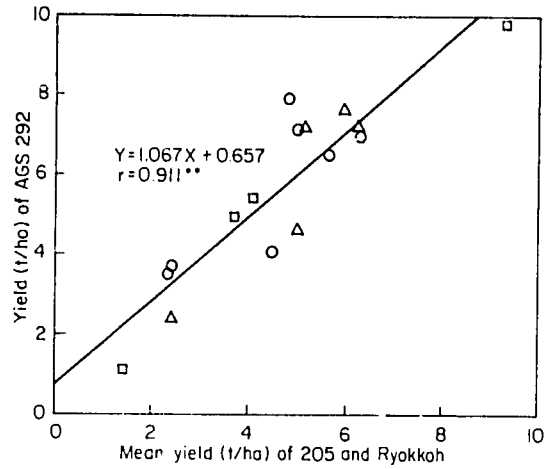

Fig. 5. The relationship of seed yield of AGS 292 and the average yield of 205 and Ryokkoh at different locations in spring (o), summer (□) and autumn (△) 1985 and 1986.

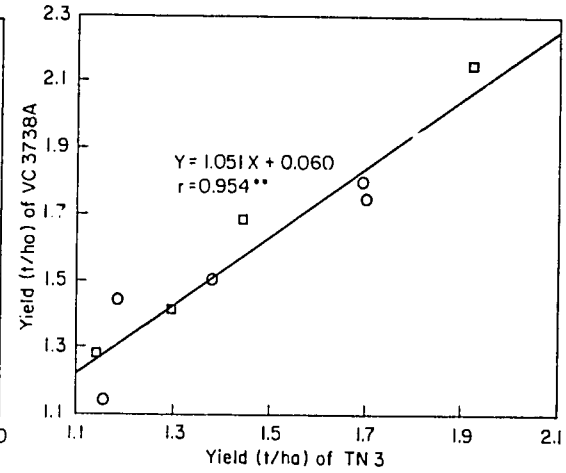

Fig. 6. The relationship of seed yield of VC 3738A and TN 3 at different locations in spring (o) and summer (□) 1987.

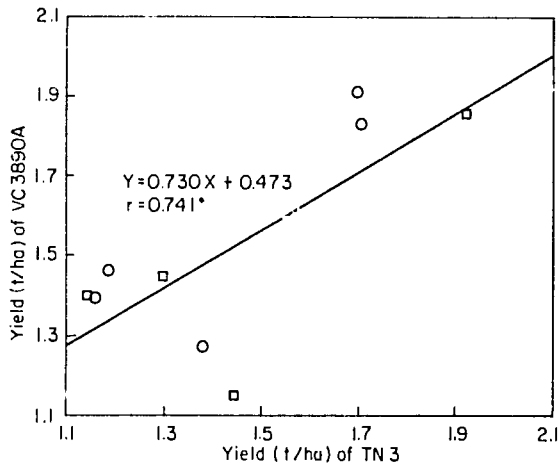

Fig. 7.
The relationship of seed yield of VC 3890A and TN 3 at different locations in spring (o) and summer (□) 1987.

4. Processing tomato

One of the main objectives of the processing tomato breeding program in Taiwan is to develop high and stable-yielding genotypes with heat tolerance to extend production period and obtain high quality fruits. These trials, including four AVRDC F_1 processing tomato hybrids were evaluated mainly in the Chianan area. Results showed that all four AVRDC F_1 hybrids did better than the check entry, TK 70, during the two cropping seasons in 1986, except PT 4037 in the autumn planting (Table 7). However, these hybrids only performed similarly as the other check, TN 3 (PT 3027), during winter but not during the autumn planting, which implied that TN 3 still had better heat tolerance than the other entries. Their qualities in terms of color and soluble solids content were similar to that of TK 70; but TK 70 had the biggest fruit size.

5. Fresh market tomato

These trials were all conducted in the highlands, 500 to 600 m above sea level, except for AVRDC.

All six AVRDC lines had higher average yield across locations than the check entry, TSS 1 in 1986 summer RYT (Table 8). Similar to last year's results, the FMTT group, particularly in the lowland

Table 7. Yield and horticultural characters of entries in the Taiwan processing tomato regional yield trials, 1986.

Entry	Yield* (t/ha)	Days to maturity	Fruit size (g)	pH	Soluble solids (°Brix)	Titratable acidity (%)	Hunter color (a/b)
			Autumn				
PT 1017	134.7	125	53.7	4.16	5.18	0.45	2.73
PT 4027	146.7	123	53.5	4.17	4.58	0.43	2.69
PT 4037	116.9	124	72.2	4.15	4.61	0.43	2.61
PT 4045	143.1	125	82.4	4.11	5.25	0.50	2.66
TN 3	151.6	127	59.3	4.22	4.92	0.38	2.73
TN 2	123.8	131	81.8	4.22	4.93	0.37	2.73
TK 70	126.0	128	88.6	4.20	4.95	0.47	2.63
			Winter				
PT 1017	91.3	119	49.7	4.13	4.92	0.46	2.67
PT 4027	92.8	119	55.0	4.21	4.96	0.41	2.63
PT 4037	80.1	120	69.1	4.18	5.15	0.45	2.60
PT 4045	96.0	119	71.2	4.19	4.99	0.44	2.62
TN 3	90.5	121	58.9	4.20	4.46	0.37	2.65
TN 2	44.2	121	72.2	4.31	4.97	0.32	2.74
TK 70	66.2	123	81.5	4.29	5.00	0.39	2.66

*The average yield across three locations.

Table 8. Yield of entries in the Taiwan summer tomato regional yield trials, summer 1987.

Entry	Yield (t/ha)							Index
	Chinshan	Pengdun	Hsinyi	Yuchi	Hsinsher	Shanhua	Mean	
FMTT 3	55.7 a	63.9 cd	52.9 a	57.5 a	11.4	8.8 ab	41.7 ab	119
FMTT 22	60.0 a	75.0 a	51.3 ab	51.0 b	8.2	10.5 a	43.3 a	124
FMTT 23	56.1 a	64.0 cd	43.2 d	45.7 bc	10.8	7.2 b	37.9 abc	108
FMTT 27	43.6 b	61.0 cd	39.1 e	43.9 c	20.1	7.9 ab	35.9 bc	103
FMTT 33	60.6 a	71.1 ab	49.0 b	51.9 ab	8.0	10.4 a	41.8 ab	119
FMTT 34	55.8 a	66.2 bc	41.7 d	44.4 c	20.6	7.0 b	39.3 abc	112
TSS No.1	44.0 b	54.2 ef	46.3 c	50.4 b	14.1	0.7 c	35.0 bcd	100

area of Shanhua, showed their heat tolerance compared to TSS 1. Among the entries, FMTT 22 gave the highest average yield and the highest yield in most of the trials.

6. Chinese cabbage

Yields of Chinese cabbage had significant variations among locations in the 1987 summer RYT. The average yields across entries varied from 1.5 t/ha in Luchu to 38.2 t/ha in Chupei. The former was mainly attributed to heavy rain brought about by a typhoon and the latter was due to late transplanting in summer.

All four AVRDC lines outyielded the check variety, Summer Light No. 4, consistently in all locations, except AVRDC 85-120 in Penghu Island. AVRDC 85-216 gave the highest average yield of 22.3 t/ha, which was 53% higher than the check (Table 9).

7. Sweet potato

Results of average yields across five locations and agronomic characters of entries in the 1987 summer RYT are shown in Table 10. Among four AVRDC lines, only CN 1407-8 and CN 1345-8 tended to have similar yields to the check cultivars. Compared to the checks, however, their dry matter

Table 9. Yield and horticultural characters of entries in the Taiwan Chinese cabbage regional yield trials, summer 1987.

Entry	Mean yield (t/ha)	Days to maturity		Harvest rate (%)	Mean head wt.(g)	Head shape index	Solidity (g/cc)
		Direct seeding	Trans-planting				
AVRDC 82-156	18.3	66.5	45.8	82.8	486	1.36	0.44
AVRDC 83-2	17.8	67.0	42.8	86.6	586	1.23	0.39
AVRDC 85-120	18.1	63.5	45.9	83.6	594	1.40	0.39
AVRDC 85-216	22.3	68.0	45.6	87.1	685	1.58	0.41
Summer Light No.4	14.6	63.5	43.5	83.8	505	1.14	0.38

Table 10. Yield and agronomic characters of entries in the Taiwan sweet potato regional yield trials, summer 1986.

Entry	Marketable root yield (t/ha)	Dry matter	Protein	Sugar	Starch	Fiber
CN 1407-8	15.4 abcd	33.5	4.54	9.5	71.6	3.14
CN 1310-5	15.0 bcd	32.9	5.86	10.3	72.1	3.51
CN 1405-14	11.6 cde	29.9	5.27	10.7	67.0	3.54
CN 1345-8	16.1 abc	33.9	6.83	9.7	71.2	3.48
C 66-L-51	8.5 e	36.2	3.67	9.0	74.4	2.93
C 69-27	10.0 de	33.5	3.21	11.5	73.8	3.36
C 70-141	12.5 cde	36.4	4.29	9.2	76.1	3.21
C 70-245	13.9 bcde	34.5	3.80	11.1	71.6	3.35
TN 68-6	20.7 a	27.9	5.22	11.2	70.7	3.27
TN 67-16	18.2 ab	26.5	5.18	15.5	63.9	4.21
TN 66	20.6 a	25.5	6.63	13.4	57.9	4.33

contents had been increased and their sugar contents had been reduced, both showing the progress of the AVRDC sweet potato breeding program.

8. Sweet pepper

There were significant seasonal effects on the yield of sweet pepper; the 1986 autumn trial had higher yields but smaller fruit size compared to the 1987 spring trial in all three locations (Table 11).

Among the entries, Gypsy gave the highest yields — 50% higher than the other entries — during both cropping seasons, particularly during the spring planting. Giant Bell had the biggest fruits in both planting seasons. Blue Star and 0329 had lower firmness and 0329 had significantly higher sweetness than the other entries.

9. Hot pepper

Generally, hot pepper grew better in spring than in autumn planting seasons in Taiwan, except Passion and Szechuan which had higher yields than the other entries in autumn (Table 12). Passion outyielded the other entries during both seasons. Hungarian Yellow Wax was the earliest maturing cultivar among the entries, while Farmer's Newcomer had the biggest fruits.

10. Cauliflower

Yields of cauliflower were much lower in spring 1987 RYT than in the 1986 autumn RYT (Table 13) mainly because of the higher mean air temperature during the growth of the former (26.7°C) compared to the latter (24.8°C). Not one of the entries performed better than the check cultivar (45 days) in the autumn planting. In late spring planting, F_1 451 significantly outyielded the other entries, obviously showing its heat tolerance.

Table 11. Yield and horticultural characters of entries in the Taiwan sweet pepper regional yield trials.

Entry	Autumn 1986		Spring 1987		Firmness	Fruit thickness (cm)	Sweetness (°Brix)
	Mean yield (t/ha)	Fruit size (g)	Mean yield (t/ha)	Fruit size (g)			
Blue Star	37.0	98	13.9	132	0.57 b	0.38	3.43 b
Gypsy	43.3	64	22.7	108	0.64 a	0.40	3.24 b
Dalbon	35.5	101	13.4	141	0.64 a	0.43	3.25 b
Green Bell	39.6	96	14.8	142	0.62 a	0.40	3.30 b
Giant Bell	37.7	104	13.3	155	0.62 a	0.38	3.12 b
VD Berg (0506)	40.7	103	14.1	120	0.63 a	0.43	3.32 b
3856	33.9	88	12.2	129	0.63 a	0.42	3.11 b
0329	35.8	90	14.9	155	0.60 b	0.44	3.85 a

Table 12. Yield and horticultural characters of entries in the Taiwan hot pepper regional yield trials.

Entry	Marketable yield (t/ha)	Days to maturity	Days to flowering	Plant height (cm)	Fruit length (cm)	Fruit width (cm)
		Autumn 1986				
Farmer's Newcomer	26.8 bc	111	41	71.5	16.8	2.2
Passion	42.5 a	120	63	79.2	13.3	1.5
Hungarian Yellow Wax	24.7 bcd	104	8	55.0	12.0	2.8
Twist Hot	11.4 d	104	41	49.1	8.9	1.0
Hong Shan Ho	15.4 cd	117	42	63.7	10.7	1.7
Szechuan (ck)	34.1 ab	124	63	79.2	11.8	1.0
		Spring 1987				
Farmer's Newcomer	34.0 b	107	25	30.6	8.3	1.8
Passion	40.0 a	114	25	32.5	8.2	1.3
Hungarian Yellow Wax	35.1 ab	98	13	28.3	6.3	2.0
Twist Hot	23.1 c	104	13	24.4	5.4	1.3
Hong Shan Ho	30.2 b	112	18	31.2	7.7	1.6
Szechuan (ck)	21.9 c	108	25	39.1	7.8	0.9

Table 13. Yield and horticultural characters of entries in the Taiwan cauliflower regional yield trial in AVRDC.

Entry	Yield (t/ha)	Days to maturity	Mean growth (g)	Mean head wt.(g)	Head length (cm)	Head width (cm)	Plant length (cm)	Plant width (cm)
			Autumn 1986					
F_1 451	25.2 ab	44.5	1210	502	10.3	14.2	37.0	18.4
Fengshan Extra Early	18.5 c	48.9	1192	426	10.4	14.1	42.9	19.2
Chia Tai No.1	24.2 b	45.2	1212	512	10.9	14.6	43.0	18.3
45 days (ck)	29.8 a	50.0	1578	634	12.9	14.9	46.5	21.3
			Spring 1987					
F_1 451	9.2 a	46.8	953	391	12.3	12.3	38.0	17.9
Fengshan Extra Early	2.1 c	51.3	492	179	11.8	6.8	38.3	16.0
Chia Tai No.1	4.4 b	51.9	496	245	11.6	9.4	38.5	16.0
45 days (ck)	5.3 b	51.4	645	272	13.4	11.3	45.1	19.3

11. Chinese radish

Yields of Chinese radish were higher in autumn 1986 than spring 1987 (Table 14). However, the mean air temperature during their growth was similar at 24.5°C and 24.8°C, respectively. It appeared that the differences in daylength (from 12.4 to 11.4 and 12.9 to 13.8 hours, respectively) might have contributed to the distribution of assimilates; hence, the plants in spring planting had more leaves.

Among the entries, Chu Pei Kan Zuyi and Tung Shih Kan Zu gave higher yields than the other entries in autumn, while 40 Days Early and Daeburyong yielded high in spring.

12. Mustard

It took about 30 to 40 days for mustard to mature in both seasons (Table 15). Among the three cultivars tested, Chinhsingly had the highest yield in autumn while Tender Green yielded the highest in spring. The low yields of Gisilba were mainly due to high rate of bolting.

Table 14. Yield and horticultural characters of entries in the Taiwan Chinese radish regional yield trials.

Entry	Mean yield (t/ha)	Days to maturity	Leaf no./ plant	Root length (cm)	Root width (cm)
		Autumn 1986			
Chu Pei Kan Zuyi	43.5	55	15.4	19.9	7.9
Tung Shih Kan Zu	45.8	55	15.0	19.7	8.0
40 Days Early	34.4	47	15.7	25.4	6.5
Summer Top	26.5	56	16.2	18.5	6.3
Daeburyong	35.9	56	15.0	19.1	6.8
Tour Tou Yi	43.6	55	15.5	19.8	8.1
		Spring 1987			
Chu Pei Kan Zuyi	9.7 b	49.6 b	19.5 ab	18.3 b	5.5
Tung Shih Kan Zu	7.9 b	49.1 b	20.6 a	20.7 b	6.0
40 Days Early	14.8 a	48.0 c	21.1 a	25.2 a	5.6
Summer Top	9.7 b	50.9 a	15.0 c	18.9 b	4.9
Daeburyong	14.5 a	49.5 b	16.6 bc	20.2 b	5.5
Tour Tou Yi	9.0 b	49.6 b	20.8 a	19.5 b	5.8

Table 15. Yield and horticultural characters of entries in the mustard regional yield trials in AVRDC.

Entry	Yield (t/ha)	Days to maturity	Leaf no./ plant	Leaf length (cm)	Leaf width (cm)
		Autumn 1986			
Gisilba	7.5 c	30	126	12.1	7.5
Tender Green	21.7 b	34	32	34.0	24.8
Chihsingly	46.2 a	41	10	42.1	40.1
		Spring 1987			
Gisilba	5.5 c	35.0	248	9.2	6.4
Tender Green	39.0 a	37.3	69	7.8	15.2
Chihsingly	29.6 b	40.9	45	32.5	25.6
Ta Peng Pao	24.5 b	39.5	48	28.4	24.9

13. Snap bean

Rust is one of the major constraints in snap bean production in Taiwan. Hence, the snap bean RYTs were carried out with and without fungicides. Results showed that all entries outyielded the check cultivar, Thailand, under the treatment without fungicides during the autumn planting (Table 16). Witsa had the highest yield in the fungicide-protected treatment. There was no significant differences in snap bean yield among treatments and cultivars.

Table 16. Yield and horticultural characters of entries in the Taiwan snap bean regional yield trials.

Entry	Treatment	Autumn 1986		Spring 1987	
		Yield (t/ha)	Pod length (cm)	Yield (t/ha)	Pod length (cm)
Without fungicides					
Taichung #11		21.2	15.0	26.4	15.4
Taichung #12		19.9	16.1	23.2	16.7
Taichung #16	Without	20.7	16.5	24.4	16.8
Black Creasback	Fungicides	20.0	15.0	22.8	15.2
Thailand		15.7	15.9	23.3	15.8
With fungicides					
Black Creasback		20.5	15.1	23.2	15.7
Thailand		15.4	16.1	25.0	17.6
Witsa	With	30.2	18.8	24.3	19.1
Paichia 7"	Fungicides	23.2	15.3	21.5	15.2

Studies on the Relationship of Seed and Pod Size of Vegetable Soybean 205 (Tzurunoko)

Summary

Large pod size is one of the important items in vegetable soybean quality. It was noticed that the pod size of one of the most popular vegetable cultivars, 205 (Tzurunoko), was getting smaller each year. This project, in cooperation with Kaohsiung DAIS, was thus directed at finding the possible problems responsible for this phenomenon and seeking solutions to ensure the quality of this vegetable soybean. The first set of experiments studied the effects of seed sizes sown on pod size, marketable and total pod yields, and seed size and seed yield. Results showed that seed size sown might not be a major factor responsible for the decreasing pod size. On the other hand, the cultivating management procedures might have an effect on this phenomenon; this warrants further research.

Introduction

Large pod size is one of the important criteria determining vegetable soybean quality. It was noticed that the pod size of one of the most popular vegetable soybean cultivar, 205, was getting smaller each year. The method wherein farmers produced their own seeds without selecting seed size could be related to decreasing pod size. This project, in cooperation with the Kaohsiung DAIS, investigated the possible reasons behind this phenomenon and sought solutions to ensure the quality of vegetable soybean.

Materials and Methods

Seeds of the vegetable soybean cultivar, 205, were grouped in four different sizes, i.e. 100-seed weight of 43, 40, 30 and 20 g. These seeds were then used in two sets of experiments. One set was

planted in three seasons at two locations, Kaohsiung DAIS and AVRDC, with an RCB design in four replications to study the effects on marketable and total pod yields, and pod size. The other set was planted at AVRDC to determine seed yield and seed size.

Results and Discussion

Results showed that neither marketable nor total pod yield increased by increasing the size of seeds sown. The average pod size, in terms of pod length, pod width, and per kilogram pod number, was not significantly affected. Although the smallest seeds had the lowest average seed size harvested in summer and the lowest seed yield in autumn 1986 among the four seed-size groups, the percentages of harvested seeds in different size groups were not significantly influenced by size of seeds sown (Table 17). It was concluded that seed size might not be the major factor responsible for the decreasing pod size of vegetable soybean cultivar, 205.

Results of consistently higher marketable and total pod yields, and pod size of vegetable soybean planted at AVRDC compared to that at Kaohsiung DAIS showed that inappropriate management of vegetable soybean cultivation could be partially responsible for decreasing pod size of Tzurunoko. However, this warrants further studies. Moreover, the higher yields at AVRDC were more pronounced in total yield than in marketable yield; hence, lower percentage of marketable to total yield was obtained. This suggests room for improvement of the management techniques at AVRDC to increase the marketable yield of vegetable soybean.

Table 17. Effect of seed sizes sown on yield and seed size of vegetable soybean, variety 205 (Tzurunoko).

Seed size (g/100 seeds)	Summer		Autumn				
	Yield (t/ha)	Seed size (g/100 seeds)	Yield (t/ha)	Percentage in different seed size			
				43	40	30	22
43	1.7	22.9 a	1.8 a	11.6	37.3	45.9	5.2
40	1.6	21.8 a	1.6 ab	12.1	37.4	47.3	3.3
30	1.4	21.4 a	1.9 a	11.6	34.2	48.4	5.9
22	1.4	18.9 b	1.5 b	10.8	32.1	48.9	8.4

Soil Science

Improved Cropping Systems

Introduction

Crop rotation suppresses soilborne diseases, preserves soil organic matter, increases soil nitrogen, balances soil nutrients, and improves the physical properties of soil. This project, which started in 1983, aims to 1) develop crop rotation systems specifically tailored to the tropics, 2) evaluate the effects of previous crops and successive application of mulch and compost on tomato and soybean yields, 3) develop new technologies feasible to summer vegetable cultivation in the humid tropics, and 4) develop labor-, fertilizer-, chemical- and water-saving crop rotation systems.

Materials and Methods

The number of rotation systems starting with six different cropping sequences in autumn 1983 was extended to 10 sequences from summer 1984. The cropping sequences from autumn 1985 are listed in Table 1.

Individual crops were planted in 50-m^2 plots. A randomized design with two replications was used. Although the fertilizer application rate for each crop was different in each cropping sequence and also between different cropping sequences, the total amounts of N, P and K applied per annum to each cropping system was fixed at the rate of 200, 120 and 220 kg/ha, respectively.

Results and Discussion

The yields of rice and corn in different cropping sequences are presented in Tables 2 and 3, respectively. Rice yield in different cropping sequences or different cropping seasons did not vary greatly. Corn yield, however, varied by season, mainly due to insect damage. Mungbean yield in different cropping sequences is presented in Table 4. Mungbean yield either in the spring or autumn croppings was always low because of root damage caused by Fusarium. However, mungbean yield in the summer croppings after rice cultivation was fairly high and did not show any symptom of root diseases.

Sweet potato yield decreased significantly during continuous cropping both in autumn and summer, possibly due to rat damage (Table 5). Symptoms associated with continuous cropping hazards, however, were not clearly seen during sweet potato growth.

Chinese cabbage yield in different cropping sequences is presented in Table 6. Its yield in the autumn cropping was always higher when the previous cropping was either rice or sweet potato, but it varied each year during summer and spring croppings mainly because of damage by diseases and heavy rains. The Chinese cabbage yields in the summers of 1984 and 1985 were fairly high, while those in 1986 and 1987 were low mainly due to typhoon damage.

The yield of the spring croppings of Chinese cabbage is presented in Figure 1. Rotation nos. 6, 7 and 8 were the same as Chinese cabbage in spring, tomato in summer and soybean in autumn, but had different organic manure applications. The application of compost with rice straw mulching (Rotation no. 7) or rice straw mulching alone (Rotation no. 8) resulted in significantly higher yield

Table 1. Rotation system tested for the AVRDC mandate crops.

Rotation no.	Spring	Summer	Autumn
1	Rice	Mungbean	Tomato
2	Soybean	Rice	Sweet potato
3	Soybean	Chinese cabbage	Corn
4	Tomato	Corn	Soybean
5	Soybean	Sweet potato	Chinese cabbage
6	Chinese cabbage	Tomato	Soybean
7	Chinese cabbage (30 t/ha compost + mulching)	Tomato (30 t/ha compost + mulching)	Soybean
8	Chinese cabbage (mulching)	Tomato (mulching)	Soybean
9	Rice	Tomato (30 t/ha compost + mulching)	Soybean (30 t/ha compost + mulching)
10	Rice	Tomato (mulching)	Soybean

Table 2. Rice yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Marketable yield (t/ha)	Total (t/ha)
Spring 1984	1	Tomato	4.84	4.84
Summer 1984	2	Mungbean	4.67	4.67
Spring 1985	1	Tomato	4.23	4.23
Spring 1985	9	Soybean	3.73	3.73
Spring 1985	10	Soybean	3.39	3.39
Summer 1985	2	Mungbean	3.12	3.12
Spring 1986	1	Tomato	5.06	5.06
Spring 1986	9	Soybean	4.87	4.87
Spring 1986	10	Soybean	4.40	4.40
Summer 1986	2	Soybean	5.14	5.14
Spring 1987	1	Tomato	4.20	4.20
Spring 1987	9	Soybean	4.66	4.66
Spring 1987	10	Soybean	4.18	4.18
Summer 1987	2	Soybean	4.16	4.16

Table 3. Corn yield in different cropping sequences.

Planting time[z]	Rotation no.	Previous crop	Marketable yield (t/ha)	Total (t/ha)
Summer 1984	4	Tomato	0.00	0.00
Summer 1985	4	Tomato	0.00	0.00
Summer 1986	4	Tomato	4.58	5.83
Autumn 1986	3	Chinese cabbage	19.09	19.09
Summer 1987	4	Tomato	2.98	4.09

[z]In the summers of 1984 and 1985, corn was harvested as green manure.

Table 4. Mungbean yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Yield (t/ha)
Autumn 1983	6	Rice	0.78
Spring 1984	2	Sweet potato	1.06
Summer 1984	1	Rice	2.09
Autumn 1984	6	Tomato	0.00
Autumn 1984	7	Tomato	0.85
Autumn 1984	8	Tomato	0.49
Spring 1985	2	Sweet potato	0.36
Summer 1985	1	Rice	1.89
Summer 1986	1	Rice	1.83
Summer 1987	1	Rice	1.81

Table 5. Sweet potato yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Marketable yield (t/ha)	Total yield (t/ha)
Autumn 1983	2	Rice	17.6	22.3
Summer 1984	5	Soybean	12.0	13.3
Autumn 1984	2	Rice	14.7	17.0
Summer 1985	5	Soybean	8.2	9.7
Autumn 1985	2	Rice	8.3	9.8
Summer 1986	5	Soybean	6.2	7.6
Autumn 1986	2	Rice	8.5	9.9
Summer 1987	5	Soybean	5.2	5.9

Table 6. Chinese cabbage yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Marketable yield (t/ha)	Total yield (t/ha)
Autumn 1983	5	Rice	28.0	54.8
Spring 1984	6	Mungbean	25.6	48.0
Summer 1984	3	Soybean	27.1	52.4
Autumn 1984	5	Sweet potato	21.6	47.1
Spring 1985	6	Mungbean	12.2	31.4
Spring 1985	7	Mungbean	30.3	65.4
Spring 1985	8	Mungbean	14.7	35.9
Summer 1985	3	Soybean	30.7	58.3
Autumn 1985	5	Sweet potato	28.3	47.7
Spring 1986	6	Soybean	3.0	6.6
Spring 1986	7	Soybean	11.6	23.5
Spring 1986	8	Soybean	9.0	17.4
Summer 1986	3	Soybean	8.6	23.8
Autumn 1986	5	Sweet potato	29.5	48.5
Spring 1987	6	Soybean	29.2	48.0
Spring 1987	7	Soybean	36.1	55.3
Spring 1987	8	Soybean	35.0	55.0
Summer 1987	3	Soybean	15.2	28.1

in Chinese cabbage. The yield was lower in plants without organic manure (Rotation No. 6) for three years, resulting from disease suppression (Table 7).

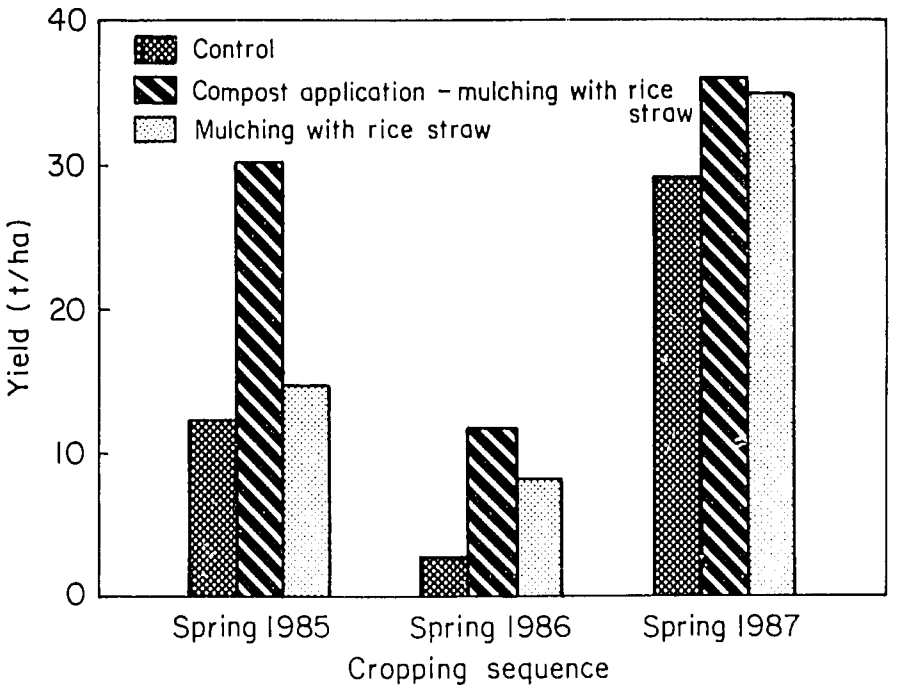

Fig. 1. The effect of compost application and mulching with rice straw on the yield of Chinese cabbage in the rotational cropping system.

Table 7. Effect of compost application and mulching with rice straw on disease suppression in Chinese cabbage in the rotational cropping system.

Rotation no.	Spring 1985 (%)	Spring 1986 (%)	Spring 1987 (%)
6[z]	41.0	47.9	2.1
7[y]	13.6	10.7	1.4
8[x]	38.9	19.3	1.4

[z]6 = control; [y]7 = compost application + mulching with rice straw; and [x]8 = mulching with rice straw.

Soybean yield under different cropping sequences is presented in Table 8. Soybean showed no growth retardation in the same cropping sequences for four years. The spring soybean crop always had higher yield than the autumn crop regardless of the previous crop. Soybean yield in cropping sequences increased gradually in both spring and autumn for four years. Soybean with compost application and rice straw mulching had the highest yield.

Tomato yield in different sequences is presented in Table 9. Tomato in the spring and autumn croppings always had higher yield regardless of the previous crops, i.e. rice, soybean or mungbean. Tomato yield in any cropping system during summer was very low mainly due to diseases.

In the summer tomato cropping of 1985, a new heat-tolerant cultivar, CL 5915-153, was introduced. It gave higher yield due to more disease resistance and more heat tolerance than CL 1131-38, the previous cultivar used. But in the summers of 1986 and 1987, CL 5915-153 suffered markedly from bacterial spot due to heavy rain. Tomato yield, therefore, was decreased significantly.

Table 8. Soybean yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Yield (t/ha)
Autumn 1983	4	Rice	2.59
Spring 1984	3	Buckwheat	3.74
Spring 1984	5	Chinese cabbage	3.87
Autumn 1984	4	Corn	2.62
Autumn 1984	9	Tomato	3.08
Autumn 1984	10	Tomato	2.31
Spring 1985	3	Buckwheat	3.85
Spring 1985	5	Chinese cabbage	3.72
Autumn 1985	4	Corn	2.38
Autumn 1985	6	Tomato	2.63
Autumn 1985	7	Tomato	2.45
Autumn 1985	8	Tomato	2.59
Autumn 1985	9	Tomato	2.75
Autumn 1985	10	Tomato	2.73
Spring 1986	2	Sweet potato	4.42
Spring 1986	3	Buckwheat	3.93
Spring 1986	5	Chinese cabbage	3.82
Autumn 1986	4	Corn	3.14
Autumn 1986	6	Tomato	2.92
Autumn 1986	7	Tomato	2.95
Autumn 1986	8	Tomato	3.08
Autumn 1986	9	Tomato	3.47
Autumn 1986	10	Tomato	2.77
Spring 1987	2	Sweet potato	4.13
Spring 1987	3	Corn	4.32
Spring 1987	5	Chinese cabbage	4.19

Table 9. Tomato yield in different cropping sequences.

Planting time	Rotation no.	Previous crop	Marketable yield (t/ha)	Total yield (t/ha)
Autumn 1983	1	Rice	46.4	46.4
Spring 1984	4	Soybean	43.3	43.3
Summer 1984	6	Chinese cabbage	15.6	15.6
Summer 1984	7	Fallow	15.8	15.8
Summer 1984	8	Fallow	17.6	17.6
Summer 1984	9	Fallow	17.4	17.4
Summer 1984	10	Fallow	14.8	14.8
Autumn 1984	1	Mungbean	57.4	57.4
Spring 1985	4	Soybean	67.3	67.3
Summer 1985	6	Chinese cabbage	29.9	29.9
Summer 1985	7	Chinese cabbage	46.2	46.2
Summer 1985	8	Chinese cabbage	46.8	46.8
Summer 1985	9	Rice	46.8	46.8
Summer 1985	10	Rice	45.9	45.9
Autumn 1985	1	Mungbean	29.3	47.6
Spring 1986	4	Soybean	56.7	57.3
Summer 1986	6	Chinese cabbage	6.2	9.9
Summer 1986	7	Chinese cabbage	9.0	14.2
Summer 1986	8	Chinese cabbage	8.3	13.6
Summer 1986	9	Rice	7.3	10.3
Summer 1986	10	Rice	7.8	11.6
Autumn 1986	1	Mungbean	62.6	81.9
Spring 1987	4	Soybean	62.8	66.7
Summer 1987	6	Chinese cabbage	11.0	11.9
Summer 1987	7	Chinese cabbage	10.5	11.5
Summer 1987	8	Chinese cabbage	10.8	11.8
Summer 1987	9	Rice	15.3	17.0
Summer 1987	10	Rice	10.5	11.5

Conclusion

This study utilized a crop rotation system to evaluate different cropping patterns and the effects of mulch and compost on the yields of six crops. Results showed that:

1. Soybean and rice in a sequence cropping are both adequate crop rotations with no continuous cropping hazards while maintaining relatively high yields.
2. The cropping of soybean, rice and tomato are recommended in the spring.
3. Mungbean cropping is highly recommended in summer, rice is also recommended.
4. In autumn, Chinese cabbage and corn croppings, as well as tomato and soybean, are highly recommended.
5. Application of compost with mulching increased yield and suppressed disease in Chinese cabbage.

Continuous Soybean Cropping

Summary

Since autumn 1983, soybean has been cultivated twice or thrice a year, in spring, summer and autumn on the same land. Soybean yield has increased gradually each year, and reached 4.6 t/ha in the spring cropping of 1987. No continuous cropping hazard has been observed.

Introduction

Under intensive farming, an adequate crop rotation should be adopted to avoid continuous cropping hazards. This project aimed to determine how long soybean can be cultivated continuously on the same land in the tropics without a great decrease in yield.

Materials and Methods

Soybean has been cultivated successively on the same land twice a year, in spring and autumn, since autumn 1983. In summer all the experimental plots were covered with rice straw to save labor on weeding and protect the soil from the rain. Just before the autumn cultivation, rice straw was plowed into the soil of the experimental plots. At harvest only the pods were harvested; the rest of the plants were plowed into the soil. Since 1986 soybean had been cultivated in three seasons, spring, summer and autumn. The cropping sequence is presented in Figure 2.

The experiment was conducted using a split split-plot design with two replications. The main plot consisted of two cultivars, Kaohsiung no. 8 (KS 8), which is a broad-leaf type dominant cultivar in Taiwan as a check and AGS 129 (narrow-leaf type) as an AVRDC advanced line. Details of the subtreatments in 1987 are summarized in Table 10.

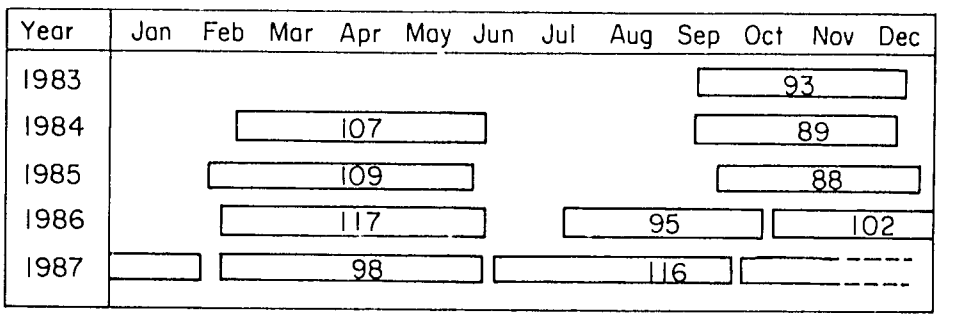

Fig. 2. Cropping sequence of soybean. Numerals in the figure indicate days of growth duration.

Table 10. Treatments used in continuous cropping of soybean in 1987.

Main plot: Cultivars AGS 129 and Kaohsiung 8
Subplot : Compost application (30 t/ha) with and without fertilization (kg/ha)

	N	P_2O_5	K_2O
Basal	60	90.0	60
Top 1	30	7.5	30
Top 2	30	7.5	30
Total	120	105.0	120

Top 1 = 0 days after R_1; Top 2 = 10 days after R_4.

Results and Discussion

Yield and yield components. The soybean yield of each cultivar in continuous cropping is presented in Figures 3 and 4. Soybean plants showed no symptoms of continuous cropping hazards even after nine successive cultivations. The yield of the spring and summer croppings increased slightly each year and reached 4.6 and 3.1 t/ha in 1987, respectively. On the other hand, the yield of the autumn crop decreased every year due to delayed sowing time.

The spring croppings have produced significantly higher yields than the autumn croppings. The sowing of the autumn crop, especially in 1986, was delayed due to the summer soybean crop. The delayed sowing resulted in many immature seeds of AGS 129 due to low temperature during the late growth stage. However, KS 8 produced 2.9 t/ha of seeds because of vigorous growth characterized by its broad-leaf and determinate genotype.

Relation of total dry weight to yield. The yield of soybean cultivar AGS 129 increased proportionally with increase in total dry weight (Fig. 5). A similar result was observed in KS 8, but when dry weight exceeded 24 g/plant, the yield stopped increasing (Fig. 6). KS 8 is a broad-leaf type cultivar, therefore, vigorous vegetative growth in the spring cropping may have caused mutual shading of leaves during the late growth stage, resulting in increased numbers of empty pods and decreased yield. AGS 129, on the other hand, is a narrow-leaf and indeterminate type cultivar; hence, mutual shading was not very serious. As a result, the yield increased with increased total dry matter production.

In summary AGS 129 was more tolerant to high-population cultivation and performed better in the spring and summer cropping, while KS 8 was suitable for the autumn cropping. Due to its broad-leaf character, the initial growth of KS 8 was faster than AGS 129 and it matured earlier.

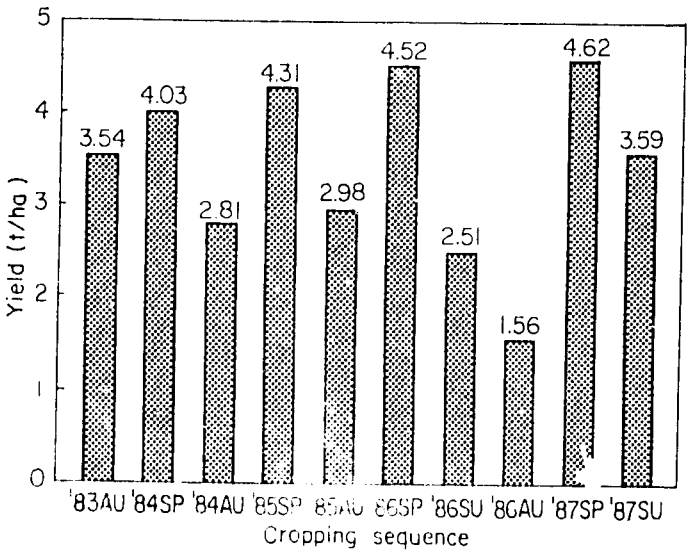

Fig. 3.
Changes in the yield of soybean AGS 129 in continuous cropping from autumn 1983 to summer 1987. SP = spring planting, SU = summer planting, AU = autumn planting.

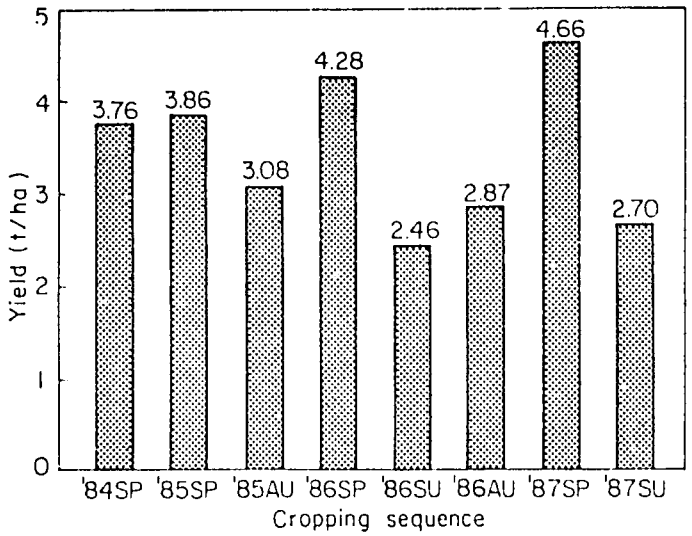

Fig. 4.
Changes in the yield of soybean KS 8 in continuous cropping from spring 1984 to summer 1987. SP = spring planting, SU = summer planting, and AU = autumn planting.

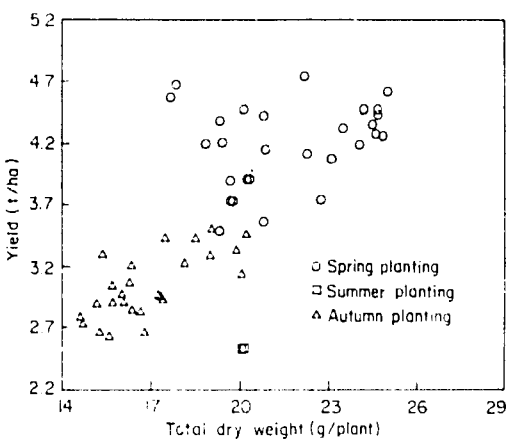

Fig. 5. Relationship between total dry weight and yield of soybean AGS 129 in continuous cropping from autumn 1983 to spring 1987.

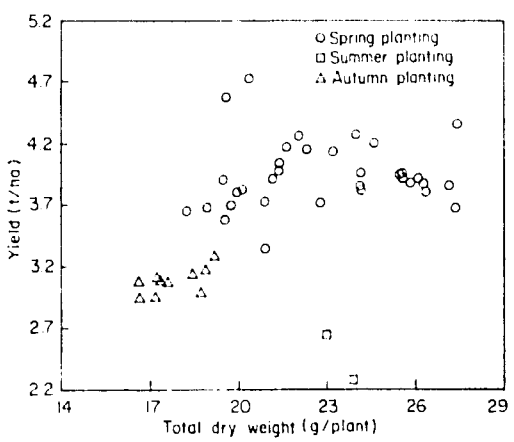

Fig. 6. Relationship between total dry weight and yield of soybean KS 8 in continuous cropping from spring 1984 to spring 1987.

Contribution of each yield component to yield of different cultivars. Soybean yield was plotted against seed number in Figures 7 and 8 for cultivars AGS 129 and KS 8, respectively. The yields of both cultivars increased with increasing seed number. To obtain the same yield level, AGS 129 required more seeds than KS 8 because of its smaller seed size.

The effect of 100-seed weight on yield is shown in Figures 9 and 10. There was a seasonal variation in each cultivar, and the spring cropping produced higher 100-seed weight than the autumn cropping. However, this component is characterized by the cultivar itself. KS 8 is a large-seeded cultivar, and its 100-seed weight varied from 21 to 23 g in the autumn cropping and 22 to 34 g in the spring cropping. AGS 129 had an average 100-seed weight of 14.5 to 16 g in the autumn cropping and 16 to 23 g in the spring cropping.

Figures 11 and 12 show the relation between 100-seed weight and seed number per plant in cultivars AGS 129 and KS 8, respectively. The relation between 100-seed weight and seed number in the spring cropping showed that the larger the number of seeds the lighter the 100-seed weight. In the autumn cropping, however, the 100-seed weight and seed number showed no relation in either cultivar.

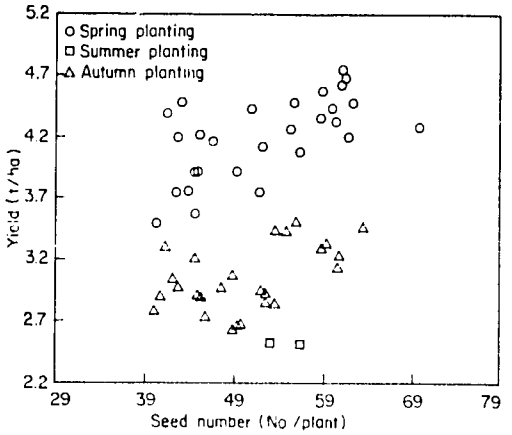

Fig. 7. Relationship between seed number and yield of AGS 129 in continuous cropping from autumn 1983 to spring 1987.

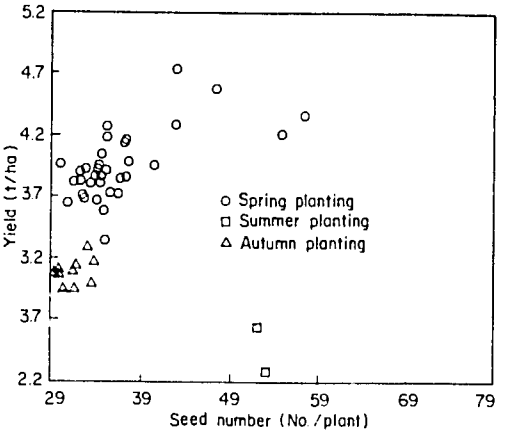

Fig. 8. Relationship between seed number and yield of KS 8 in continuous cropping from spring 1984 to spring 1987.

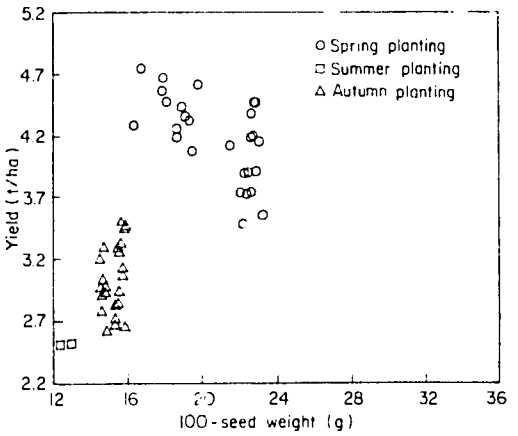

Fig. 9. Relationship between 100-seed weight and yield of AGS 129 in continuous cropping from autumn 1983 to spring 1987.

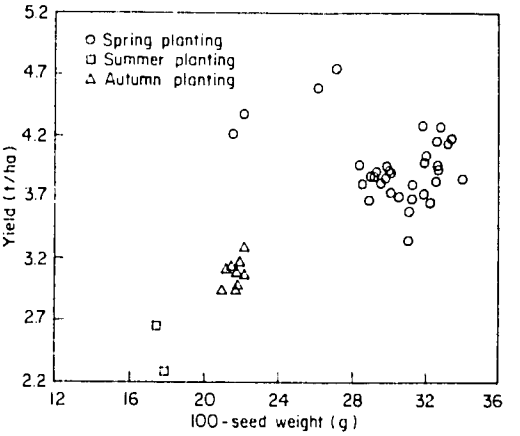

Fig. 10. Relationship between 100-seed weight and yield of KS 8 in continuous cropping from spring 1984 to spring 1987.

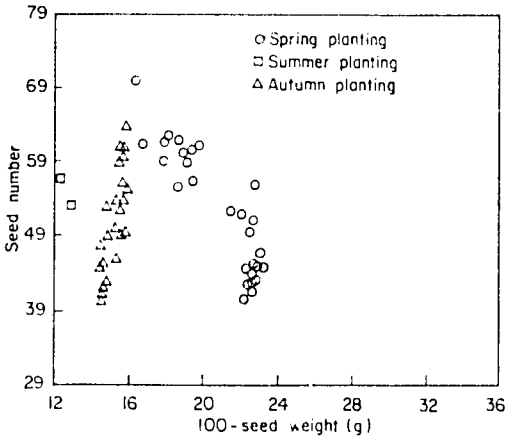

Fig. 11. Relationship between 100-seed weight and seed number of AGS 129 in continuous cropping from autumn 1983 to spring 1987.

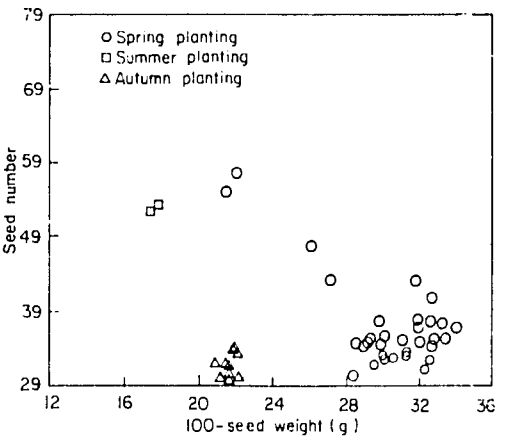

Fig. 12. Relationship between 100-seed weight and seed number of KS 8 in continuous cropping from spring 1984 to spring 1987.

The relationships among yield, seed number and 100-seed weight are shown in Figures 13 and 14. To obtain high yields of soybean in the tropics, it is more important to increase the seed number than the 100-seed weight during the spring cropping. A total of 18 to 23 g 100-seed weight and 50 to 65 seeds per plant is a better combination for AGS 129, while 29 to 35 g 100-seed weight and 40 to 50 seeds per plant is better for KS 8.

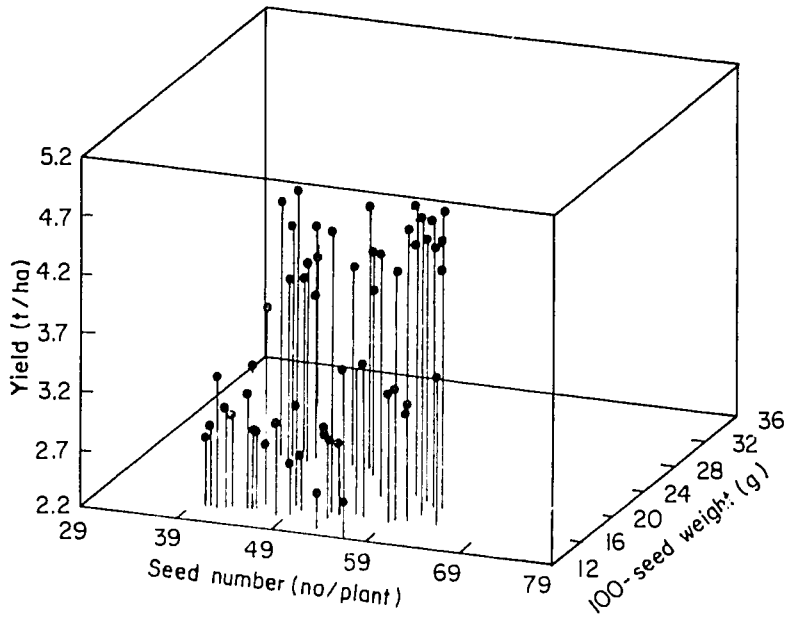

Fig. 13. Relationships among seed number, 100-seed weight and yield of AGS 129 in continuous cropping from autumn 1983 to spring 1987.

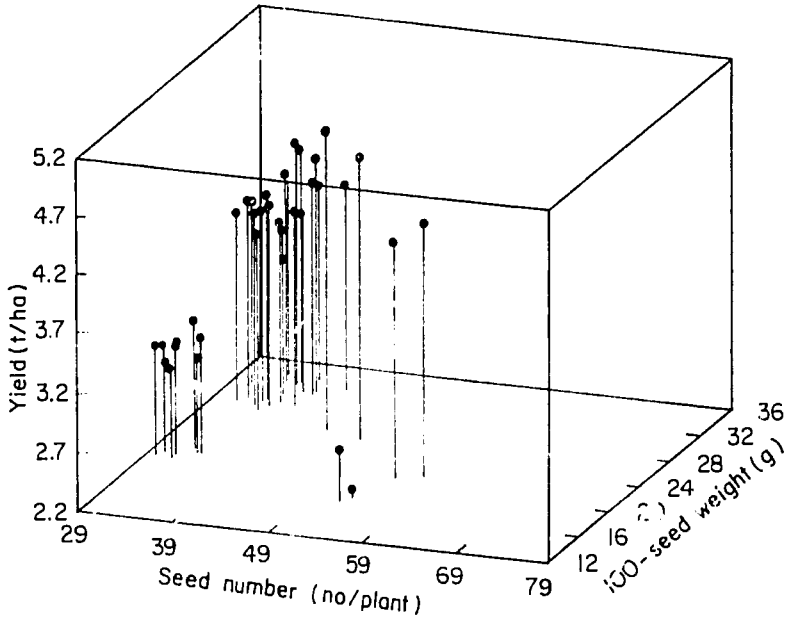

Fig. 14. Relationships among seed number, 100-seed weight and yield of KS 8 in continuous cropping from spring 1984 to spring 1987.

Development Program

Training

In 1987, 40 trainees from nine countries (Table 1) enrolled in courses covering nine different disciplines (Table 2) at AVRDC.

AVRDC provided a total of 92.63 man-months or 7.72 man-years of training. About one-third of the time was provided by Plant Breeding and two-thirds shared by the eight other disciplines (Table 2).

Only two out the of the 40 trainees came from the outreach programs in Indonesia and Korea; the rest came from the national/other programs (Table 3).

Tomato ranked first among the crops chosen by the participants as a subject of their studies, followed by soybean, Chinese cabbage, sweet potato, mungbean and pepper (Table 4).

Sixty-three percent of the scholarship funds were provided by eight sponsors (Table 5) and 37% by AVRDC.

Table 1. Enrollment and period of scholarship, 1987.

Countries	No. of scholars	Man-months
Egypt	1	1.0
Fiji	1	0.63
Germany, Federal Republic of	2	11.0
Indonesia	1	3.0
Korea	2	12.0
Philippines	8	15.5
Singapore	1	0.5
Taiwan	23	46.0
Yemen Arab Republic	1	3.0
Total	40	92.63

Table 2. Distribution of AVRDC training scholars by subject/discipline and period of training, 1987.

Subject/Discipline	RI	RS	RF	PT	SPT	VS	SST	Total	Man-months
Plant Breeding	2	–	–	–	2	1	7	12	33.0
Plant Pathology	–	1	–	–	–	–	1	2	10.0
Plant Physiology	–	–	–	–	–	–	2	2	4.0
Entomology	–	–	–	–	–	–	6	6	12.0
Chemistry	–	–	–	–	1	–	6	7	12.63
Crop Management	–	–	–	–	1	–	–	1	3.0
Cropping Systems	–	–	–	–	–	–	1	1	2.0
Information	–	–	1	–	–	–	–	1	12.0
R and D Management	–	–	–	–	8	–	–	8	4.0
Total	2	1	1	0	12	1	23	40	92.63

RI = Research Intern; RS = Research Scholar; RF = Research Fellow; PT = Production Trainee; SPT = Special Purpose Trainee; VS = Visiting Scientist; SST = Summer Student Trainee; and R and D = Research and Development.

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Table 3. Distribution of trainees according to program, December 1987.

Countries	Outreach program	National/other programs	Total	Man-months
Egypt		1	1	1
Fiji		1	1	0.63
Germany, Federal Republic of		2	2	11
Indonesia	1		1	3
Korea	1	1	2	12
Philippines		8	8	15.5
Singapore		1	1	0.5
Taiwan		23	23	46
Yemen Arab Republic		1	1	3
Total	2	38	40	92.63

Table 4. Commodity interest of the 1987 trainees.

Commodity	RI	RS	RF	PT	SPT	SST	VS	Total
Tomato	–	–	–	–	1	8	–	9
Soybean	1	–	1	–	–	6	–	8
Chinese cabbage	–	1	–	–	2	4	–	7
Sweet potato	–	–	–	–	–	5	–	5
Mungbean	–	–	–	–	–	3	1	4
Peppers	1	–	–	–	–	1	–	2
Others	–	–	1	–	9	–	–	10
Total	2	1	2	–	12	27	1	45

[z]See Table 2 for details.

Table 5. Training sponsors in 1987.

Asian Vegetable Research and Development Center
Asian Development Bank/Indonesia — TA No. 5119-INO
Second Laguna de Bay Irrigation Project — National Irrigation Administration/Philippines
German Agency for Technical Cooperation
German Agency for Technical Cooperation/Rural Development Project Al Mahwit Province, Yemen
German Academic Exchange Service
United States Agency for International Development/Egypt
United States Agency for International Development/Fiji
Eastreco/Nestle, Singapore

Tropical Vegetable Information Service

Tropical Vegetable Information Service

Summary

The Tropical Vegetable Information Service (TVIS) is a multidiscipline, multicomponent activity coordinated by the Development Program. The main activity of TVIS is the implementation and coordination of the IDRC-funded TVIS project. The TVIS related literature data bases contain over 7,393 processed records and will continue to be expanded. A total of 16 publications had been completed and 11 additional publications are expected to be published by the end of the first phase of the project.

Introduction

The Tropical Vegetable Information Service (TVIS), a multidiscipline, multicomponent activity, is coordinated and administered by the Development Program.

The TVIS project was initiated at AVRDC on 1 July 1984 with a grant from the International Development Research Centre (IDRC) of Canada. The coordination of the project was transferred to the Development Program in April 1986, when it was created. This project was established to strengthen and expand the existing specialized information activities on vegetables in the tropics. The vegetables specifically covered by the grant are mungbean, soybean and Chinese cabbage.

The information transfer activities for mungbean, soybean and Chinese cabbage include: symposia, newsletters, bibliographies, technical or farmers publications and state-of-the-art reviews. Therefore, the specific project objectives are to: (1) collect, store and analyze documents on mungbean, soybean rust and Chinese cabbage; (2) establish a computerized information retrieval system using MINISIS; and (3) conduct a workshop/symposium on mungbean as a means of bringing together world scientific reserves on this crop. The expected project outputs are: (1) selective dissemination of information (SDI), document delivery, and question and answer service; (2) mungbean soybean rust and Chinese cabbage bibliographies; (3) triannual newsletter (one issue devoted to soybean rust); (4) technical bulletins and farmers' manuals; (5) state-of-the-art reviews for Chinese cabbage and soybean; (6) directories of tropic and subtropic research personnel working on mungbean, soybean and Chinese cabbage; and (7) mungbean symposium proceedings.

Accomplishments

TVIS Documents Published. During the first 3½ years, the program published and distributed widely through the AVRDC mailing list 17 documents listed in Table 1.

Status of TVIS Literature Data Base. The AVRDC Library was responsible for establishing a computerized information retrieval system using the MINISIS program; and for collecting, storing and analyzing documents on mungbean, soybean rust and Chinese cabbage. The Library was also responsible for providing the Office of Information Services (OIS) with newly processed data base records for publication in *TVIS News*, and the appropriate data bases for publication of the bibliographies. The total number of records in the Library's TVIS bibliographic data base is 7,393, of which 3,761

(51%) records are accompanied by an abstract. Hard copy documents are available for nearly all of the 7,393 data base records and the documents not available are currently being ordered. Full information concerning the status of the TVIS literature data base are listed in Table 2:

Table 1. TVIS publications published since 1985.

Publication	Data completed
Newsletters	
TVIS News Vol. 1, No. 1	February 1985
Soybean Rust Newsletter Vol. 7	October 1985
TVIS News Vol. 1, No. 2	November 1985
TVIS News Vol. 2, No. 1	March 1986
Soybean Rust Newsletter Vol. 8	June 1987
TVIS News Vol. 2, No. 2	June 1987
Bibliographies	
Annotated Bibliography of Diamondback Moth (Chinese cabbage)	February 1985
Soybean Rust Bibliography	September 1987
Technical/Extension Reports/Manuals	
Agromyzid Flies of Some Native Legume Crops in Java	September 1984
AVRDC Soybean Evaluation Trial (ASET)	December 1985
International Mungbean Nursery Reports	December 1985
Chinese Cabbage Proceedings (reprint)	February 1987
Assessing Rainy Season Vegetable Production Alternatives: A case study in 'upstream' farming systems research	May 1987
Chinese Cabbage Cultural Practices in the Tropics	August 1987
Soybean Varietal Improvement Workshop	August 1987
Thesaurus	
Tropical Vegetable Thesaurus	1985
Abstracts	
Abstracts (Mungbean Symposium)	November 1987

Table 2. Status of the TVIS literature data base.

	Data base	Abstracted	Scientific editing	On order
Soybean rust	338	338	321	23
Soybean	1828	1437	597	12
Mungbean	3973	1534	919	140
(diseases and pests)	(801)	(801)	(801)	
Chinese cabbage	1254	452	36	128
Total	7393	3761	1873	303

Question and Answer, SDI and Document Delivery Services. During the reporting period from June 1986 to June 1987, the AVRDC question and answer service related to the TVIS crops was primarily the responsibility of the OIS and individual scientists. During this period, OIS received over 252 individual requests from 77 different countries/territories. Of these requests, 218 were for information on soybean, 158 for mungbean and 112 for Chinese cabbage. The scientific staff received questions and provided answers to 1,112 individuals in 110 countries, 444 on mungbean, 446 on soybean and 222 on Chinese cabbage.

The AVRDC Library and Documentation has provided SDIs to 127 individuals and institutions throughout the world. It has also received requests for and delivered 192 documents including 84

on soybean, 99 on mungbean and 9 on Chinese cabbage. The documents were sent as 1,088 pages of photocopy to nine countries, namely, Bangladesh, Canada, Cuba, Indonesia, Peru, Singapore, Thailand, the United Kingdom and the U.S.A.

Mungbean symposium. The Second International Symposium on Mungbean was successfully conducted from 16 to 20 November 1987 in Bangkok, Thailand. A total of 207 participants from 31 countries attended the Symposium where 78 papers were presented.

AVRDC-Indonesia Bilateral Program

This report presents the results of research on Chinese cabbage and tomato trials in 1986-87 in connection with the cooperation between the Agency of Agricultural Research and Development/Lembang Horticultural Research Institute (AARD/LEHRI) of Indonesia and AVRDC. Although some trials had been reported by Dr. Thongchai Tonguthaisri, former Resident Scientist at LEHRI, his data are cited in this report to get an overall idea of how the accessions performed in different locations and seasons.

The trials were carried out in Lembang (1,250 m above sea level), Berastagi/North Sumatera (1,400 m a.s.l.), Subang (100 m a.s.l.) and Delta Upang/South Sumatera (2 m a.s.l., i.e. transmigration and swampy area). Research at Universitas Islam Malang on Chinese cabbage variety trials carried out in Lawang (500 m above sea level) using AVRDC accessions is also included in this report.

Chinese Cabbage Variety Trials

Materials and Methods

Five trials were carried out by LEHRI and one by Universitas Islam Malang. A randomized complete block design was used, with three to six replications depending on the number of accessions being tested. Twenty-four seedlings were planted on a 6 m^2 plot, except in Delta Upang with 10 seedlings per plot, and a plant distance of 60 × 50 cm^2. Stable manure at 15 t/ha was applied on the holes one to three days before transplanting, along with 100 kg P_2O_5/ha, 100 kg K_2O/ha and 50 kg N/ha. The remaining nitrogen fertilizer, 50 kg N/ha, was applied four weeks later.

Results and Discussion

In the first trial in Lembang, the early growth of the seedlings in the field looked normal but later the plants showed very slow growth. The plants were vigorous in the morning but wilted during the day due to clubroot infection. There was no entry that showed resistance to this disease.

Hybrid 82-46 performed well in head quality, uniformity and yield in the lowlands. However, this hybrid as well as 77 M(2/3)-43 showed susceptibility to bolting in the highlands. Hybrid 62 (ASVEG 1) had the best performance among the entries: it was early, uniform and high yielding in the lowlands as well as in the highlands. Other hybrids which showed better performance than the control varieties were Hybrids 82-157, 83-2 and 82-156.

Higher yields were obtained in Lawang at medium elevation compared to those planted in the highland and lowland probably due to the higher rate of fertilizers applied (Table 1). The rate of fertilizer application at medium elevation was 200 kg N/ha, 80 kg P_2O_5/ha and 150 kg K_2O/ha, while in the highlands and lowlands it was 100 kg each of N, P_2O_5 and K_2O/ha. Days to maturity and mean head weight of Chinese cabbage evaluated in five locations are presented in Table 2.

The varieties tested in Delta Upang produced good yields. The land area in Delta Upang is swampy, with low pH (4.8) and during the growing period the plants were watered with saline water.

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Table 1. Yield of Chinese cabbage in five locations.

Entry	Yield (t/ha)				
	Lembang (1250 m)	Berastagi (1400 m)	Lawang[z] (500 m)	Subang (100 m)	Delta Upang (2 m)
82-46	5.5 d	5.4 c	-	11.8 a	29.2 a
82-156	10.7 bc	18.1 ab	-	7.9 ab	-
82-157	12.4 abc	16.8 ab	-	12.3 a	-
83-2	9.5 c	16.9 ab	-	10.5 a	-
83-20	12.4 abc	19.1 ab	-	-	-
Hybrid 62	15.9 a	17.5 ab	42.8 bcd	13.1 a	35.0 a
Hybrid 58	-	-	54.6 cd	6.7 ab	-
Hybrid 59	-	-	58.6 d	-	-
Nagaoka F_1	14.4 ab	-	-	-	-
77 M(3)-26	-	-	42.8 bcd	-	-
77 M(3)-27	13.7 abc	22.5 a	47.8 bcd	-	-
77 M(3)-33	-	-	36.5 ab		
77 M(3)-35	12.9 abc	19.4 ab	24.6 a	0.9 b	-
77 M(3)-40	10.7 b	16.5 ab	46.2 bcd	-	-
77 M(2/3)-41	-	-	38.3 abc	-	-
77 M(2/3)-43	10.4 bc	15.8 b	43.4 bcd	2.5 b	-
77 M(2/3)-46	9.7 bc	19.7 ab	-	3.8 b	-
B-40	11.8 abc	18.3 ab	-	-	-
Sangihe	9.9 bc	18.7 ab	-	1.4 b	28.2 a
Talaud	12.3 abc	16.3 ab	-	3.0 b	28.7 a

[z]Estimated yield from 50,000 plants/ha.

Table 2. Days to maturity and mean head weight of Chinese cabbage in five locations.

Entry	Day to maturity[z]					Mean head weight (kg)				
	Lbg	Btg	Lwg	Sbg	Du	Lbg	Btg	Lwg	Sbg	Du
82-46	45 def	65	-	60	49 a	0.40 abc	-	-	0.58 ab	0.74
82-156	44 fgh	69	-	60	-	0.32 bc	0.54		0.46 b	-
82-157	43 gh	68		60	-	0.37 abc	0.50	-	0.57 ab	-
83-2	43 gh	64	-	69	-	0.30 c	0.51	-	0.57 ab	-
83-20	45 e-h	67	-	-	-	0.38 abc	0.57	-	-	-
Hybrid 62	42 h	68	n.s.[y]	51	49 a	0.52 a	0.52	0.86 bcd	0.49 ab	0.85
Hybrid 58	-	-	44	60	-	-	-	1.09 cd	0.50 ab	-
Hybrid 59	-	-	55	-	-	-	-	1.17 d	-	-
Nagaoka F_1	54 ab	-	-	-	-	0.46 ab	-	-	-	-
77 M(3)-26	-	-	n.s.	-	-	-	-	0.86 bcd	-	-
77 M(3)-27	49 cde	67	n.s.	-	-	0.42 abc	0.69	0.96 bcd	-	-
77 M(3)-33	-	-	n.s.	-	-	-	-	0.73 ab	-	-
77 M(3)-35	50 bcd	65	n.s.	62	-	0.40 abc	0.58	0.49 a	0.56 ab	-
77 M(3)-40	46 d-f	67	n.s.	-	-	0.36 bc	0.49	0.92 bcd	-	-
77 M(2/3)-41	-	-	n.s.	-	-	-	-	0.77 abc	-	-
77 M(2/3)-43	42 h	64	n.s.	61	-	0.33 bc	0.47	0.87 bcd	0.46 ab	-
77 M(2/3)-46	45 e-h	67	-	60	-	0.31 c	0.59	-	0.52 ab	-
B-40	56 a	68	-	-	-	0.36 bc	0.55	-	-	-
Sangihe	52 bc	64	-	62	49 a	0.31 c	0.55	-	0.65 a	0.69
Talaud	48 c-f	67	-	62	49 a	0.38 abc	0.49	-	0.51 ab	0.74

[z]Lbg = Lembang, Btg = Berastagi, Lwg = Lawang, Sbg = Subang and Du = Delta Upang. [y]n.s. = no available data.

Tomato Variety Trials

Materials and Methods

Four trials were conducted in Lembang and Subang in dry and wet seasons. In the dry season, 30 entries in Lembang and 37 entries in Subang were used while in the wet season 24 entries were used

in Lembang. A randomized complete block design was used, with 12 seedlings per row, and a distance of 60 cm between rows and 50 cm within the row. Stable manure at 30 t/ha was applied into each hole along with 100 kg P_2O_5/ha and 100 kg K_2O/ha and 50 kg N/ha. The remaining N fertilizer was applied 30 days later at 50 kg/ha.

Results and Discussion

Dry season trials. There were six high-yielding lines in the highlands, i.e. LG 154-1208, LSU-36-3-0, LSU-34-6-0, Berlu-6, LG-153-553 and Berlu-6 (Table 3). The LG selections were the result of SSD selection of Gondol × Intan and Gondol × Ratna crosses made by Dr. R. T. Opeña of AVRDC at Lembang. The LSU selections were crosses from segregating populations of Lousiana State University (USA), while Berlu numbers were selections from Berlian. About 26.6 to 32.4%

Table 3. Results of dry season trials, Lembang and Subang, May-September 1986.

Entry	Wt. of marketable fruit per plot (kg)		Marketable fruit yield (t/ha)		Estimated total yield (t/ha)	
	Lembang	Subang	Lembang	Subang	Lembang	Subang
Kingkong F_1	11.63 kl	2.50 c-g	7.9	5.0	9.1	5.1
LSU-34-6-0	18.38 a-e	1.10 e-g	14.9 (3)	2.2	16.1 (1)	2.2
LSU-36-3-0	18.52 a-e	0.60 e-g	15.8 (2)	1.2	16.9 (2)	1.2
LSU-37-7-0	12.04 jl	6.70 a	9.6	13.4 (1)	11.3	13.7 (1)
LSU-39-2-0	12.97 g-l	2.30 c-g	9.8	4.6	11.2	4.7
LSU-40-2-0	12.85 h-l	1.50 e-g	8.4	3.1	9.6	3.1
LSU-42-6-0	14.62 d-k	3.90 a-f	10.6	7.7 (6)	11.7	7.9 (6)
LG 153-217	–	0.40 fg	–	0.8	–	0.8
LG 153-232	13.60 g-l	–	11.9	–	13.1	–
LG 153-332	14.10 e-k	0.20 g	11.8	0.4	12.9	0.4
LG 153-459	15.95 c-k	0.45 f-g	9.8	0.9	10.9	0.9
LG 153-488	12.27 il	–	10.8	–	11.8	–
LG 153-553	18.81 a-d	5.50 a-c	13.9 (5)	11.1 (3)	14.8 (5)	11.4 (3)
LG 153-698	11.77 kl	0.90 e-g	11.5	1.9	12.6	1.9
LG 154-858	17.14 b-h	5.20 a-d	11.2	10.4 (4)	12.0	10.7 (4)
LG 154-1028	13.51 g-l	–	11.9	–	13.3	–
LG 154-1208	1[illegible] 1 a-c	–	17.1 (1)	–	18.1 (1)	–
Berlu-0	2[illegible] 07 ab	3.20 b-g	14.3 (4)	6.4	15.2 (4)	6.5
Berlu-1	14.91 d-k	6.20 a-b	11.8	12.5 (2)	13.1	12.8 (2)
Berlu-2	16.04 c-k	3.50 a-g	11.9	6.9	13.0	7.1
Berlu-3	16.64 b-j	1.40 e-g	11.3	2.9	12.3	2.8
Berlu-6	22.37 a	2.10 c-g	13.8 (6)	4.2	14.6 (6)	4.3
ITH - 1	18.22 a-f	2.20 c-g	11.2	4.4	12.0	4.5
ITP - 7	14.13 e-k	2.90 b-g	9.2	5.9	10.2	6.0
GDH-L 2	13.13 g-l	–	9.9	–	10.8	–
GDH-BL-1	17.54 b-g	–	12.9	–	13.9	–
GDH-BL-8	9.30 l	–	7.9	–	8.8	–
CL 11D-1-2-0-66	–	–	–	–	–	5.5
CL 5915-93D[illegible]-1-0	–	2.00 c-g	–	3.9	–	4.0
CLN 95-280D[illegible]-1-0	–	0.60 c-g	–	1.1	–	1.1
CLN 95-280D[illegible]-4-0	–	4.20 a-e	–	8.4 (5)	–	8.7 (5)
PT 858 selection	–	3.30 a-g	–	6.7	–	6.8
PT 862 selection	–	2.70 b-g	–	5.4	–	5.5
Taman Sel. No. 2	13.80 f-l	2.00 e-g	11.0	4.0	12.1	4.1
Berlian	16.77 b-i	1.10 e-g	10.9	2.1	11.8	2.1
Berlian-0	16.58 c-j	1.80 d-g	10.8	3.5	11.6	3.5
Gondol	12.79 a-l	0.01 g	10.7	0.04	11.7	0.04
C.V	15.1	77.31				

of all of the entries were infected by late blight, while the bacterial wilt infections were low, ranging from 4.3% to 7.6%.

In the lowland only four entries yielded more than 100 t/ha, i.e. LSU-37-7-0, Berlu-1, LG-153-553 and LG 154-858. Six entries could not survive the environmental stress (heat) even if straw mulch was applied.

Wet season trials. Nine AVRDC lines gave better yield than Ratna, i.e. eight FMTT lines and one CL 5915 line (Table 4). However, only three varieties gave total yields of more than 10 t/ha, i.e. FMTT 19, FMTT 18 and FMTT 16, and only two gave marketable fruit yield of more than 10 t/ha, i.e. FMTT 19 and FMTT 18. Late blight infections ranged from 0 to 35% and bacterial wilt from 5% to 15%.

Table 4. Results of wet season trials at Lembang, November 1986.

Entry	Wt. of fruit/plot (kg)		Yield (t/ha)		Days to maturity	Fruit size (g)
	Total	Marketable	Total	Marketable		
FMTT 3	4.8 a-f	4.6 a-g	6.9	6.6	94	43 f
FMTT 4	5.7 c-g	5.4 c-g	8.2	7.7	97	40 c-f
FMTT 13	6.9 e-h	6.6 f-i	9.8 (5)	9.4 (4)	95	45 f
FMTT 16	7.2 f-h	6.8 g-i	10.4 (3)	9.8 (3)	94	39 c-f
FMTT 18	8.0 g-h	7.5 h-i	11.5 (2)	10.7 (2)	94	32 a-c
FMTT 19	8.5 h	8.2 i	12.2 (1)	11.7 (1)	96	35 b-e
FMTT 21	6.3 d-h	5.9 d-i	9.0	8.5	94	34 b-e
FMTT 22	5.6 c-g	5.1 b-g	8.0	7.2	94	42 f
FMTT 23	7.0 e-h	6.5 e-i	9.9 (4)	9.3 (5)	94	53 g
CL 5915-39D$_4$-1-2	4.1 a-d	3.5 a-c	5.8	5.0	90	29 ab
CL 5915-39D$_4$-1-0-L-2	4.2 a-d	3.7 a-d	6.0	5.3	94	33 a-c
CL 5915-93D$_4$-1-0-0-1	2.8 a	2.7 a-b	4.1	3.8	96	35 b-e
CL 5915-153D$_4$-3-3-0	4.5 a-e	4.2 a-e	6.5	6.0	94	34 b-d
CL 5915-206D$_4$-2-1-0	4.7 a-e	4.3 a-f	6.7	6.2	94	40 d-f
CL 5915-206D$_4$-2-2-0-4	2.4 a	2.6 a	3.4	3.7	95	30 ab
CL 5915-206D$_4$-2-4-0	6.1 d-h	5.6 c-h	8.8	8.0	98	41 e
CL 5915-206D$_4$-2-5-0	4.7 a-e	4.4 a-g	6.7	6.4	81	34 a-c
CLN 65-349D$_5$-2-0	2.6 ab	2.5 a	3.8	3.5	90	27 a
Ratna	5.0 b-g	4.1 a-d	7.1	5.9	93	35 b-e
Intan	3.5 a-c	2.6 a	5.0	3.7	94	27 a

Agronomy of Chinese Cabbage in the Lowland

Agronomic trials of Chinese cabbage in the lowland were carried out in the dry and wet seasons. The trials consisted of studies on the effects of (1) mulching and planting distance on Talaud variety and (2) liming, nitrogen and phosphorous fertilizers on Chinese cabbage.

Effects of Mulching and Planting Distance

The experiment aimed to study the effects of mulch application and planting distance on the growth and yield of Chinese cabbage in the dry season in the lowland area of Subang, which is 100 m above sea level. A randomized block design with four replications was employed. The treatments consisted of eight combinations of mulch application and planting distance with single and double row plantings. Results showed that mulching and planting distance significantly influenced the growth and yield of Chinese cabbage, but these effects varied depending on the variables observed.

The M_1D_4 treatment had the best response in terms of plant growth, especially on the increasing leaf canopy diameter of the plants. Treatments M_1D_4 had high yield but these were not significantly different. M_0D_2 treatment produced the longest head (Table 5). The effects of mulching and planting distance in double row planting of Chinese cabbage under lowland conditions in Subang need to be studied further.

Effects of Lime Nitrogen and Phosphorous Fertilizers

The study on the effects of liming, nitrogen and phosphorous fertilizers on Chinese cabbage var. Sangihe was carried out in Subang (100 m a.s.l.) in dry season from August to October 1986 as well as in wet season from December 1986 to February 1987. A split-plot design with three replications was used in each season. Liming vs. nonliming was the main plot and 10 treatment combinations of N and P were used as subplots.

In the dry season, plant height at four weeks after transplanting (WAT) and canopy diameter at two WAT were significantly increased by lime application. Liming increased total yield by 22.5% and head yield by 14.6%. In general, the effects of NP treatments on plant growth and head yield of Chinese cabbage were significantly different. However, interaction between the two factor treatments was not significantly influenced by the variables observed. In this experiment, the highest head yield of Chinese cabbage was attained by applying N_2P_2 (Table 6).

Table 5. Effects of mulching and planting distance on canopy diameter, head weight and head size.

Treatment	Canopy diameter (DAT)[z]			Head wt.	Head size (cm)	
	15	30	40	(t/ha)	Length	Diameter
M_0D_1 - sr. 60 × 40 cm	22.3 c	39.3 b	43.9 b	10.5 c	15.9 abc	8.4 a
M_0D_2 - dr. 4 × 40 cm	27.4 ab	40.4 b	44.3 ab	12.5 abc	17.6 a	7.8 a
M_0D_3 - sr. 60 × 30 cm	28.1 ab	39.2 b	44.8 ab	12.4 abc	16.3 ab	7.7 a
M_0D_4 - dr. 40 × 30 cm	26.5 b	39.5 b	44.7 ab	15.5 a	16.5 ab	7.2 a
M_1D_1 - sr. 60 × 40 cm	28.4 ab	39.0 bc	44.7 ab	10.9 bc	15.9 abc	7.8 a
M_1D_2 - dr. 40 × 40 cm	30.0 a	42.1 ab	43.7 b	15.5 a	15.8 abc	7.6 a
M_1D_3 - sr. 60 × 30 cm	26.6 b	32.8 c	45.5 ab	12.3 abc	14.1 c	8.0 a
M_1D_4 - dr. 40 × 30 cm	30.7 a	44.2 a	48.3 a	14.9 ab	15.4 bc	7.3 a
C.V. (%)	7.66	5.12	5.45	19.17	8.16	12.07

[z]DAT = days after transplanting.

Table 6. Effects of lime, N and P fertilizers on plant height and diameter of Chinese cabbage var. Sangihe in dry and wet seasons in the lowland.

Treatment	Plant height (cm)				Canopy diameter (cm)			
	4 WAT[z]		6 WAT		4 WAT		6 WAT	
	DS	WS	DS	WS	DS	WS	DS	WS
L_0	22 b	16 a	26 a	16 a	35 a	27	40 a	24 a
L_1	25 a	17 a	29 a	17 a	35 a	27	42 a	26 b
C.V. (%)	6.7	9.68	12.83	31.48	7.69	7.54	16.94	7.74
N_0P_0	20 c	11 a	25 b	12 a	34 bc	16 a	40 a	17 a
N_1P_1	23 b	16 b	27 b	16 cd	34 abc	26 b	42 a	25 cd
P_2	24 ab	16 b	26 b	15 bc	35 c	27 bc	41 a	25 c
P_3	24 ab	15 b	28 ab	14 ab	32 c	24 b	41 a	22 b
N_2P_1	24 ab	18 c	27 ab	19 cd	34 abc	31 d	40 a	28 cd
P_2	25 a	18 c	27 ab	17 cde	36 ab	29 cd	40 a	26 cd
P_3	24 ab	18 c	27 ab	17 cd	37 a	29 cd	43 a	27 cd
N_3P_1	25 a	19 c	30 a	20 c	36 a	30 cd	41 a	27 cd
P_2	25 a	18 c	28 ab	17 cde	37 a	29 cd	41 a	28 d
P_3	24 ab	18 c	30 a	18 cde	35 abc	29 cd	41 a	27 cd
C.V. (%)	6.94	6.81	7.85		6.52		16.94	10.30

[z]WAT = weeks after transplanting.

Agronomy of Tomato in the Lowland

Experiments on the agronomy of tomato in the lowland were carried out in Subang in the dry and wet seasons. The experiments looked into the effects of: (1) mulching and plant spacing system on Berlian variety, and (2) liming, N and P fertilizers on Berlian tomato in the dry and wet seasons.

Effects of Mulching and Plant Spacing

The effects of mulching and plant spacing on the growth and yield components of the tomato variety Berlian was studied in a farmer's field in lowland Subang, about 100 m above sea level, from September to December 1986. A randomized block design with four replications was employed. The treatments consisted of eight combinations of mulching (with vs without straw mulch) and four plant spacing systems (single row, 60 × 40 cm; double row, 50 × 40 cm; single row, 60 × 50 cm; and double row, 50 × 50 cm). Results showed that mulching did not significantly affect the growth. However, yield components tended to increase with the application of straw mulch. Applying straw mulch increased total yield by 9.65% and marketable yield by 9.7% compared to the treatments without mulching. The best planting system under this experiment was single row with 60 × 50 cm spacing combined with mulch application.

Effects of Lime, N and P Fertilizers

Experiments were carried out in Subang in the dry and wet seasons from August to November 1986 to study the effects of lime application and N and P fertilizers on the growth and yield of the tomato variety Berlian in the lowland. The treatments used were liming as the main plot and eight N and P combinations as the subplots. A split-plot design with three replications was employed in each season.

In the dry season, there was no significant interaction among the treatments on the growth and yield of tomato. However, the N and P fertilizers significantly increased growth and yield. The fertilizer combination of 90 kg N/ha and 45 kg P_2O_5/ha increased growth and yield. The effects of lime, nitrogen and phosphorous fertilizers on tomato yield are presented in Table 7.

In the wet season, no significant interaction was observed between lime, N and P fertilizer. N and P fertilizer combination had a significantly different effect on plant growth which depended on the stages of plant growth.

Preliminary Trials of F_1 Seed Production of Chinese Cabbage Hybrid 62

Two parent lines of Hybrid 62 (ASVEG 1) were received from AVRDC for preliminary F_1 seed production of Chinese cabbage in Lembang. The first trial aimed to observe the vernalization requirement of both parents to induce their flowering. The F_1 seed production trials were then carried out. Seeds of both parents were sown in different petri dishes and vernalized for three weeks. Unfortunately, one parent seed germinated less than the other parent. Therefore, the seedlings were planted in 1:2 proportion in plant number. Then seeds of both parents were again sown, vernalized and planted using the same proportion; two rows of each parent were planted alternately. The first trial was from 23 July to 14 November 1987 while the second trial was from 4 August to 7 December 1987. It seemed that parent 1 was more productive than parent 2. The yield of F_1 seed is presented in Table 8.

Multilocation Trials of Chinese Cabbage and Tomato

Five Chinese cabbage hybrids and one open-pollinated variety were used for multilocation trials in three lowland and two medium elevation areas in Java. At the same location and time, two

LG lines (originated from SSD selection) and seven local selections were tested. The trials were conducted in dry and wet seasons. The locations were: Subang (100 m a.s.l.), Purwokerto (65 m a.s.l.), Probolinggo (2 m a.s.l.), Cicalengka (400 m a.s.l.) and Muntilan (500 m a.s.l.). The Chinese cabbage hybrids tested were: Hybrid 62 (ASVEG 1), 82-46, 82-157, 83-2, Hybrid 58 and B-40 (open-pollinated variety). The tomato varieties were: GH-5, Berlu-6, 4210, LG 154-858, LG 153-553, CL 5915-93D4-1-0, CL 1131-0-0-43-8-1, CL 1131-0-0-7-20-11 and CLN 95-280D5-4-0. The first season trial was started in September/October 1987 and will be completed in December 1987/January 1988.

Table 7. Effects of lime, nitrogen and phosphorous fertilizers on tomato yield in dry and wet seasons in the lowland.

Treatment	Marketable fruit yield (kg)		Estimated yield (t/ha)	
	DS (10 plants)[z]	WS (10 plants)[y]	DS[x]	WS
Lime (t/ha)				
0.0	5.4 a	8.1 a	17.3	26.7
1.5	5.8 a	14.0 b	19.1	45.9
C.V. (%)	–	high	–	
N-P fertilizer (kg/ha)				
0-0	3.2 b	8.5 a	10.6	28.1
45-45	5.4 b	11.2 ab	17.8	37.0
-90	4.4 ab	7.1 a	14.5	23.4
-135	5.5 ab	10.5 ab	18.0	34.6
90-45	5.9 a	14.7 b	19.4	48.6
-90	5.6 ab	8.1 a	18.4	26.8
-135	5.8 a	10.6 ab	19.0	34.8
135-45	6.5 a	13.8 b	21.5	45.4
-90	5.9 a	14.0 b	18.4	46.4
-135	5.7 a	11.5 ab	18.9	38.0
C.V. (%)	–	high		

[z]Source: Yusdar, Hilman and Suwandi. 1987. Effects of liming and N-P fertilization on berlian variety of tomato. Research Report, LEHRI. [y]Source: Yusdar and Hilman. 1987. Effect of lime and N-P fertilizer application on Berlian variety of tomato in rainy season. Research Report. [x]DS = dry season, WS = wet season.

Table 8. Yield of F_1 seed production of Chinese cabbage, Hybrid 62, Lembang.

Trial	Ratio of parent	Number of plants		Total seed yield (g)		Seed yield/plant (g)	
		parent 1	parent 2	parent 1	parent 2	parent 1	parent 2
1	1 row:2 rows	15	35	28.5	21.5	1.9	0.6
2	2 rows:2 rows	40	40	47.4	25.9	1.2	0.6

[z]Source: Permadi, A. H. 1987. Preliminary trial on F_1 seed production of Chinese cabbage, ASVEG 1. Research Report, LEHRI.

AVRDC-Korea Bilateral Program

Breeding for Heat Tolerance in Chinese Cabbage

More than 100 combinations have been tested as of 1986 to breed heat-tolerant Chinese cabbage hybrid with compact heading form and better quality than that of "Sambok" and "Manha", which were released for lowland summer cultivation in 1981. Each year several promising combinations with good heading form and high harvest ratio, etc. were selected and tested. However, disease resistance and harvest ratio were usually not reproduced accordingly due to heavy and/or long rainfall, which caused the plants to be infected by soft rot, downy mildew and bacterial rot disease. Consequently, the number of surviving plants was seriously diminished.

Seedtimes of all trials until 1986 were around late June which was the worst cultivation season because of high temperature and heavy rainfall. Thus, to escape those critical periods, four different seedtimes: 5 June, 30 June, 15 July and 5 August with 13 combinations were tested in 1987. Ten combinations were selected in 1985 and 1986 and the other three were new ones derived from B-18, introduced from AVRDC, crossed with three different lines and obtained in 1986 by single-seed-descent method, SSD31-2, SSD63-2 and SSD139-3. During the first seedtime, only the former 10 combinations were tested with the 1986 seeds.

Characteristics of Parents

The characteristics of 10 parent lines used for combinations are shown in Table 1. Five HES lines showed compact heading form but the other five lines from AVRDC were overlapping. Maturity of the former was rated middle to late while the latter was extremely early to early. The former was more susceptible to soft rot but more resistant to virus than the latter. SSD139-3 was the heaviest among all parents. The number of leaves of SSD139-3 was almost 60 but the others were below 45. SSD139-3 was also resistant to both soft rot and virus, thus it seemed to be a good material for breeding heat-tolerant hybrids.

Table 1. Characteristics of 10 parent lines used for combinations under lowland summer condition in 1987.[z]

Line code[y]	Heading[x] form	Maturity[w]	Infection (%)		Plant wt. (kg)	No. of leaves
			Soft rot	Virus		
450...14	SH-JU	L	3.8	0	1.33	41.8
450...15	NH	L	0	6.3	1.34	33.6
SSD31-2-2-1	JU	M	39.3	39.3	0.75	43.6
SSD63-2-2-2	JU	ML	16.7	16.7	0.83	39.0
SSD139-3-2-2	JU	L	0	0	1.83	58.8
B-18-1-2-3	OL	EE	0	27.3	–	–
B-18-5-1-1	OL	EE	0	39.3	–	–
77 M(3)...1-1-2	OL	E	0	0	1.14	38.4
77 M(3)...5-2-3	OL	M	11.5	0	1.27	42.4
76 M(2)...-2	OL	E	0	27.8	–	–

[z]Data of 30 June seedtime. [y]450..... = 450-3-9-5-6, 77 M(3)..... = 77 M(3)-35-18-LT, 76 M(2)..... = 76 M(2)-18-3-4-8-4-8-1. [x]NH = nonheading, SH = semiheading, JU = joined-up, OL = overlapping. [w]EE = extremely early, E = early, M = medium, ML = medium late, L = late

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Disease Resistance According to Seedtimes

Infection by diseases of selected and nonselected combinations in 1987 are shown in Table 2. In soft rot the earlier the seedtimes, the higher the infection ratio. Virus infection was lowest during the first seedtime and highest during the second seedtime. Two selected combinations, SSD139-3 × SSD31-2 and SSD139-3 × B-18, were tolerant to both soft rot and virus in the second seedtime. Harvest ratios of the third and fourth seedtimes were higher than the rest of the seedtimes in all combinations (Table 3). SSD139-3 × B-18 also showed high harvest ratio at the second seedtime.

Characteristics of Selected Combinations

Two combinations selected in 1987 showed joined-up heading form. Maturity time of SSD139-3 × SSD31-2 was average and that of SSD139-3 × B-18 was early. The weight of these two combinations at about 60 days after sowing showed little difference in all seedtimes. At about 70 days after sowing of the third and fourth seedtimes, weight increased slightly over those at 60 days but head compactness increased more. At about 60 days after sowing, the number of leaves of the first and fourth seedtimes in SSD139-3 × SSD31-2 and control was more than that of the other two combinations. Those of the 70 days after sowing was more than those of the 60 days at the third and fourth seedtimes. But the number of leaves of SSD139-3 × B-18 did not increase in all seedtimes and harvest dates.

It is uncertain whether the good characteristics of selected combinations in 1987 will be reproduced during the next trial. Thus, selected combinations will be tested again next year with different seedtimes.

Table 2. Percent infection of selected combinations from 1985 by soft rot and virus according to the different seedtimes under lowland summer conditions in 1987.

Combination	Soft rot				Virus				Selection year
	Sowing time				Sowing time				
	June 5	June 30	July 15	Aug. 5	June 5	June 30	July 15	Aug. 5	
450...14-1-1 × B-18-5-1-1[z]	44.5	13.3	0	0	0	39.7	14.5	8.3	1986
450.15-1-1 × 77 M(3)...-1	21.4	17.7	1.2	0	0	5.3	3.7	2.4	1986
450.15-6 × 76 M(2)...-2	47.6	17.3	0	2.4	0	2.5	9.1	7.1	1985
SSD139-3-2-1 × SSD31-2-2-1	32.7	3.9	1.3	0	1.2	2.2	0	0	1987
SSD139-3-2-2 × B-18-1-2-2	–	0	0	0	–	0	0	0	1987
JunSeung (Cont.)	14.3	8.3	2.4	0	2.4	0	0	1.2	–

[z]450... = 450-3-9-5-6, 77 M(3)... = 77 M(3)-35-18-LT, -1-1, 76 M(2)... = 76 M(2)-18-3-4-8-4-8-1.

Table 3. Percent harvest of selected combinations from 1985 according to different seedtimes under lowland summer conditions in 1987.

Combination	Sowing time				Selection year
	June 5	June 30	July 15	Aug. 5	
450.14-1-1 × B-18-5-1-1[z]	12.5	25.2	84.5	86.9	1986
450.15-1-1 × 77 M(3)...-1	44.0	48.6	95.2	96.4	1986
450.15-6 × 76 M(2)...-2	10.7	35.9	90.5	86.9	1985
SSD139-3-2-1 × SSD31-2-2-1	33.3	70.5	98.8	95.2	1987
SSD139-3-2-2 × B-18-1-2-2	–	92.9	97.6	100.0	1987
JunSeung (Cont.)	67.9	53.6	97.6	96.4	-

[z]450... = 450-3-9-5-6, 77 M(3)... = 77 M(3)-35-18-LT, -1-1, 76 M(2)... = 76 M(2)-18-3-4-4-8-1.

Cytoplasmic Male Sterility in Chinese Cabbage

Raphanus-Originated CMS

In 1986 CMS 60 days and CMS Cheongbang were still not considered isogenic because they were not nearly like their recurrent parents in leaf color, leaf length and plant weight even though their generations were BC_7F_1 and BC_6F_1, respectively. Therefore, in 1987 one more backcross was carried out.

Seed setting of both CMS 60 days and CMS Cheongbang was lower than their recurrent parents. In 1987 seed setting rates of all lines decreased compared to that of 1986. Unfortunately, the reason for this could not be determined. The seed germination rate of CMS 60 days was almost the same as its recurrent parent and higher than CMS Cheongbang. The morphology of CMS lines was very similar to their parents but leaf color at the early stage was still light. Except for leaf length, both CMS lines were not similar to their parents in terms of plant weight and number of leaves (Table 4).

Although the two CMS lines were in the BC_8F_1 and BC_7F_1 generation, they were not isogenic as their recurrent parents. Thus, they need more backcrosses to develop their seed setting ability and other characteristics.

B. Juncea-Originated CMS

BC_4F_1 generation was made in 1987 with three CMS lines. The seed setting rate in 1987 was lower than in 1986 and each CMS line was very low compared to their recurrent parents (Table 5). The leaf color of CMS lines in the field was still much lighter than their recurrent parents. An advanced generation will be made next year.

B. campestris-Originated Male-Sterile Plants

To clarify the genetic background of male-sterile plants which originated from the Korean native turnip, *B. campestris*, found in 1986, two male-sterile plants originated from different lines were crossed with eight male-fertile lines. All offsprings of the male-sterile lines crossed with three lines of male-sterile plants found in 1986 segregated into male-sterile and male-fertile at the same rate, but when

Table 4. The performance of CMS lines originated from *Raphanus* and recurrent lines of Chinese cabbage.

Line	Plant wt.(kg)	Leaf length (cm)	No. of leaves	No. of pollinations	No. of seeds
CMS 60(BC_8F_1)	2.64	44.6	56.6	223	70
Recurrent	4.14	42.4	77.2	248	311
CMS CH (BC_7F_1)	2.60	44.0	70.5	126	60
Recurrent	3.16	46.0	73.2	178	498

Table 5. Seed yield and the germination rate of the CMS lines originated from *B. juncea* and recurrent lines of Chinese cabbage.

Line[z]	No. of pollinations (A)	No. of seeds (B)	B/A	Germination rate (%)
CMS CH(BC_4F_1)	106	32	0.30	55.0
Recurrent	178	498	2.80	86.0
CMS NB(BC_4F_1)	334	21	0.06	70.6
Recurrent	157	709	4.52	72.0
CMS DK(BC_4F_1)	223	1	0.00	0.0
Recurrent	99	168	1.70	76.0

[z]CMS CH = CMS Cheonghang, CMS NB = CMS Naebyung 60 days, CMS DK = Daehyeong Karack

crossed with the other lines showed all male-fertile plants (Table 6). The genetic background of the two CMS lines was assumed to be GMS or CGMS.

Next year after precise clarification of the genetic background, the male-sterile lines will be used to breed MS Chinese cabbage.

Table 6. Segregation rate of the two male-sterile lines originated from Korean native turnip, *B. campestris*, crossed with male-fertile lines.

MS[z]	MF[y]	No. of total plants	No. of MF plants	No. of MS plants	Segregation rate MF:MS
G29C-4 ×	G27A-1	42	42	0	1:0
G29C-4 ×	G27C-1	113	113	0	1:0
G29C-4 ×	G29D-5	99	58	41	1:1
G29C-4 ×	G29D-6	37	18	19	1:1
G29C-4 ×	G30A-1	57	57	0	1:0
G29C-4 ×	G30A-2	99	99	0	1:0
G29C-4 ×	G30B-1	87	87	0	1:0
G29D-1 ×	G26-1	44	44	0	1:0
G29D-1 ×	G27A-1	61	61	0	1:0
G29D-1 ×	G29C-5	24	13	11	1:1

[z]MS = Male sterile plants. [y]MF = Male fertile plants.

Increasing Yield of New Processing Tomato Through the Culture Method

In Korea, breeding efforts during the past 10 years or more have greatly contributed to the genetic improvement of processing tomato for nonstaking culture. However, the rainy spell in summer followed by high temperature and humidity give rise to severe yield losses in nonstaking culture of tomato every year. Therefore, an appropriate culture method was required to overcome this environmental constraint.

In 1987 AVRDC's TM 103 variety and Jinhong developed in HES were used as experimental materials to determine the efficient culture method for yield improvement. Five culture methods were used in this experiment.

Total yield of both varieties was dependent on the yield at the maximum stage of harvest; early yield was superior in staking culture with pinching but late yield was not significantly different among the culture methods for both varieties. It was assumed that higher early yield in staking culture with pinching was due to enhanced fruit set and development by preventing nutrient consumption needed for lateral shoot growth.

Yield of TM 103 reached almost 80 t/ha for nonstaking culture with high ridge, net prop culture and staking culture without pinching in spite of a heavy rain at harvest stage compared to an ordinary year. Jinhong had a similar yield pattern to TM 103, except in nonstaking culture with high ridge, which had relatively low yield. As for TM 103, nonstaking culture with high ridge could produce higher yield due to excellent fruit set ability, in spite of a high rate of damaged fruits and low-planting density (Table 7). Low rate of damaged fruits and high planting density in net prop culture and staking culture without pinching led to favorable yield. Staking culture with pinching resulted in the lowest yield because of very poor fruit set; however, it gave the highest fruit weight.

On the other hand, Jinhong showed an almost similar tendency for all characters as TM 103 (Table 8). However, nonstaking culture with high ridge did not produce favorable yield because of the high percentage of damaged fruits, particularly due to blossom end rot.

The rate of fruit decay was higher than the percentage of fruits damaged by blossom end rot for both varieties (Table 9). Net prop and staking culture were more effective in reducing fruit decay, and the trend was more evident in Jinhong. In rate of blossom end rot infection, Jinhong had an irregular

pattern, while infection in TM 103 was not significantly different among the culture methods used, probably because blossom end rot is a phenomenon of Ca deficiency followed by shortage in soil water content.

Consequently, net prop culture and staking culture without pinching were found promising in reducing the percentage of damaged fruits. Superior fruit set ability of TM 103 in nonstaking culture with high ridge compensated sufficiently for low planting density and relatively high rate of damaged fruits.

Table 7. Effect of different culture methods on major yield traits of TM 103.[z]

Treatment	No. of total fruit/plant	No. of normal fruit/plant	Fruit wt.(g)	% of fruit damaged*	Yield/ plant (kg)	Planting density (plants/ha)
T1	119.6 a	91.8 a	58.6 b	23.2 ab	5.4 a	14814
T2	97.2 b	68.4 b	57.8 b	29.9 a	4.0 b	14814
T3	72.6 c	60.6 b	51.5 b	16.5 b	3.1 b	24691
T4	73.3 c	60.1 b	50.6 b	18.0 b	3.0 b	24691
T5	31.9 d	27.0 c	70.7 a	15.6 b	1.9 c	24691

*% fruit damaged = % of decayed fruits + % of fruits damaged by blossom end rot [z]Mean separation within columns by DMRT at 5% level of significance

Table 8. Effect of different culture methods on major yield traits of Jinhong.[z]

Treatment	No. of total fruit/plant	No. of normal fruit/plant	Fruit wt.(g)	% of fruit damaged*	Yield/ plant/(kg)	Planting density (plants/ha)
T1	103.1 a	71.7 a	51.8 b	30.4 a	3.7 a	14814
T2	95.2 a	71.8 a	53.1 b	24.8 b	3.8 a	14814
T3	61.7 b	50.6 b	52.1 b	17.9 c	2.6 b	24691
T4	59.7 b	48.3 b	52.5 b	19.4 bc	2.5 bc	24691
T5	30.4 c	25.2 c	68.7 a	17.4 c	1.7 c	24691

*% fruit damaged = % of decayed fruits + % of fruits damaged by blossom end rot [z]Mean separation within columns by DMRT at 5% level of significance

Table 9. Effect of different culture methods on fruit decay and damage by blossom end rot of TM 103 and Jinhong.[z]

Treatment	TM 103		Jinhong	
	% of decayed fruits	% blossom end rot	% of decayed fruits	% blossom end rot
T1	18.4 ab	4.8	19.8 a	10.6 a
T2	24.3 a	5.6	20.3 a	4.5 c
T3	12.8 bc	3.7	14.8 b	3.1 c
T4	14.0 bc	4.0	13.9 b	5.5 bc
T5	8.9 c	6.7	8.0 c	9.4 ab

[z]Mean separation within columns by DMRT at 5% level of significance.

AVRDC-Malaysia Vegetable Research Program

An estimated 10,000 ha of lowland vegetables and 2,000 ha of highland vegetables are planted annually in Peninsular Malaysia with a production of about 480,000 t. About 15% of this is exported to Singapore. Vegetables and vegetable products including white potato, garlic, onions, cabbage, dried chilies, tomatoes, dried beans, preserved vegetables and mushrooms valued at about M$250 million per year are imported.

Vegetable research in Malaysia has been intensified in the past few years in view of the concerted efforts of the government to reduce the huge food import and increase vegetable exports. The vegetable research program of the Malaysian Agricultural Research and Development Institute (MARDI) has been reorganized for 1988, and will be divided into the following subprograms according to the following research disciplines: development of improved varieties, development of efficient crop production systems, management of pests and diseases, technology promotion and transfer, postharvest handling and processing, and industry monitoring.

The vegetable crops that will be given top priority in 1988 are chili, tomato, cabbage, asparagus, shallots and white potato.

Preliminary Yield Trial of Tomato

Thirty-four AVRDC tomato lines were evaluated against two local checks, MT 1 and MT 11, on peat soil. Ten of these lines were processing types. The results indicated that none of the AVRDC lines produced significantly larger fruits or higher yields than the local check, MT 1 (Table 1).

Preliminary Yield Trial of Chinese Cabbage

A replicated yield trial of 25 Chinese cabbage varieties was conducted at Jalan Kebun station. Thirteen varieties were from AVRDC. The performance of the top 15 varieties is given in Table 2. Autumn Queen produced the highest yield of 43.3 t/ha which was significantly higher than both the MARDI and AVRDC checks, Saladeer and Hybrid 62, respectively. Promising AVRDC varieties, 82-156, 82-157, 77M(3)-40 and 77 M(2 3-46) that outyielded the local check by at least 16% will be evaluated with varieties from other sources in further yield trials.

Table 1. Performance of the top four AVRDC tomato varieties against the local check, MT 1.[z]

Variety	Fruit weight		Fruit no.	
	Plot (kg)	Plant (g)	Plot (kg)	Plant (g)
CL 5915 136D-4-01-0	9.92 a	991.5 ab	353.0 ab	35.5 ab
CL 5915-2-1	9.86 a	986.0 ab	228.0 ab	22.8 b
CL 5915-3-2	9.33 ab	1171.7 a	368.7 a	46.9 a
CL 143	8.13 ab	894.8 ab	245.7 ab	27.0 b
MT 1 (check)	7.63 ab	924.1 ab	327.7 ab	34.0 ab

[z]Data derived from ANOVA with 36 means. Means followed by the same letter(s) are not significantly different at 5% level.

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Table 2. Performance of top 15 Chinese cabbage varieties in a preliminary yield trial in Jalan Kebun.[z]

Variety	Mean head wt. (g)	Solidity (g/cc)	Soft rot (%)	Unadjusted yield (t/ha)
Autumn Queen*	1300 a	0.5 cd	14.0 cd	43.3 a
82-156	1094 ab	0.8 ab	0.0 d	36.5 ab
82-157	1088 ab	0.7 ab	0.0 d	36.3 ab
Green Sun*	1047 abc	0.7 ab	3.7 d	34.9 abc
77 M(2/3-46)	1041 abc	0.7 ab	20.0 b	33.3 abc
77 M(3)-40	954 abc	0.7 ab	16.7 cd	34.4 abc
77 M(3)-27	923 bcd	0.6 abc	6.7 d	30.8 bcd
83-46	888 bcd	0.7 abc	3.3 d	29.6 bcd
83-20	887 bcd	0.8 ab	13.3 cd	29.6 bcd
77 M(2/3-43)	880 bcd	0.6 abcd	6.7 d	29.4 bcd
Saladeer* (MARDI check)	857 bcd	0.5 bcd	17.3 cd	28.6 bcd
83-2	849 bcd	0.7 abc	26.7 bcd	26.6 bcd
Hybrid 62 (AVRDC check)	829 bcd	0.7 abc	13.7 ed	26.7 bcd
77 M(3)-35	782 bcd	0.6 abcd	13.3 cd	26.1 bcd
B-40	661 d	0.5 d	20.0 b	20.0 d

[z]Data from ANOVA with 25 means. Means followed by the same letters are not significantly different at 5% level. *Non AVRDC varieties.

Preliminary Yield Trial of Sweet Potato Varieties

A replicated yield trial was conducted in Serdang in which 27 superior varieties from AVRDC were tested against three high-yielding varieties from MARDI and one good local variety. The most outstanding varieties were CN 1219-1 and I 423 with yields of 20.9 and 18.4 t/ha fresh tubers, respectively. Highest dry tuber yields were obtained from CN 1219-1 and PC 1-177. The performance of the 10 most promising sweet potato varieties is shown in Table 3.

Preliminary Yield Trial of Soybean Varieties

A replicated yield trial was conducted on four AVRDC varieties and a local check in Serdang. Three varieties produced significantly higher yields than the local check, Palmetto. Two of these varieties, AGS 190 and G 81083-63, are vegetable types with a seed size of more than 20 g/100 seeds. The results of the trial are given in Table 4.

Table 3. Performance of the 10 promising sweet potato varieties in a yield trial in Serdang.[z]

Variety	Fresh tuber yield (t/ha)	Dry tuber yield (t/ha)	Dry matter content of tuber (%)
CN 1219-1	20.9 a	5.1 a	24.12 abcd
I 423	18.4 a	4.0 abcd	22.07 bcd
Bukit Naga	17.6 a	4.8 abc	26.94 abc
CN 1280-3	15.9 a	4.0 abcd	24.71 abcd
PC 1-177	15.8 a	5.0 ab	31.17 ab
CN 1028-15a	14.8 a	2.0 d	14.54 d
CN 1181-312	14.7 a	2.7 cd	18.38 cd
Local variety	14.7 a	3.8 abcd	23.85 abcd
CN 1232-9	14.4 a	3.5 abcd	24.47 abcd
AVRDC Selection 1	14.2 a	2.6 cd	18.91 cd

[z]Data derived from ANOVA with 31 means. Means followed by the same letters are not significantly different at the 5% level.

Table 4. Results of preliminary yield trial of soybean varieties in Serdang.[z]

Variety	Days to maturity	Plant height at maturity (cm)	Yield (kg/ha)	100-seed weight (g)
AGS 129	87 b	49.2 b	2131.0 a	15.3 c
AGS 190	94 a	28.5 c	2094.2 a	27.2 a
G 81083-63	85 b	31.6 c	2066.0 a	21.5 b
Palmetto (check)	85 b	60.5 a	1427.6 b	11.5 d
AGS 292	70 c	21.8 d	576.4 c	22.2 b

[z]Means followed by the same letters are not significantly different at 5% level.

Initial Yield Trials of Mungbean Varieties

An initial yield trial (IYT) was conducted using 14 mungbean varieties from AVRDC. Results indicated that there were no significant differences among the yields of all varieties tested (Table 5). The top four performers were VC 2768A, VC 2523A, VC 1628 and VC 2778A, with yields above 1000 kg/ha. These varieties will be used in subsequent yield trials together with materials from other sources.

Another yield trial was conducted with eight mungbean varieties in late 1987. None of the AVRDC varieties outyielded the local check, VC 1163-2-2-6-2-B (Table 6). The three varieties, VC 1502A, VC 2770C and VC 3664A with yields exceeding 1000 kg/ha, were selected for further evaluation.

Evaluation of Cauliflower Varieties from Several Countries

Twenty commercial varieties from Japan, Taiwan, Netherlands, U.S.A. and Thailand were evaluated on peat soil at Jalan Kebun. The four best-yielding varieties were Snow Top, Snow Queen, Fengshan Extra Early and Chai Tai *1. These varieties not only produced significantly heavier heads but also gave yields that were 53% to 70% higher than the check, Superball (45 days). A summary of the results is given in Table 7.

Preliminary Evaluation of Garlic Varieties

A trial was conducted at Cameron Highlands station to evaluate the performance of four garlic varieties from Taiwan. The varieties were Fu-Wei, Ho-Mei, Shi-lo and Shi-Kong. No significant difference in yield was observed among the varieties. The yields obtained were low-ranging from 2.27 t/ha for Shi-Kong to 2.93 t/ha for Fu-Wei. However, Shi-lo produced heavier bulbs with least weight reduction during storage. It will be further evaluated before release to farmers.

Research on Chili or Hot Pepper

Research conducted on chili included screening of varieties for high yields, hybridization to develop lines with desirable agronomic traits and incorporation of disease resistance into these lines, fertilizer and disease management studies.

Resistance to Anthracnose

Among the various genotypes screened in the past, Cili Padi (*Capsicum annuum* var. *aviculare*) had been identified as the most resistant followed by Serrano Tampiqueno, a Mexican cultivar. Crosses were made to incorporate the resistant factor or factors from Cili Padi to susceptible cultivars. Work is in progress to purify these advanced materials (F_6) and evaluate their agronomic performance.

Table 5. Results of initial yield trial of 14 mungbean varieties from AVRDC in Serdang.[z]

Variety	Plant height at maturity (cm)	Seed weight (g/100 seeds)	Yield (kg/ha)
VC 2768A	67.7 abc	7.23 abc	1134.4 a
VC 2723A	77.3 a	5.50 d	1042.1 a
VC 1628	70.7 ab	7.20 abc	1026.6 a
VC 2778A	71.4 ab	7.73 a	1024.3 a
VC 2750	58.2 abc	7.07 abc	1019.9 a
VC 2755	70.9 ab	7.70 ab	988.0 a
VC 1089A	77.2 a	5.57 a	974.5 a
VC 2750B	57.7 abc	7.03 abc	879.2 a
VC 1973A	62.1 abc	7.53 ab	852.5 a
VC 2768B	62.1 abc	7.30 abc	834.7 a
VC 1482	63.0 abc	5.70 d	827.4 a
VC 2784A	54.1 bc	7.10 abc	816.5 a
VC 1163-2-2-6-2-B (check)	49.2 bc	6.57 c	782.4 a
VC 1000C	47.1 c	6.93 bc	716.7 a

[z]Means followed by the same letters are not significantly different at 5% level.

Table 6. Results of initial yield trial of eight mungbean varieties in Serdang.[z]

Variety	Plant height at maturity (cm)	Seed weight (g/100 seeds)	Yield (kg/ha)
VC 1163-2-2-6-2-B (check)	65.0 a	6.8 a	1427.1 a
VC 1562A	56.4 a	6.8 a	1145.3 ab
VC 2770C	53.2 a	6.5 a	1117.7 ab
VC 3664A	46.5 a	6.2 a	1079.9 ab
VC 3528A	53.5 a	6.1 a	894.0 b
VC 1178A	48.5 a	6.7 a	872.5 b
VC 2778C	57.1 a	6.8 a	848.8 b
VC 3542A	46.4 a	6.9 a	694.4 b

[z]Means followed by the same letters are not significantly different at 5% level.

Table 7. Results of preliminary evaluation of 11 cauliflower varieties on peat soil.[z]

Variety	Days to maturity (DAP)	Weight/head (g)	Unadjusted yield (t/ha)
Snow top	64.7 ab	386.7 a	15.5 a
Snow Queen	53.0 cde	350.0 ab	14.0 ab
Fengshan Extra Early	60.0 bc	336.7 ab	13.5 ab
Chai Tai #1	49.0 e	333.3 ab	13.3 ab
F_1 451	50.0 de	316.7 abc	12.7 abc
Snow King	67.7 a	283.3 abc	11.3 abc
Mikado	55.3 cde	266.7 bc	10.7 bc
Green Harmony	59.0 bc	263.3 bc	10.5 bc
Farmer Early #2	71.3 a	263.3 bc	10.5 bc
Farmer Extra Early	57.0 cd	240.0 bc	9.6 bc
Superball 45 days (ck)	59.0 bc	216.7 c	8.7 c

[z]Data derived from ANOVA with 20 means. Means followed by the same letters are not significantly different at 5% level.

Resistance to Viruses

The five viruses prevalent in Malaysia had been identified as chili veinal mottle virus (CVMV), tomato spotted wilt virus (TSWV), cucumber mosaic virus (CMV), tobacco mosaic virus (TMV) and tobacco leaf curl virus (TLCV). The incidence of CVMV was much higher while the other viruses often occurred in mixed infection with CVMV. A resistance gene against CVMV from *C. annuum*

var. *aviculare* had been successfully incorporated into susceptible cultivars and the advanced material is now at the F_6. Emphasis is currently placed on breeding for resistance to multiple viruses. Progenies that are resistant to both CVMV and CMV had been isolated from crosses between resistant Mexican varieties and susceptible cultivars.

Other Research Activities

Evaluation of commercial varieties and hybrids of lettuce, white potato, asparagus, long bean, French bean and cucumber from local and foreign seed companies was also conducted. Promising varieties were identified among the following species: cabbage (2), white potato (5 for lower and 6 for higher altitudes in Cameron Highlands) and lettuce (4). The germplasm collection of traditional vegetable and medicinal plant species had been increased to 190 accessions comprising of 113 species.

Other researches done during the year included fertilizer trials (asparagus, cabbage and tomato), pruning trial on asparagus, irrigation studies on chili, vegetable cropping system studies, mechanization (transplanting and pesticide spraying), and vegetable production under rain shelter.

Studies on pest and disease management included chemical control of diamondback moth, *Plutella xylostella*; cabbage webworm, *Hellula undalis*; virus vectors of chili and leaf miner of sugar peas, *Chromatomyia horticola*. Several screening trials were conducted to determine the efficacy of various fungicides against anthracnose of chili, bacterial diseases of cabbage and tomato, late blight of tomato and rust disease of long bean. Several interim integrated packages were also tested to determine their effectiveness in the control of virus diseases of chili.

Conclusion

Several persistent and difficult problems still plague the vegetable industry in Malaysia despite concerted research efforts to overcome them. It is in these areas that pooling of resources and experiences will provide the fastest as well as the most benefits to participating countries. MARDI hopes that AVRDC will provide the necessary technical support and cooperation in the development of technologies in the following areas:

- Supply of high quality varieties of Chinese cabbage, tomato, soybean, mungbean, sweet potato, chili and cauliflower,
- Supply of disease-resistant sources/varieties with virus and anthracnose resistance in chili, and virus and bacterial resistance in tomato,
- Crop protection such as integrated pest management of *Plutella* and bacterial soft rot in cabbage and integrated control of virus diseases in chili,
- Vegetable production under rain shelter, and
- Production program.

AVRDC-Philippine Outreach Program

The AVRDC-Philippine Outreach Program (AVRDC/POP) conducts research on mungbean, soybean, Chinese cabbage, tomato and sweet potato mainly to evaluate AVRDC varieties and cultural practices and determine their suitability to local conditions and requirements.

In 1987, AVRDC/POP distributed a total of 651 seed packets to 48 recipients and cooperators. These are broken down to 214 seed packets of tomato, 101 of Chinese cabbage, 216 of mungbean and 120 of soybean, distributed to 9, 14, 11 and 14 recipients and cooperators, respectively.

Preliminary Yield Trial of Chinese Cabbage

Summary

Fifteen entries of F_1 hybrids and open-pollinated lines were evaluated and compared to the check, Reyna Elena (Hybrid 62) during the wet and dry seasons. There were significant differences between entries, but none significantly outyielded the check which produced 16.9 t/ha marketable head yield during the dry season and 19.9 t/ha during the wet season. Hybrid 82-156 was highly resistant to soft rot with 2% infection, while lines 77 M(2/3)-43, Hybrid 57 and 82-46 with 18.3%, 16.7% and 14.7% infections, respectively, were rated susceptible.

Introduction

Seven hybrids and eight open-pollinated Chinese cabbage lines were compared against the check, Reyna Elena, during the dry and wet seasons of 1986-87. The study aimed to identify lines with high marketable head yields adapted for the lowland tropics.

Materials and Methods

The hybrids and open-pollinated lines from AVRDC were each planted in 1 m × 4.8 m raised subplots distributed in RCBD and replicated three times. Two furrows 50 cm apart were set in each subplot. One seedling each was planted 40 cm between hills within the furrows and the subplots were mulched with rice straw. The plants were fertilized with 60-35-33 kg N, P_2O_5 and K_2O/ha, respectively, at planting. Sidedressing with 20 kg N/ha was done one week after transplanting (WAT) and two subsequent applications of 20 kg N/ha and 25 kg K_2O/ha were done two WAT and at head initiation, respectively.

Results and Discussion

Dry season trial. Of the 16 entries evaluated, only Hybrid 58 with 19.6 t/ha outyielded the check, Reyna Elena, which produced 16.9 t/ha. However, the difference was not statistically significant. Moreover, Hybrid 58 had the highest mean head weight of 609 g among the entries and higher harvest rate and solidity compared to the check. During the cropping season, total precipitation was 115.1 mm and mean temperature was 28.3°C maximum and 20.7°C minimum (Table 1).

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Table 1. Yield performance of the AVRDC Chinese cabbage lines under PYT 1986-87.

Entry	Computed yield (t/ha)		Mean head wt. (g)		Harvest[x] rate (%)		Solidity[w] (g/cc)		Soft rot rating (%)
	DS[z]	WS[y]	DS	WS	DS	WS	DS	WS	WS
Hybrid 82-46	16.4	12.7	503	650	98	57	0.59	0.60	14.7
Hybrid 82-156	15.5	14.2	483	640	97	64	0.53	0.49	2.0
Hybrid 82-157	13.9	17.5	438	608	95	87	0.52	0.54	6.7
Hybrid 83-2	15.8	17.2	491	669	97	77	0.62	0.60	10.0
Hybrid 83-20	16.4	15.6	500	744	98	75	0.57	0.51	5.0
77 M(3)-27	12.2	13.0	436	696	83	56	0.47	0.48	6.7
77 M(3)-35	8.9	3.9	346	550	77	21	0.35	0.47	11.0
77 M(3)-40	9.1	7.7	339	578	81	39	0.43	0.46	7.0
77 M(2/3)-43	15.0	11.8	490	668	91	53	0.48	0.58	18.3
77 M(2/3)-46	13.8	17.5	480	748	87	70	0.43	0.50	4.0
Reyna Elena (ck)	16.9	19.9	535	669	95	89	0.40	0.51	7.0
77 M(3)-26	12.8	10.9	425	747	90	43	0.49	0.45	9.3
77 M(3)-33	11.6	8.4	481	553	74	44	0.53	0.48	6.3
77 M(2/3)-41	15.5	12.4	492	705	95	53	0.48	0.48	8.3
Hybrid 58	19.6	12.0	609	797	97	40	0.53	0.54	11.3
Hybrid 59	15.4	10.7	503	700	92	45	0.38	0.41	16.7
Grand Mean	13.7	13.0	470	664	86.6	57	0.49	0.51	
LSD 5%	3.18	6.52	130	122.8	12.9	25.2	ns	ns	
LSD 1%	4.28	8.78	ns	ns	17.4	33.9	ns	ns	
CV (%)	14.00	30.00	16.6	11.1	9.0	26.0	20.40	16.80	

[z]Dry season — transplanted 12 December 1986, harvested 16-30 January 1987. [y]Wet season — transplanted 24 June 1987; harvested 30 July to 4 August 1987. [x]Percentage of harvestable stand. [w]An approximate measurement of head firmness expressed in g/cc.

Wet season trial. The grand mean yield for the 16 entries was 13.3 t/ha. There was not much fluctuation in yield between entries except for 77 M(3)-35 which produced 3.9 t/ha. No entry outyielded the check, Reyna Elena (19.9 t/ha). Hybrid 58 had the highest mean head weight of 797 g while the check resulted in a harvest rate of 89%. The most resistant to soft rot infection was Hybrid 82-156 (2% infection). Total precipitation during the cropping season was 150.5 mm and mean minimum temperature was 31.8°C (Table 1).

So far, Reyna Elena (Hybrid 62) is still the best variety for cultivation in the lowland tropics. Its marketable head yields were relatively stable in both wet and dry seasons. Most of the hybrids and a few open-pollinated lines also showed relative stable head yields in both seasons. However, Hybrids 82-46, 58, 59 and the open-pollinated line 77M(2/3)-43 appeared to be susceptible to soft rot infection, especially during the wet season.

General Yield Trial of Chinese Cabbage

Summary

A wet season trial was conducted on four promising selections to reconfirm their yield potentials over the check under the prevailing hot humid conditions of the lowland tropics.

The check, Reyna Elena (Hybrid 62), obtained the highest yield of 18 t/ha followed closely by entry 82-46 with 17.5 t/ha. The grand mean yield for the five entries was 15.9 t/ha. The percentage of soft rot infection was low for all the entries, except Hybrid 58 which had 1% infection.

Introduction

Promising lines with consistent high yields under the preliminary yield trial were selected and further evaluated in the general yield trial.

The study was conducted during the wet season only. Two stable hybrids (Hybrids 58 and 59) and two new ones (82-46 and 82-157) were compared to the check, Reyna Elena.

Materials and Methods

Each entry was planted on 25 June 1987 in double-row 1 × 4.8 m^2 raised beds distributed in RCBD and replicated four times. The rows were set 50 cm apart and the hills 40 cm within the rows. The plants were fertilized at 60-35-33 kg of N, P_2O_5 and K_2O/ha, respectively, at planting. Sidedressing with 20 kg N/ha was done one week after transplanting (WAT). Two subsequent applications of 20 kg N/ha and 25 kg K_2O/ha were done two WAT and at head initiation, respectively. The standard AVRDC guide was followed in evaluating the entries.

Results and Discussion

No significant differences on marketable head yield were observed among the entries. The check, Reyna Elena, produced the highest yield of 18 t/ha. The grand mean for all the entries was 15.9 t/ha. Hybrids 58 and 59 showed low harvest rate which may be due to the old seed stock used in the trial. Percentage of soft rot infection was low for all the entries except Hybrid 58 which had 19.5%.

During the cropping season, total precipitation was 151.1 mm and mean temperatures were 32.0°C maximum and 24.7°C minimum.

So far, the new Hybrids 82-46 and 82-157 appeared to be comparable to the check, Reyna Elena, as far as head yield, mean head weight, solidity and soft rot rating are concerned.

Hybrid Seed Production of Chinese Cabbage Variety Reyna Elena (Hybrid 62)*

Summary

For the Chinese cabbage hybrid seed production in Baguio City during the cool season, the parental lines of Reyna Elena (Hybrid 62), E-7 and B-18 needed vernalization periods of 21 days and 14 days, respectively, at 9°C. The optimal fertilizer rate was 150-90-90 kg of NPK/ha. Both under- and over-vernalization had a negative effect on flower and seed production.

Introduction

AVRDC developed a heat-tolerant hybrid variety, ASVEG 1 (Hybrid 62), for the hot and humid tropics. This variety, locally known as Reyna Elena, proved to be well adapted in the lowland areas of the Philippines and was, therefore, released for commercial production. Following its release, a study on the hybrid seed production conducted at the Department of Agriculture Baguio Experiment Station proved that the technology developed at AVRDC was economically feasible under local conditions. In cooperation with AVRDC and POP, the seed production technology was further verified by East-West Seed Company in 1986-87 at the Baguio Experiment Station. The study was designed to determine the optimal seed vernalization period and fertilizer rate of both parental lines for hybrid seed production in the Philippines.

Materials and Methods

The experiment was divided into female and male vernalization experiments. Both experiments were analyzed independently. In the field, the experiments were mixed in a chessboard arrangement in which the female filled up the black squares and the male occupied the white squares or vice versa.

In the female vernalization experiment, RCBD was used with four treatments in four replications. The plot size was 12 m^2 and the planting distance was two rows on one bed, 0.4 m between rows and 0.4 m between plants within the rows. Fertilizer at 60-90-90 kg NPK/ha was applied three WAT.

*Summarized from the East-West Seed Co. report, 1987.

Pest and disease control measures were applied as needed. The treatments were 21, 14, 7 and 0 days seed vernalization for F_1, F_2, F_3 and F_4, respectively.

The experimental design, plot size, planting distance and pest and disease control used in the male vernalization experiment were similar to the female vernalization experiment, except for the fertilizer application.

The treatments were as follows:

M_1: 28 days seed vernalization; 150-90-90 kg NPK/ha; vernalization seven days ahead of F_1.
M_2: 28 days seed vernalization; 90-90-90 kg NPK/ha; vernalization seven days ahead of F_1.
M_3: 28 days seed vernalization; 150-90-90 kg NPK/ha; vernalization simultaneous with F_1.
M_4: 28 days seed vernalization; 90-90-90 kg NPK/ha; vernalization simultaneous with F_1.
M_5: 14 days seed vernalization; 150-90-90 kg NPK/ha; vernalization started seven days after F_1.
M_6: 14 days seed vernalization; 90-90-90 kg NPK/ha; vernalization started seven days after F_1.
M_7: 14 days seed vernalization; 150-90-90 kg NPK/ha; vernalization 14 days after F_1.
M_8: 14 days seed vernalization; 90-90-90 kg NPK/ha; vernalization 14 days after F_1.

During the vernalization of both parents, the seeds were placed overnight in a moistened cotton-lined 4-inch petri dish with lid, then transferred to a refrigerator modified with continuous light and temperature adjusted to 8° to 10°C. After the required days of vernalization treatment, the seedlings were pricked in 2 × 4 inch paper pots containing steam- sterilized soil media. The seedlings were transplanted 26 days after pricking. Pinching of the flower stalks was done 28 days after transplanting in treatments F_1, M_1 and M_2, and at flower stalk emergence in the other treatments. All other cultural practices were uniform throughout the experiment.

Results and Discussion

The effects of vernalization and nutrients on the vegetative and reproductive growth of the male and female lines of Chinese cabbage hybrid Reyna Elena are summarized in Table 2.

Results of the study showed that seed vernalization had a limited effect on the survival rate of transplanted seedlings. The optimal vernalization period for the female line E7 was 21 days at 9°C and for the male line B-18, 14 days at 9°C. The optimal fertilization level for the male line in this experiment was 150-90-90 kg NPK/ha while that for both lines in a commercial seed production was higher than 120-90-90 kg NPK/ha. Both under- and over-vernalization had a negative effect on flower production.

Table 2. Effects of vernalization and nutrients on vegetative and reproductive growth.

Treat-ments	% of survival	Days to 50% flowering	No. of open flowers and pods at 50% flowering	% of flowering, 7 DA 50% flowering	No. of open flowers and pods, 7, DA 50 % flowering	% of flowering, 14 DA 50% flowering	No. of open flowers and pods, 14 DA 50% flowering
F1	93	38	18.33 b*	100	63.58 ns*	100	110.67 bc
F2	97	52	17.63 b	82	87.18 ns	100	207.20 a
F3	96	62	34.95 a	70	88.08 ns	96	149.70 b
F4	98	70	15.38 b	60	84.28 ns	91	71.55 c
CV(%)			33.75		19.45		
M1	98	38	10.40 d*	100	38.25 c*	100	87.20 c
M2	91	38	8.35 d	100	51.90 c	100	65.35 c
M3	90	44	10.40 d	98	51.25 c	100	133.85 b
M4	94	44	9.00 d	98	72.05 abc	100	149.25 ab
M5	92	47	22.25 a	98	96.45 ab	100	156.90 ab
M6	91	45	18.45 a	100	102.30 a	100	165.40
M7	89	66	21.20 ab	66	69.55 abc	90	89.35 c
M8	89	60	16.25 c	54	64.30 abc	88	79.05 c
CV(%)			10.85		22.14	10.94	

*Mean separation within columns was determined using Duncan's Multiple Range Test at 5% level.

Single-Seed-Descent Trial of Tomato

Summary

The single-seed-descent (SSD) trial conducted during the 1986-87 dry season (DS) was composed of three sets of planting. These were: Set 1 with 10 AVRDC open-pollinated lines; Set 2, with seven F_1 hybrids, four open-pollinated lines and five East-West Seed Co. F_1 hybrids (all fresh market lines); and Set 3 with 52 AVRDC processing tomato F_1 hybrids.

Most of the open-pollinated fresh market tomato lines that showed good yield performance were elevated to the preliminary yield trial during the 1987 wet season (WS).

Introduction

Advanced generation tomato lines from AVRDC were tested under the SSD trial to evaluate their yield performance under local conditions. Entries from private seed companies like the East-West Seed Co. were also included in the test. Seeds of the open-pollinated lines that showed potential were multiplied for further evaluation in the PYT. For F_1 hybrids, fresh seeds were requested from the breeders.

Materials and Methods

During the 1986-87 dry season, 78 new lines of both fresh market and processing tomatoes were evaluated at the POP under the SSD trial in three sets of planting. The entries were distributed in RCBD, replicated three times for Sets 1 and 2, and twice for Set 3. Each subplot was 5 m^2.

The total fertilizer applied was 78-156-78 kg of N, P_2O_5 and K_2O/ha, respectively. These were applied three times: 26-104-26 kg NPK/ha as basal, and two subsequent applications of 26-26-26 kg NPK/ha at two and four weeks after transplanting. The crop culture and data collected were patterned after the AVRDC recommended procedure in conducting tomato evaluation trials.

Results and Discussion

The yields of the entries in set 1 ranging from 17.2 to 36.8 t/ha were comparable to the check (26.2 and 27.3 t/ha). Line CL 5915-93 D4-1-0 (28.3 t/ha) and CL 5915-93 D4-1-0-C (36.8 t/ha) yielded slightly higher than the checks, but the difference was not significant. The entries flowered in about 23 days and matured from 69 to 83 days after transplanting. In general, the AVRDC lines produced bigger fruits than the check. Fruit worms and blossom end rot were severe in all entries. The total precipitation during the crop season was 558.6 mm with minimum and maximum temperatures of 21.3°C and 29°C, respectively.

So far, none of the 10 open-pollinated test entries significantly outyielded the two checks when planted during the dry cool season for tomato production.

The yields and other horticultural characteristics of the open-pollinated lines and F_1 hybrids in set 2 were compared to the check variety Marikit. Lines EWSC 1-B and EWSC 2-C produced the highest yields of 35.5 and 35.4 t/ha, respectively. However, these were not significantly different from the check Marikit which yielded 26.8 t/ha. All entries produced significantly bigger fruits over the check. The prevalence of fruit worms was very high in all the AVRDC lines. The highest fruit crack rate was observed on FMTT 19 while EWSC 1-A, 1-B and 2-B had the highest rate of blossom end rot (BER).

During the cropping season, total precipitation was 71.2 mm with mean maximum and minimum temperatures of 29°C and 20°C, respectively. Occasional supplemental irrigation was applied especially during the flowering and early fruit development stages. From this trial conducted during the regular season for tomato production, only three EWSC F_1 hybrids nos. 1-B, 2-B and 2-C so far slightly outyielded the open-pollinated check Marikit.

Set 3 in Table 3 shows that the 10 highest yielding processing type F_1 hybrid tomatoes which produced 40.3 to 44.5 t/ha did not significantly outyield the check Marikit (33.4 t/ha). All the entries flowered in about 25 days and matured in 69 to 87 days after transplanting. Fruit size varied among

the entries with PT 4062 (87.0 g) being the biggest. Fruit worm and blossom end rot were prevalent on all the entries during the season.

During the trial, total precipitation was 475.7 mm with 430.5 mm occurring at prebloom stage of the crop. Temperature was 21.4°C minimum and 28.3°C maximum.

Table 3. Mean yield and some horticultural characters of the highest yielding SSD entries (dry season).[z]

Entry	Yield (t/ha)	Days to Flowering	Days to Maturity	Fruit size (g)	Polar dia. (cm)	Equitorial dia. (cm)	Disease rating[y] FW	Disease rating[y] BER
PT 4058	44.5	20.5	71	49.0	4.6	4.5	1.5	3.5
PT 4027	42.6	26.5	74	52.5	4.5	4.5	2.0	3.0
PT 4073	42.6	20.5	78	54.0	4.8	4.1	1.5	2.5
PT 4063	42.4	25.0	78	80.0	4.8	5.2	2.0	3.0
PT 4064	42.3	25.5	81	85.5	4.5	5.1	2.0	2.5
PT 4062	41.3	25.0	87	87.0	4.5	5.3	2.5	2.5
PT 4148	41.2	21.5	76	43.0	4.2	4.2	2.0	2.0
PT 4057	40.8	24.0	78	49.0	4.2	4.3	1.5	2.5
PT 4049	40.7	28.5	85	77.0	4.5	5.3	2.8	2.5
PT 4147	40.3	21.5	69	42.0	4.2	4.3	2.5	3.5
Marikit (ck)	33.4	26.5	69	32.0	3.4	3.8	2.0	3.0
Grand mean (53 entries)	34.4	25.4	79.2	59.5			2.0	2.8
CV (%)	19.4	10.34	8.7	17.2			27.4	25.2
LSD.05	ns	5.27	ns	20.5			ns	ns

[z]Transplanted 4 November 1986 and harvested 12 January to 6 February 1987 with seven harvests.
[y]Ratings from 1 to 5, with increasing order of severity.

Preliminary Yield Trial of Tomato

Summary

Of the 13 AVRDC open-pollinated fresh market tomato lines evaluated during the 1986-87 dry season, only CL 5915-222 D6-0-5 with 33.1 t/ha outyielded the check (30.5 t/ha), but the difference was not significant. In the wet season, two sets of planting were made. In Set 1, the check variety Marikit outyielded all the test entries including the eight open-pollinated lines and seven F_1 hybrids. In Set 2, six out of the 11 open-pollinated lines outyielded the check Marikit.

Introduction

Lines from the SSD trial selected based on yield performance and fruit qualities were evaluated in the PYT for two wet and dry seasons. The study aimed to identify heat- and moisture-tolerant lines that will produce high marketable yields during the wet season, and with resistance to bacterial wilt, fruit worms and physiological disorders.

Materials and Methods

Each entry, evaluated in both wet and dry seasons, was planted in 5-m^2 subplots in RCBD and replicated three times.

The 1986-87 dry season trial composed of 13 open-pollinated fresh market tomato lines was transplanted on 26 November 1986. During the wet season, two sets of planting were made. Set 1 with eight open-pollinated lines and seven F_1 hybrids (all fresh market tomatoes) were transplanted on 1 July 1987, and Set 2 with 11 open-pollinated fresh market types on 16 July 1987.

Results and Discussion

There were significant yield differences among entries during the 1986-87 dry season trial. However, none significantly outyielded the check Marikit which produced 30.5 t/ha. Test entry CL 5915-222 D6-0-5 which yielded 33.1 t/ha was comparable to the check. Flowering ranged from 21 to 27 days and maturity of fruits from 68 to 81 days. Highest fruit set of 4.3 was recorded on CL 5915-156 D4-1, while biggest fruits (55 g/fruit) were observed on CL 5915-206 (G) D4-2.

The yield and important characteristics of eight open-pollinated and seven F_1 hybrids planted on 1 July 1987 (Set 1)are compared in Table 4. The check variety, Marikit, outyielded all the AVRDC lines and hybrids. However, the yield of CL 5915-93 D4-1-0-C-1 was comparable to the check. All lines produced nonmarketable yields due to various causes. Flowering ranged from 15 to 26 days. The highest fruit set rating of 4.0 was from CL 5915-93 D4-1-0-C-1; and the biggest fruits (62 g/fruit) were recorded from CL 5915-93 D4-1-0-L-2 (62.7 g) and FMTT 16 (62.5 g). All the entries were attacked by fruit worms with the check as the most susceptible. Entry FMTT 22 had the highest incidence of bacterial wilt infection while FMTT 19 was very susceptible to TMV and FMTT 21 to cracking. Fruit rot of various causes was most severe on CLN 65-349 D5-2-0. The 1987 wet season test was the first preliminary trial for this set of materials.

In Set 2, also conducted during the 1987 wet season, six lines outyielded the check, Marikit, but the difference was not significant. The highest marketable yield of 13.5 t/ha was produced by CL 5915-93 D6-1-0. Days to flowering ranged from 19 to 25 days. Fruit worm infestations were severe on CL 1131-0-0-7-2-0-11-0. Bacterial wilt, tobacco mosaic virus and southern blight affected all the entries at varying degrees of severity. The highest incidence of fruit cracking was on CL 5915-124 (G) D4-2.

So far, from the two sets of wet season planting of tomatoes, seven test entries, all open-pollinated lines, proved to be as productive as the check, Marikit. However, the yield differences were not statistically significant.

General Yield Trial of Tomato

Summary

CL 143-0-1-3-3-1 and CL 551-6-0-18-1-1 had completed the four-season evaluation during the 1986-87 dry season. These will be submitted for regional yield trial when enough seeds have been produced. During the 1987 wet season, four promising selections from the PYT were elevated to the GYT.

Introduction

Lines found promising after the four-season preliminary trial were evaluated in the general yield trial. The objectives of this study were to further screen lines for heat and moisture tolerance and to determine lines resistant to tropical pests and diseases. CL 143-0-1-3-3-1 and CL 551-6-0- 18-1-1 will be submitted to the RYT when enough seeds have been produced. Four new lines were added to the GYT in the 1987 wet season, bringing the total entries evaluated during the wet season to 15.

Materials and Methods

Each entry was transplanted in 5-m^2 subplots distributed in RCBD with four replications.

The 1986-87 dry season trial was composed of 13 entries, while the two 1987 wet season tests had 15 entries.

Results and Discussion

AVRDC open-pollinated fresh market tomato lines were evaluated under the GYT for 1986-87 dry season and 1987 wet season. Seven out of 13 lines outyielded the check, Marikit. However, only CL 551-6-0-18-1-1 with 39.1 t/ha significantly outyielded the check, Marikit (31.1 t/ha).

Table 4. Mean yield and some horticultural characters of the fresh market tomatoes in the PYT, Set 1, 1987 wet season.[z]

Entry	Yield (t/ha)		Days to flower	Fruit set rating[y]	Fruit size (g)	Pest, disease and physiological disorders[x]				
	Marketable	Nonmarketable				FW	BW	TMV	Cr	FR
CL 5915-39 D4-1-2-0	7.1	2.9	22.7	3.0	39.1	3.3	2.7	2.0	1.3	2.0
CL 5915-206 D4-2-2-0	6.0	2.0	15.0	3.7	50.3	2.3	1.3	3.3	1.7	1.3
CL 5915-206 D4-2-4-0	3.2	1.9	25.0	2.3	45.1	2.7	1.0	4.0	1.3	1.7
CL 5915-206 D4-2-5-0	3.7	2.9	25.0	3.0	45.7	2.3	2.7	3.7	1.7	1.3
CL 5915-93 D4-1-0-L-2	9.2	3.1	24.7	2.7	62.7	2.7	1.0	4.3	1.0	2.3
CL 5915-153 D4-3-3-0	10.3	1.6	23.3	3.3	33.6	2.7	1.3	3.3	2.0	2.3
CL 5915-93 D4-1-0-C-1	14.5	2.5	20.3	4.0	34.0	2.7	2.0	2.3	1.3	2.0
CLN 65-349 D5-2-0	12.8	2.0	22.7	3.7	36.1	3.0	1.7	3.3	1.3	3.3
FMTT 3	5.4	1.4	22.0	2.3	52.8	2.7	4.0	2.0	1.0	2.3
FMTT 14	6.0	1.2	24.0	3.0	56.0	3.0	2.7	2.3	1.0	2.0
FMTT 16	10.6	1.9	25.0	3.0	62.5	2.7	1.3	2.7	1.7	2.3
FMTT 18	11.8	2.6	25.0	3.3	48.1	2.0	1.7	3.3	2.0	2.7
FMTT 19	10.6	1.4	24.7	3.0	42.7	2.3	1.0	4.5	1.3	2.0
FMTT 21	12.3	1.0	26.0	3.0	43.4	2.7	2.7	2.3	2.7	2.0
FMTT 22	4.1	0.6	25.7	2.0	35.3	1.7	4.3	2.3	2.0	2.3
Marikit (ck)	14.8	2.6	20.0	3.3	26.7	3.7	1.7	3.7	2.0	2.7
Grand Mean	8.9	2.0	23.9	3.0	44.6	2.6	2.1	3.1	1.6	2.2
LSD .05	4.2	ns	2.11	0.74	12.2	ns	0.9	1.99	ns	ns
CV (%)	28.4	52.4	5.29	14.9	16.5	32.17	23.1	27.0	48.4	35.2

[z]Transplanted 1 July 1987 and harvested seven times from 25 August to 11 September 1987. [y]Rating of 1 to 5 with 1 = slight setting and 5 = heavy setting. [x]FW = fruit worm; BW = bacterial wilt; TMV = tomato mosaic virus; Cr = cracking; and FR = fruit rot.

During the 1987 wet season trial, four new lines were added to the GYT set of entries. Lines CL 1131-0-0-43-4-12 and CL 1131-0-0-43-8-1 significantly outyielded the check, Marikit, on 22 June and 1 July plantings, respectively.

The important horticultural characteristics of each entry are presented in Table 5. Flowering was from 14 to 20 days while maturity was from 50 to 63 days from transplanting. CL 5915-369 (G) D4-1 had the highest fruit set rate of 4.3. The biggest fruits were produced by CL 5915-206 (G) D4-1 (43.5 g). Fruit worms, bacterial wilt and cracking affected all the AVRDC lines at varying degrees.

Regional Yield Trial of Tomato

Summary

The regional yield trial was conducted in 11 stations throughout the country. AVR-3 (CL 143-0-10-3) slightly outyielded the check, Improved Pope, by 0.31% during the 1985-86 dry season (NTC Annual Report, 1986). AVRDC line CL 1344-48 outyielded the check, Improved Pope, by 19.86%.

Line CL 2784-1-1-4, an open-pollinated processing tomato, was approved by the Philippine Seedboard in May 1987. It was locally named as "Mapula".

Introduction

The regional yield trial was conducted in 11 cooperating stations throughout the country. The study aimed to identify the most promising tomato varieties that will be adapted to different microenvironmental patterns of the region. Results from the four-season trials become the basis for release of the outstanding varieties for commercial production by the Philippine Seedboard.

One AVRDC fresh market tomato was among the entries evaluated during the crop year 1985-86 dry season and three during the 1986 wet season. The data for crop year 1986-87 dry season and 1987 wet season for both fresh market and processing tomatoes were not yet complete as of this writing.

Table 5. Some horticultural characters of AVRDC lines included in the GYT, 1987 wet season.

Entry	Days to Flowering	Days to Maturity	Fruit set rating[z]	Fruit size (g)	Pest, disease and physiological disorder rating[y] FW	BW	TMV	SS	Cr
CL 1131-0-C-7-2-C	18	61	3.7	25.4	2.7	1.3	1.7	2.0	2.0
CL 1131-0-43-4-12	15	52	4.0	24.8	1.0	1.3	1.0	2.0	4.3
CL 1131-0-43-8-1	14	50	4.0	19.8	1.3	2.0	1.3	1.3	4.3
CL 5915-197 (G) D4-1	16	60	3.7	25.7	1.3	1.7	3.0	1.7	4.3
CL 5915-223 (G) D4-2	15	52	4.0	22.7	1.3	1.7	2.7	2.7	3.7
CL 5915-153 (G) D4-2	17	63	3.0	35.2	1.7	1.3	1.7	1.3	4.0
CL 5915-217 (G) D4-1	15	53	3.7	23.0	1.0	1.7	2.0	1.7	3.3
CL 5915-362 (G) D4-1	16	61	3.7	30.3	1.7	2.7	2.0	2.7	2.3
CL 5915-222 (G) D4-0	17	56	3.7	22.3	1.7	1.0	2.7	2.0	3.3
CL 5915-369 (G) D4-1	18	57	4.3	32.0	2.3	1.0	2.0	1.7	2.7
CL 5915-455 (G) D4-1	17	61	3.7	26.1	1.0	2.3	3.0	1.7	2.7
CL 5915-206 (G) D4-1	20	63	4.0	43.5*	1.3	1.3	1.7	2.7	2.0
CL 5915-229 D6-1-4	19	54	3.3	37.2	1.3	3.3	2.3	1.3	1.0
CL 5915-153 D6-3-3	16	63	3.3	36.6	2.0	1.0	2.3	2.3	2.7
CL 5915-222 D6-0-5	16	61	3.3	36.7	1.3	2.3	3.0	3.7	2.0
Marikit (ck)	16	61	3.0	25.0	2.0	2.0	1.3	4.0	1.0
Grand Mean	16.6	57.9	3.6	29.1	1.6	1.7	2.1	2.2	2.9
LSD .05	1.8	7.1	ns	14.07	ns	0.91	1.3	1.49	1.81
CV (%)	6.6	7.4	12.42	29.0	48.0	32.2	30.9	40.6	32.7

[z]Fruit worm rating

Rating	Average no. of fruit/cluster
1	0-1
2	1.1-2.4
3	2.5-3.4
4	3.5-4.4
5	4.5 and above

[y]Pest, disease & disorder ratings

Rating	% infection/infestation
1	1-5
2	6-24
3	25-49
4	50-74
5	75-100

Materials and Methods

The standard procedure prescribed by the NCT for vegetables was used by all cooperating stations. The test entries were evaluated against standard checks in 6-m^2 subplots, distributed in RCBD and replicated four times.

Results and Discussion

The mean yield and important horticultural characteristics of fresh market tomatoes evaluated during the 1985-86 dry season in 11 testing stations are shown in Table 6. AVR-3 (CL 143-0-10-3) slightly outyielded the check, Improved Pope, by 0.37%. Maturity of the fruits varied from 70 to 71 days. All entries had vigorous growth. The visual quality rating was highest in UPL-Tm6.

The results of the 1986 wet season RYT are presented in Table 7. Of the three AVRDC test lines, only CL 1344-48 outyielded the check, Improved Pope, by 19.86%. Maturity ranged from 58 to 62 days. The plants showed vigorous growth and the fruits had very good vigor rating.

Germplasm Collection and Maintenance of Sweet Potato

Summary

A total of 110 sweet potato accessions from local and foreign sources, mostly from AVRDC, are maintained at the station. The collection serves as source of research materials for POP and other research organizations.

Table 6. Mean yield and other horticultural characters of fresh market tomatoes under the RYT, 1985-86 dry season.[z]

Entry	Yield (t/ha)	% inc. over check	Maturity (day)	Vigor rating[y]	Firmness	VQR[x]	Fruit Dia. Equi. (cm)	Fruit Dia. Polar (cm)
Improved Pope (check)	40.4	–	71.3	1.8	2.4	8.4	3.9	4.8
UPL Tm-6 (check)	40.3	–	69.7	1.8	2.7	8.5	3.2	3.8
AVR-3 (CL 143-0-10-3)	40.6	0.37	70.7	1.8	2.8	7.8	4.2	4.1
C-132	39.2	–	70.9	2.0	4.0	8.2	4.5	3.8

Source: 1986 NCT Annual Report. [z]From 11 testing stations. [y]Vigor rating legend: 1 = most vigorous; 2 = vigorous; 3 = moderately vigorous; 4 = weak; and 5 = very weak. [x]Visual quality rating (VQR): 9 = excellent (field fresh); 8 = very good (defects hardly noticeable); 7 & 6 = good (defects moderate); 5 & 4 = fair (defects moderate); 3 = poor (defects moderate); 2 = no longer edible; and 1 = nonedible under visual condition.

Table 7. Mean yield and horticultural characteristics of fresh market tomatoes evaluated under the RYT, 1986 wet season.[z]

Entry	Potential yield (t/ha)	% inc over check	Maturity (day)	Vigor	Firmness	VQR[y]	Fruit Dia. Equi. (cm)	Fruit Dia. Polar (cm)
Improved Pope (check)	10.3	–	62	1.50	2.7	8.3	3.5	4.5
UPL-Tm6	16.1	56.01	58	2.00	2.7	7.8	3.3	3.6
CL 1344-48	12.4	19.86	59	2.00	3.7	8.3	4.2	3.8
C-132	12.4	19.86	58	2.00	3.7	8.6	4.1	3.9
CL 1344-78	10.6	2.42	62	2.00	3.0	8.3	4.6	4.1
CL 1094-84	10.6	3.00	60	1.75	3.0	8.3	4.3	3.8

[z]From five testing stations. [y]Vigor rating legend: 1 = most vigorous; 2 = vigorous; 3 = moderately vigorous; 4 = weak; and 5 = very weak.

Introduction

New sweet potato hybrids and accessions selected at AVRDC for high tuber yields, resistance to major pests and diseases and high dry matter contents are periodically received at POP. These materials, together with those collected from other sources, are maintained and evaluated at the station. Promising lines are further evaluated in replicated trials and finally in the NCT from which new varieties for national or regional recommendations are selected.

Materials and Methods

New sweet potato accessions received from AVRDC or collected from other sources are planted and maintained in 12-inch earthen pots kept in the screenhouse for quarantine purposes and multiplication. The materials are later planted in 6-m^2 nursery plots in the field for initial observation of the morphological and agronomical characters and for propagation of planting materials. The promising entries are then evaluated in replicated yield trials and given to other researchers.

Results and Discussion

Aside from the entries evaluated at POP, a total of 4,710 cuttings of different sweet potato accessions were given free upon request to researchers from different institutions.

Preliminary Yield Trial of Sweet Potato

Summary

Twenty-five AVRDC sweet potato lines were evaluated under the PYT for the second year against the check, BNAS, to determine their marketable tuber yield and other agronomic characters. Two

sets of planting were made in 1986; the first set during the wet season (planted 6 June 1986) and the second set during the dry season (12 December 1986).

In the wet season trial, 10 test entries with marketable tuber yield ranging from 21.9 to 34.0 t/ha significantly outyielded the check, BNAS (9.8 t/ha). The three highest yielding entries CN 1219-1, CN 942-47 and CN 1232-9 also produced high yields during the 1985-86 dry season trial.

The second set planted during the dry season did not produce credible data due to severe drought; hence, it is not included in this report.

Introduction

Promising lines initially selected from the germplasm collection study were evaluated in replicated trials under the PYT. The study aimed to evaluate the marketable tuber yield potential, reaction to scab infection and dry matter contents of new sweet potato lines. The 22 test entries in the present study had been evaluated for the second year under PYT.

Materials and Methods

Each entry, evaluated in the wet and dry seasons, was planted in double-row 6-m^2 subplots distributed in RCBD and replicated three times. The planting distance was 75 cm between rows and 25 cm between hills with one cutting per hill. Fertilizer was applied at planting at 90 kg each of N, P_2O_5 and K_2O/ha. The AVRDC cultural management practices for sweet potato trial was used.

Results and Discussion

During the wet season, 10 entries showed significantly higher marketable tuber yield which ranged from 21.9 to 34.0 t/ha compared with the check, BNAS, which had only 9.8 t/ha. The three high-yielding entries were: CN 1219-1, CN 942-47 and CN 1232-9 with yields of 34.0, 32.8 and 31.5 t/ha, respectively. These also showed an impressive and consistent performance in yield during the 1985-86 dry season. In terms of root diameter, no significant differences were observed among the entries including the check. The root length of test entry I-42-3 and CN 1219-1 with 16.06 cm and 15.62 cm, respectively, had significantly higher values compared to the other test entries. However, their difference was not significant.

The results during the dry season were unreliable due to severe drought that prevailed during the season, hence were not included in this report.

General Yield Trial of Sweet Potato

Summary

The promising lines from the preliminary yield trial were evaluated in the general yield trial to confirm further their marketable root yield, reaction to major pests and diseases and other agronomic characters.

Sixteen promising lines were evaluated against the check, BPI-Sp2, during the 1986-87 wet and dry seasons. Results of the wet season trial showed that none of the test entries outyielded the check, BPI-Sp2, which yielded 20.1 t/ha. However, six lines, LS 27-12, CI 5[illegible]-3, CI 949-1, CI 916-46, CI 951-6 and CI 916-66, with yields ranging from 10.6 to 18.8 t/ha may be considered promising. In the dry season trial, entries CI 946-30, CI 913-6 and CI 946-25 with yields of 9.98, 10.56 and 10.88 t/ha, respectively, had significantly outyielded the check, BPI-Sp2 (6.48 t/ha). The grand mean yield for the 17 entries was 6.11 t/ha.

Introduction

The general yield trial (GYT) was undertaken to further assess the root yields, reaction to major diseases and other desirable characters of promising lines selected from the PYT.

Sixteen selected lines from PYT were evaluated under the GYT against the check, BPI-Sp2, during the wet and dry seasons of 1986-87. The same set of entries will be further evaluated for another two seasons before the most promising lines are identified for inclusion to the regional yield trial (RYT).

Materials and Methods

The trial during the wet season was conducted on 18 July 1986 and the dry season on 17 February 1987. In both plantings, each entry was set in double-row 6-m^2 subplots distributed in RCBD with four replications. The AVRDC cultural management procedures for sweet potato evaluation trial were used.

Results and Discussion

In the wet season trial, no test entry outyielded the check, BPI-Sy2, which produced a mean marketable tuber yield of 20.1 t/ha (Table 8). However, six lines, LS 27-12, CI 949-1, CI 916-46, CI 951-6, CI 916-66 and CI 551-3, with yields ranging from 10.6 to 18.8 t/ha may be considered promising. The poor performance of the entries may be due to the adverse weather conditions during the crop season. Total precipitation was 1,708.5 mm (with six typhoons), which caused the entries to over-vegetate and produce a high mean (2.2 t/ha) of nonmarketable root yield.

During the dry season, entries CI 946-30 (10.0 t/ha), CI 913-6 (10.6 t/ha) and CI 946-25 (10.9 t/ha) significantly outyielded the check, BPI-Sy2 (6.5 t/ha). The grand mean yield for the 17 entries was 6.1 t/ha. The overall poor performance of the entries may be due to soil moisture stress, especially during the early vegetative stage of the crop. Total rainfall during the crop season was 373.3 mm, of which 286.9 mm occurred during the last two months before the crop harvest. There were also significant differences in nonmarketable tuber yields, with CI 950-27 (1.3 t/ha), CI 949-1 (1.5 t/ha) and CI 913-6 (1.0 t/ha) producing the most.

Table 8. Root yield and some yield components of AVRDC sweet potato lines under general yield trial, 1986-87 wet and dry seasons.

Entry	Wt. of marketable root yield (t/ha)		Wt. of nonmarketable root yield (t/ha)		Root length (cm)		Root diameter (cm)	
	WS[z]	DS[y]	WS	DS	WS	DS	WS	DS
LS 27-12	18.8	2.4	1.7	0.3	12.2	8.4	7.1	5.5
CI 551-3	12.9	4.3	3.5	0.6	11.9	10.4	5.6	4.9
CI 949-1	12.9	5.7	3.3	1.5*	11.3	10.4	6.0	3.9
CI 916-46	12.8	6.5	2.1	0.6	12.3	12.2	5.6	5.0
CI 951-6	12.3	2.8	2.0	1.0	11.7	11.7	4.9	4.4
CI 916-66	10.6	8.7	3.3	0.5	13.5	8.9	4.4	5.2
CI 916-70	9.7	3.2	1.8	0.4	12.0	11.0	5.4	5.9
CI 946-25	9.3	10.9	3.7	0.8	12.5	12.0	4.5	5.6
Kinastanyas	9.0	6.3	2.1	0.4	10.7	9.1	5.5	4.7
CI 950-27	8.4	7.5	3.4	1.3	11.1	9.7	4.5	4.5
CI 913-6	7.2	10.6	2.1	1.0	11.2	12.0	4.1	4.8
CI 946-30	5.7	10.0	2.5	0.7	10.0	9.5	4.2	5.2
CI 911-1	3.9	6.6	1.4	0.2	10.1	9.0	3.8	5.2
CI 916-48	3.5	4.2	0.7	0.4	10.8	10.1	4.0	5.8
CI 916-45	1.8	7.3	0.9	0.3	10.1	9.2	3.4	5.1
CI 926-3	1.1	0.5	0.4	0.7	10.2	9.6	4.7	4.5
BPI Sp-2 (Ck)	20.1	6.5	3.1	0.4	12.3	10.2	6.1	5.2
Grand Mean	9.4	6.1	2.2	0.7	11.4	10.2	5.0	5.0
LSD (.05)	6.0	3.47	1.2	0.61	1.87	2.29	0.84	0.68
LSD (.01)	8.0	4.63	1.7	0.82	ns	ns	1.13	0.91
CV (%)	45.2	39.98	39.0	63.09	11.57	15.78	10.29	6.55

[z]Planted on 18 July 1986 and harvested on 17 February 1987. [y]Planted on 22 January 1987 and harvested on 3 July 1987. *Statistically significant at 5% level over BPI Sp-2 (check).

Weevil Resistance in Sweet Potato

This study was temporarily suspended in 1987 due to lack of new lines to be evaluated for reactions to sweetpotato weevil, *Cylas formicarius formicarius* F.

So far, all the lines evaluated against the weevil were found moderately susceptible to very susceptible to visual damage.

Preliminary Yield Trial of Soybean

Summary

Twenty-two promising lines from AVRDC and other sources were evaluated in the preliminary yield trial during the dry and wet seasons of 1986-87.

During the dry season, 12 entries outyielded the highest yielding check, BPI-Sy4, of which four lines showed significant differences.

During the wet season, 14 test entries with mean bean yields ranging from 2.14 to 2.87 t/ha outperformed the check variety, BPI-Sy4, which yielded 2.11 t/ha. However, the yield differences were not statistically significant.

Introduction

The preliminary yield trial was the first stage in a series of replicated trials conducted during the dry and wet seasons. The trial aimed to identify lines with high bean yield potentials, resistance to common pests and diseases and other desirable agronomic attributes. Promising selections from the AVRDC advanced soybean breeding lines were evaluated in the PYT.

Materials and Methods

Twenty-two test entries were evaluated against standard checks, BPI-Sy4 and UPL-Sy4. Plantings were made on 16 December 1986 for the dry season and on 6 June 1987 for the wet season trial. In each trial, the entries were planted in 5-m^2 plots, distributed in RCBD and replicated three times. Complete fertilizer of 30-30-30 kg/N, P_2O_5 and K_2O/ha was applied at planting. AVRDC cultural management procedures were followed in conducting the trial.

Results and Discussion

During the dry season, 12 out of the 22 entries evaluated outyielded the highest yielding check, BPI-Sy4. However, only four test entries gave significantly higher yield than the check. No disease was observed, but all the entries were severely infested with mites at R_6.

The wet season trial showed 14 test entries with high mean bean yields ranging from 2.14 t/ha to 2.87 t/ha. These entries outyielded the check, BPI-Sy4, which yielded 2.11 t/ha. However, the yield differences were not significant. Line G 90089 gave the highest seed size of 21.6 g/100 seeds. All the entries were severely infested with mites at R_5. The entries were rated resistant to susceptible to soybean mosaic virus (SMV).

General Yield Trial of Soybean

Summary

Low yield was obtained in the dry season trial due to drought and severe infestation of mites at R_2. Only GC 50095-7-0-9 gave a highly significant difference in yield over the highest yielding check.

Of the 13 entries evaluated against the two standard check varieties during the wet season, six outyielded the higher yielding check, UPL-Sy2, with a yield of 2.63 t/ha, but the difference was not statistically significant.

So far, entry GC 50095-7-0-9 gave consistently high bean yields during the dry and wet season trials.

Introduction

Promising lines selected from the PYT were elevated to the GYT to further test their yield potentials, reaction to major pests and diseases and identify other desirable agronomic characters. The selections from the GYT are finally evaluated in the RYT for regional evaluation and possible regional and/or national recommendations.

Materials and Methods

Fifteen entries were planted in 10-m^2 plots in RCBD with four replications during the dry (planted 10 February 1987) and wet (planted 5 June 1987) seasons. The plants were fertilized at planting with 30 kg each of N, P_2O_5 and K_2O/ha. All other cultural practices and data collected were based on AVRDC procedures.

Results and Discussion

Of the 13 test entries evaluated against the two standard checks, only GC 50095-7-0-9, which yielded 0.88 t/ha, significantly outyielded the highest yielding check, UPL-Sy2 (0.55 t/ha). However, a low mean yield of 500 kg/ha was obtained during the dry season due to severe drought and severe infestation of mites at R_2 growth stage. No disease infection was noted during the trial.

During the wet season trial, six of the 13 test entries evaluated outyielded the higher yielding check, UPL-Sy2, with a yield of 2.63 t/ha. However, the yield difference was not statistically significant. The grand mean yield for all entries was 2.46 t/ha. Significant differences were also obtained in other yield components measured. All entries were rated resistant to moderately susceptible to purple stain and soybean mosaic virus.

So far, entry GC 50095-7-0-9 gave consistent high bean yield during the dry and wet season trials.

Regional Yield Trial of Soybean

Summary

Promising soybean lines from the general yield trial (GYT) were evaluated in the regional yield trial (RYT) against two standard checks. The entries were evaluated during the dry and wet seasons in 12-m^2 four-row plots distributed in RCBD with four replications. The procedure described in the Upland Crops National Cooperative Trial (UCNCT) of the Philippine Seedboard was followed during the test.

After a six-crop season trial, EGSY-19 (AGS 19) was recommended for technology adaptation (TA) and technology verification (TV) testing in different regions. The results from the two season-TA/TV testing are the basis for future regional recommendations of varieties.

Introduction

The regional yield trial for soybean under upland monoculture condition was conducted in cooperation with the Institute of Plant Breeding (IPB) and other institutions involved in soybean varietal improvement. Coordinated by the Technical Working Group for field legumes of the Philippine Seedboard, promising entries from various national breeding programs were assembled and evaluated for four seasons in 8 to 12 cooperating stations using a common standard procedure. The study was designed to identify high-yielding varieties with desirable agronomic attributes adapted to different regions of the country. To regionalize varietal recommendation especially for soybeans, promising

entries in the RYT were further evaluated for two seasons in the TA before releasing a variety in the region.

Materials and Methods

The promising lines selected from the PYT and GYT were submitted to the National Legume Technical Committee of the Philippine Seedboard for inclusion in the RYT. Accepted entries were evaluated against two standard check varieties in 12-m^2 four-row plots distributed in RCBD with four replications. The rows, 5 m long, were spaced 60 cm apart and about 15 plants/linear meter were maintained. The standard procedure for evaluating soybean described in the Upland Crop National Cooperative Trial (UCNCT) of the Philippine Seedboard was followed by all cooperating stations during the test.

Results and Discussion

Of the eight test entries evaluated during the dry season, only IPB Sy 138-28 and TGX 239-17E significantly outyielded the check, BPI-Sy4 (Table 9). Significant differences on 100-seed weight, days to flowering and maturity, and plant height among entries were also noted. No soybean rust and bacterial pustule were observed; but all entries were severely infested with mites at R_5 stage due to severe drought.

During the wet season, five entries were tested against two standard checks. Only LG Sy-01-24 significantly outyielded the highest yielding check, BPI-Sy4. The second highest entry, LG Sy-01-13, did not differ significantly over the check. All the entries were rated resistant to moderately resistant to purple seed stain and soybean mosaic virus.

Based on its outstanding performances in six season trials in the RYT, EGSY-19 (AGS 19) was recommended in 1987 for inclusion in the TA trial in Regions 2, 4, 6 and 12.

Three AVRDC lines, AGS 129, AGS 208 and AGS 133, selected from the GYT will be recommended for inclusion in the RYT during the 1988 pre-Seedboard meeting of the Field Legume Working Group.

Preliminary Yield Trial of Mungbean

Summary

Eighty-nine mungbean lines were evaluated in three sets of PYTs. In Set I, 16 entries had completed the third season of PYT evaluation. For this year's trial, no test lines outyielded the check BPI-Mg5 in both dry and wet seasons. Of the 23 entries evaluated in Set II, seven entries had yields ranging from 1,485 to 1,644 kg/ha which significantly outyielded the check, BPI-Mg5, with 1,205 kg/ha. In Set III, out of 50 entries, only line VC-4060-2B-2-B-1-B with mean yield of 1,447 kg/ha significantly outyielded the check, BPI-Mg5, which produced 1,104 kg/ha. From the 89 entries evaluated, eight showed high resistance to Cercospora leaf spot.

Introduction

Selections from the early breeding line were evaluated under the PYT for three to four seasons. The PYT was conducted to identify mungbean lines with high bean yield potential, desirable agronomic characteristics and disease resistance particularly Cercospora leaf spot and powdery mildew. The lines selected from this trial were elevated to the GYT.

Materials and Methods

For crop year 1986-87, a total of 89 entries were entered in the PYT. The lines were evaluated in three sets of trials. Sixteen entries in Set I were evaluated during the dry and wet seasons, while 23 entries in Set II and 50 entries in Set III were evaluated during the wet season only. In all th

Table 9. Mean yields and other agronomical characters of soybean lines under regional yield trial, dry and wet seasons, 1986-87.[z]

Entry	Bean yield (t/ha)		100-seed wt (g)		Days to flowering		Days to maturity		Plant ht. at maturity (cm)		Pest and disease rating[y]		
	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS[v]	WS(PS)[w]	WS[v]
IPB Sy 138-28	1.4**	1.7	13.9	18.0	33	35	80	104	44	139	S	2	2.75
TGX 239-17E	1.5**	1.6	11.0	13.5	40	46	85	110	52	90	S	2	1.5
IPB Sy 144-7[illegible]	1.2	-	14.0		32	-	81	-	42	-	S	-	-
TGX 780-2F	1.2	1.9	13.3	15.9	39	46	84	110	38	86	S	2.2	2.5
IPB Sy 152-2[illegible]3	1.2	-	12.2		30	-	79	-	40	-	S	-	-
TGX 888-48C	1.1	2.0	7.3	11.9	39	47	80	105	44	116	S	2	2.0
IPB Sy 154-20	1.2	-	12.6		33	-	80	-	44	-	S	-	-
BPI-Sy4 (ck)	1.1	2.4	10.9	16.5	32	-	75	97	41	117	S	2	-
UPL-Sy2 (ck)	1.0	-	16.0	-	32	-	77	-	37	-	S	-	-
EGSY-19	1.2	-	13.3	-	29	-	75	-	33	-	S	-	-
LG Sy 01-13	-	2.6	-	17.1	-	26	-	98	-	101		3	3.5
LG Sy 01-24	-	3.1**	-	17.4	-	32	-	103		111		3	2.25
Grand mean	1.2	2.2	12.4	15.7	34	38	80	104	41.5	108.55			
LSD 5%	0.18	0.46	1.46	1.5	0.59	0.30	1.25	0.82	5.20	13.92			
LSD 1%	0.25	0.63	1.97	2.05	0.80	0.50	1.68	1.12	7.01	19.07			
CV (%)	10.45	14.15	8.09	6.42	1.20	0.64	1.07	0.53	8.62	8.63			

[z]Planted 16 December 1986 (DS) and 5 June 1987 (WS) **Highly significant over the check BPI Sy4 [y]Rating of 1 to 5 with 1 = highly resistant and 5 = highly susceptible [v]Mites [w]Purple seed stain [x]Soybean mosaic virus (SMV)

sets, each entry was sown in four-row, 5-m long plots distributed in RCBD with three replications. The rows were spaced 50 cm apart. The AVRDC cultural management procedures for mungbean evaluation trial were used.

Results and Discussions

No test entry in Set I outyielded the check BPI-Mg5 in both season trials. BPI-Mg5 produced mean bean yields of 1,141 and 1,331 kg/ha for the dry and wet seasons, respectively. Lines VC 3086-B-1-B-1-B (1,124.0 kg/ha) and VC 3116-B-5-B (1,114 kg/ha) had comparative yields as the check during the dry season and only VC 3116-B-5-B (1,204 kg/ha) during the wet season. Line VC 3536-B-B-4 exhibited high resistance to both Cercospora leaf spot and powdery mildew. The disease infection, however, occurred during the late growth stage of the crop.

In Set II, the bean yields of the 23 entries evaluated during the wet season ranged from 847 kg/ha for VC 3751-3-B-1-1-B to 1,644 kg/ha for VC 3890-B-2-1-1-B. The grand mean yield was 1,318 kg/ha. Seven entries with mean yields ranging from 1,485 to 1,644 kg/ha showed significant differences over the high-yielding check BPI-Mg5 which produced 1,205 kg/ha. Slight infection with Cercospora leaf spot and virus diseases was observed from flowering to maturity.

The 50 entries in Set III were evaluated for the first season trial under the PYT. The yield of the top 10 entries ranged from 1,309 kg/ha for VC 4113-2B-4-B-3-B to 1,447 kg/ha for VC 4060-2B-2-B-1-B. The grand mean yield for the 50 entries was 1,138 kg/ha. Only VC 4060-2B-2-B-1-B significantly outyielded the check, BPI-Mg5, which produced 1,104 kg/ha.

There were significant differences observed on other agronomic characteristics measured. Infection with Cercospora leaf spot and virus diseases were noted during the wet season.

General Yield Trial of Mungbean

Summary

Three sets of entries were evaluated in the general yield trial (GYT) in 1986-87. Set I comprised of 18 test entries, five of which outyielded the highest yielding check, BPI-Mg5 (1,616 kg/ha), although their mean differences were not statistically significant. In Set II, only VC 3821-B-1-1-1-B which yielded 1,708 kg/ha outyielded the check, BPI-Mg5, with a yield of 1,629 kg/ha. Of the 11 entries in Set III, six promising lines with mean yields ranging from 1,286 to 1,496 kg/ha outyielded the check, BPI-Mg5 with a yield of 1,231.0 kg/ha. These lines were also rated moderately resistant to Cercospora leaf spot and mungbean virus.

Introduction

Selected materials from the preliminary yield trial (PYT) were elevated to the GYT to test their adaptability under local agroclimatic conditions and their reactions to common pests and diseases. The results obtained from this trial served as the basis for selecting entries to be elevated to the regional yield trial (RYT) of the National Cooperative Test.

Materials and Methods

Three sets of promising lines were evaluated during the crop season of 1986-87. Set I with 18 entries was planted on 6 July 1987 while Sets II and III were planted on 2 June 1987 for the first trial under the GYT. The entries were planted in four-row subplots distributed in RCBD and replicated three times. The AVRDC cultural management practices for mungbean evaluation trial were used.

Results and Discussion

The grand mean yield of 18 entries in Set I during the wet season was 1,364 kg/ha. Five test entries outyielded the highest yielding check, BPI- Mg5, which produced an average yield of 1,629 kg/ha.

Although high significant differences were obtained between entries, the top five entries did not significantly outyield the check variety. The promising breeding lines were VC 3121-2B-1-1-B which yielded 1,898 kg/ha, closely followed by VC 3102-B-2-2B which produced 1,797 kg/ha. Five breeding lines were rated highly resistant to Cercospora leaf spot while VC 2917-B-1-B-4-2B was tolerant to mungbean virus.

The grand mean yield of the 16 GYT entries in Set II was 1,449 kg/ha during the wet season. The highest yield of 1,708 kg/ha was produced by VC 3821-B-1-1-1-B which outyielded the highest yielding check, BPI-Mg5, which yielded 1,629 kg/ha. The differences in mean yield among the 16 entries, however, were not statistically significant. The three test entries identified highly resistant to Cercospora leaf spot were VC 3849-2B-1-1-B, VC 3751-1-B-2-2-B and VC 3890-2B-1-1-B. Virus was prevalent during the seedling stage.

In Set III among the 10 elite lines previously selected at AVRDC, six lines with mean yields ranging from 1,286 to 1,496 kg/ha outyielded the highest yielding check, BPI-Mg5, with a yield of 1,231 kg/ha (Table 10). The difference, however, was not statistically significant. The grand mean yield of the 11 entries was 1,273 kg/ha. Line VC 3907A ranked highest (1,496 kg/ha) followed by VC 3738B (1,411 kg/ha), then VC 3857A (1,380 kg/ha) and VC 3541A (1,314 kg/ha). These breeding lines were also rated moderately resistant to both Cercospora leaf spot and mungbean virus.

Table 10. Comparative growth and other agronomic characters of the six highest yielding entries relative to the check BPI-Mg5, wet season 1987.[z]

Entry	Yield (kg/ha)	100-seed weight	Days to Flowering	Days to Maturity	Plant ht.(cm)	No. of pods/plant	No. of seeds/pod	CLS rating[y]	Virus rating[x]
VC 3907A	1496	6.0	33	52	64.4	12.7	11.8	2.0	2.0
VC 3738B	1411	5.4	33	52	59.5	10.8	11.3	2.0	1.0
VC 3857A	1380	5.5	33	53	59.2	10.4	12.1	1.5	1.5
VC 3541A	1314	6.0	33	52	61.9	10.4	11.3	2.0	2.0
VC 3890A	1304	5.5	33	51	62.8	11.2	12.0	2.0	1.5
VC 3678A	1286	4.6	–	51	58.2	12.5	11.7	3.0	1.5
BPI-Mg5 (ck)	1231	5.0	–	52	66.9	12.1	11.8	1.5	2.0
Grand mean (11 entries)	1237.4	5.35	32.50	51.03	62.06	11.27	11.43	2.18	1.64
LSD (.05)	ns	0.07	ns	1.38	6.92	0.86	ns	0.70	ns
LSD (.01)	ns	0.09	ns	ns	9.85	1.22	ns	1.00	ns
CV (%)	8.79	0.58	1.71	1.19	5.00	3.43	3.23	14.50	26.00

[z]Planted 2 June 1987. [y]Scale of 1 to 5 with 1 = highly resistant and 5 = highly susceptible. [x]Scale of 1 to 3 with 1 = resistant and 3 = susceptible.

Regional Yield Trial of Mungbean

Summary

The Regional Yield Trial (RYT) is a cooperative endeavor among research institutions and agencies involved in varietal improvement. For crop year 1986-87, line EGM 1973 (VC 1973) performed exceptionally well in all RYT sites, with yields of 1,164 and 1,177 kg/ha in both dry and wet seasons, respectively. It ranked first among the 12 entries in five locations during the wet season and in two locations during the dry season. Aside from EGM 1973, the four other AVRDC entries in the RYT were all rated moderately to highly resistant to Cercospora leaf spot, powdery mildew, rust and virus diseases. They also exhibited high tolerance to lodging.

Introduction

The RYT for mungbean under upland monoculture condition was undertaken in cooperation with the Institute of Plant Breeding and other organizations involved in mungbean varietal improvement. It was conducted in 8 to 12 sites in the country to evaluate the performance of the promising mungbean lines in the different regions of the Philippines. The results obtained from the RYT served as the basis for recommending approval by the Philippine Seedboard of new varietal releases for commercial production.

Materials and Methods

Entries in the RYT were evaluated for four seasons in the different cooperating stations. The performances of the entries were reviewed by the Technical Committee each year. Entries that consistently surpassed the yield or other important characteristics of the standard checks were submitted to the Seedboard for approval, while those inferior than the checks were dropped from the trial.

For crop year 1986-87, 12 entries including the two checks were evaluated during the wet and dry seasons. Each entry was planted in 10-m^2 four-row plots distributed in RCBD with four replications. The crop management and data collection were based on the guidelines of the Upland Crops National Cooperative Trial (UCNCT) of the Philippine Seedboard.

Results and Discussion

Among the five AVRDC entries, EGM 1973 (VC 1973) performed exceptionally well in all RYT sites with mean bean yields of 1,177 and 1,564 kg/ha during the dry and wet seasons, respectively. It ranked first among the 12 entries in five locations during the wet season and in two locations during the dry season. The other promising lines were EGM 2768 with an average yield of 1,282 kg/ha in the wet season and 931 kg/ha in dry season, and EGM 1131 with an average yield of 1,235 kg/ha during the wet season and 977 kg/ha in the dry season (Table 11).

All the five AVRDC entries were rated moderately to highly resistant to Cercospora leaf spot, powdery mildew, rust and virus diseases. They were also observed to be tolerant to lodging.

International Mungbean Nursery

Summary

Of the 20 IMN mungbean entries evaluated during the wet season, lines VC 2754A with an average yield of 1,453 kg/ha and VC 2984 which produced 1,365 kg/ha outyielded the check, V 3476 or Pag-asa 1 (1,317 kg/ha). The difference, however, was not significant. The grand mean yield for the 20 entries was 1,120.21 kg/ha. Cercospora leaf spot infection for all entries was moderate with a mean rating of 2.97%.

Introduction

The IMN is an International Cooperative Trial coordinated by AVRDC. The entries are elite mungbean accessions collected from different countries of origin and sent to cooperating stations for evaluation. The study was conducted to provide information on: (a) the range of adaptation of mungbean crop; (b) specific adaptation of individual cultivars; and (c) the characteristics of the plant influencing adaptation. This also serves as a means of disseminating superior cultivars to mungbean researchers.

Materials and Methods

Twenty elite accessions from AVRDC were planted on 17 July 1987 for the wet season trial. Each entry was sown in four-row subplots distributed in RCBD and replicated three times. Row length was 5 m and distance between rows was 0.5 m. The AVRDC standard cultural management procedures were used.

Results and Discussion

The results of the top 10 entries together with the check, V 3476 (Pag- asa 1), are presented in Table 12. The yield ranged from 1,124 kg/ha for VC 2812A to 1,453 kg/ha for VC 2754A, with a grand mean yield of 1,120.21 kg/ha. Two lines, VC 2754A and VC 2984, outyielded the check V 3476 (Pag-asa 1), although the differences were not statistically significant.

Significant differences were observed for the other characters measured except for Cercospora leaf spot rating.

Table 11. Comparative growth and other agronomic characters of the promising AVRDC mungbean lines relative to two local checks evaluated in 1986-87.

Entry	Yield (kg/ha)		100-seed wt. (g)		Days to maturity		No. of pods/ plant		CLS[x] rating		PM[w] rating		Rust rating		Virus rating	lodging	
	WS[z]	DS[y]	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	WS	DS
EGM 1973	1564	1177	6.5	6.5	62	61	17	12	2.0	2.2	2.27	3.1	1.6	1.4	1.5	1.2	1.5
EGM 2768	1282	931	6.1	6.3	63	60	16	11	2.0	2.1	1.00	1.8	1.9	1.8	1.9	1.3	1.2
EGM 1131	1235	977	5.0	5.5	63	60	13	13	1.6	2.3	1.67	1.7	1.6	1.6	1.4	1.1	1.2
EGM 2307	1198	859	5.1	5.4	64	60	17	11	1.8	2.4	1.43	1.3	1.8	1.7	1.4	1.5	1.3
EGM 2755	926	826	6.4	6.6	62	60	13	11	1.9	2.2	–	2.8	2.2	1.8	1.5	1.3	1.4
Pag-asa 5 (ck)	1260	923	5.8	6.0	62	60	16	11	1.8	2.0	1.33	2.3	1.7	1.8	1.6	1.[illegible]	1.1
BPI-Mg5 (ck)	1241	939	5.8	6.0	63	60	16	12	2.0	2.0	1.33	1.5	1.7	1.5	1.6	1.3	1.3
Mean	1255.04	925.88	5.58	5.99	62.85	59.97	16.34	11.46	1.58	2.17	1.35	2.05	1.70	1.61	1.5	1.30	1.22

[z]Average of nine locations. [y]Average of six locations. [x]CLS = Cercospora leaf spot. [w]PM = Powdery mildew.

Table 12. Comparative growth and other agronomic characters of the 10 highest yielding entries relative to the check Pag-asa 1 (V 3476) during the wet season 1987.[z]

Entry	Yield (kg/ha)	100-seed weight	Days to Flowering	Days to Maturity	Plant ht.(cm)	No. of pods/plant	No. of seeds/pod	CLS rating[y]	Virus rating[x]
VC 2754A	1453	6.2	35	58	64	9.4	9.8	3.0	1.7
VC 2984	1365	3.7	33	58	68	10.9	11.8	3.7	2.3
VC 1973A	1305	6.1	34	58	75	8.7	11.1	3.3	2.0
VC 2764A	1241	5.3	35	58	69	8.3	12.0	2.3	2.0
VC 3178A	1222	5.6	35	58	61	9.6	11.7	2.7	2.7
VC 2750A	1206	5.2	35	59	63	9.7	11.5	3.0	1.7
VC 2768A	1206	6.1	34	58	66	8.2	11.9	2.3	2.0
VC 1628A	1167	5.5	35	58	65	8.2	11.6	3.0	2.3
V 2010	1130	5.7	35	59	64	6.4	12.7	2.7	2.3
VC 2802A	1124	5.0	34	58	62	9.5	11.7	3.7	1.7
V 3476 (ck)[w]	1317	5.1	35	58	63	9.0	11.6	2.7	1.7
Grand mean (20 entries)	1120.21	5.36	34.70	58.50	65.47	9.12	11.60	2.97	2.22
LSD (.05)	ns	0.98	1.03	1.10	8.72	2.11	0.90	ns	0.84
LSD (.01)	ns	0.11	0.38	1.48	ns	2.83	1.21	ns	ns
CV (%)	31.79	0.91	1.79	1.14	8.05	14.02	4.69	23.62	22.96

[z]Planted 17 July 1987. [y]Scale of 1 to 5 with 1 = highly resistant and 5 = highly susceptible. [x]Scale of 1 to 3 with 1 = resistant and 3 = susceptible.

AVRDC-Thailand Outreach and Regional Training Program

The AVRDC-Thailand Outreach and Regional Training Program (AVRDC-TOP) conducts extensive regional training on vegetable production and research. It undertakes field trials on AVRDC mandated crops and is responsible in bringing the national programs the AVRDC-generated technologies and improved germplasm and its training facilities to the other countries in the region.

The training phase of the regional training and outreach program is being carried out in close cooperation and participation of the National Training Center for Extension Workers of Kasetsart University. The AVRDC-TOP has established contacts and cooperation with various international agencies in Thailand and in other parts of the world to further promote its training program.

For the period covering June 1986 through December 1987, the following research projects and trials had been established at the TOP experimental field:

- Yield trial of AVRDC mandated crops, such as Chinese cabbage, sweet potato, tomato, mungbean, soybean and pepper;
- Crop protection trials;
- Cultural management trials;
- Seed multiplication and quality evaluation trials;
- Home garden programs including nutritional assessment studies;
- Disease and insect resistance screening; and
- Experimental research for the trainees and visiting scholars.

As part of its crop improvement program, several out-of-station research and on-farm trials were conducted in cooperation with government research and academic institutions and Thai farmers. These trials determined the performance and stability of AVRDC-developed varieties in different agroclimates and method of cultivation as well as the adaptation of AVRDC-developed technologies. For the period 1986 to 1987, a total of 56 on-farm research trials were conducted.

Tomato

From October 1986 through December 1987, three tomato yield evaluation trials were conducted at the TOP field in Kasetsart University Kamphaeng Saen campus. These were trials on the new breeding lines, one each for fresh market, table tomato F_1 hybrids, and processing tomato F_1 hybrids, and a trial for open-pollinated new AVRDC lines. Trials on the new F_1 hybrids were carried out during the cool season (October 1986 to February 1987), while the only trial on the open-pollinated lines was done during the rainy season (May 1987 to September 1987).

Of the 10 hybrids tested plus the local check, six yielded more than 30 t/ha (Table 1). FMTT 23 produced the highest market fruit yield at 37.7 t/ha followed by FMTT 16 at 36.38 t/ha. The lowest yielder was Chang Feng at 3.16 t/ha. Fruit size was significantly higher in the local check, Chang Feng. Four hybrids as well as the local check cracked. Since the crop was grown during the cool period of the year, flowering, fruit setting, ripening and harvesting were highly favored.

Table 1. Yield and other horticultural characteristics of 11 fresh market tomato varieties[z] evaluated at the TOP field, October 1986 - February 1987.

Variety	Growth habit[y]	Days to flowering	Fruit characteristics				Yield (t/ha)
			Color	Size (g)	Shape	Crack	
FMTT 3	SP+	26	uniform	102	round	-	20.24
FMTT 4	SP+	26	uniform	91	round	-	24.74
FMTT 13	SP+	27	uniform	101	round		17.17
FMTT 14	SP+	23	uniform	79	round	-	32.26
FMTT 16	SP+	24	uniform	65	round	-	36.38
FMTT 18	SP+	24	uniform	59	round	28.72	
FMTT 19	SP+	27	uniform	64	round	-	30.23
FMTT 21	SP+	24	uniform	57	round	-	35.30
FMTT 22	SP+	25	uniform	70	round	-	34.40
FMTT 23	SP+	23	uniform	89	round		37.74
Chang Feng (ck)	SP+	30.5	w/green shoulder	110.47	round		3.16

[z]Tomato varieties — 10 new AVRDC F_1 hybrids + local check. [y]SP+ = indeterminate.

Results of previous experiments indicated that processing tomatoes at the TOP field are best grown during the months of October to February. During this regular growing period, foliar diseases, though present are not severe. All of the 11 AVRDC F_1 hybrids tested during this season outyielded the commercially grown local check P 502 by as high as 147%, with PT 4148 as the highest yielder at 54.0 t/ha followed by PT 4030 at 51.5 t/ha. However, when compared statistically only these two hybrids significantly outyielded the local check which yielded only 23.5 t/ha. The local check had heavier fruits than these new AVRDC lines. PT 4132 had the highest soluble solid content at 5.04 °Brix. The pH or the acidity of the fruits ranged from 4.4 to 4.6. The highest yielder, PT 4148, and the average yielder PT 4027, were found to be the most or highly susceptible to bacterial wilt. PT 4030, which is quite resistant to bacterial wilt, was found to be the most susceptible to early blight disease followed by PT 4045. In terms of fruit color and firmness, AVRDC's new F_1 hybrids did not reach the factory standard. Processing factories in Thailand prefer red and firm tomatoes. All of the 11 AVRDC's F_1 hybrids were orange and not firm (Table 2).

The new open-pollinated tomato breeding lines from AVRDC carry heat-tolerant genes which made them set fruit during the hot-wet season with a minimum temperature of not more than 24°C. They all have larger fruit sizes than the former heat-tolerant lines tried at the TOP field. On the other hand, the check cultivar, Floradel, failed to set fruit. Among the indeterminate type, CL 5915-39D4-1-2-0 gave the highest yield of 26.6 t/ha while CL 5915-206D4-2-4-0 gave the lowest yield of 8.7 t/ha. Of the determinate types and among the eight lines tested, CL 5915-93D4-1-0 was the highest yielder at 28.3 t/ha. Yield of this group did not fall below 20 t/ha (Table 3). Fruit shapes varied from cylindrical to deep oblate. The highest yielder among the indeterminate type, CL 5915-39D4-1-2-0, also had the highest soluble solid content of 6.6 °Brix. Considering the positive characters of some of these lines, they were used in the breeding program to improve the yield of tomatoes in the lowland during off-season production.

Tomato Variety for Release in 1988

After a series of tests at the TOP field and on-farm trials conducted in different locations in Thailand, a new tomato variety has been approved for release in early 1988 under the local name 'Seedathip'. This variety, which is an F_7 of the cross of CL 1131-0-0-13-0-6 (an AVRDC line) × Seeda (local variety), is of determinate type, heat tolerant and early maturing. It has also a very short harvesting period. The first harvest is at 85 days after sowing and 80% of the fruits can be harvested in only 20 days after the first harvest. It has a yield twice that of the local variety Seeda and its fruits are ovate, small about 25 g, pink orange at ripening stage, with a strongly set/attached calyx.

This variety is an improvement over Seeda. Its release will not stop AVRDC-TOP in its tomato varietal improvement program. More work will still be carried out for further improvement using

Table 2. Results of AVRDC new F_1 hybrid processing tomato trial evaluated at KU KPS, October 1986 - February 1987.

Variety	Yield[z] (t/ha)	Fruit characteristics					Wilt (%)	Early[y] blight
		Color	Size (g)	Solid content °brix	pH	Firmness		
PT 4148	54.0 a	orange	50	4.56	4.4	–	10.2	2
PT 4030	51.5 a	orange	63	4.20	4.5	–	2.5	5
PT 4037	45.0 ab	orange	64	4.71	4.4	–	7.5	2
PT 4045	45.6 ab	orange	72	4.64	4.4	–	2.6	4
PT 4088	47.8 ab	orange	60	4.46	4.5	–	6.2	3
PT 3027	40.4 ab	orange	52	4.42	4.5	–	3.0	2
PT 4090	39.4 ab	orange	65	4.65	4.4	–	5.2	3
PT 4027	40.0 ab	orange	47	4.46	4.5	–	10.4	2
PT 4082	33.6 ab	orange	62	4.66	4.5	–	0.0	3
PT 4041	33.9 ab	orange	63	4.57	4.5	–	3.0	2
PT 4132	31.8 ab	orange	56	5.04	4.5	–	2.8	2
PT 502 (ck)	21.8 b	red	80	4.53	4.6	+	3.5	3

[z]Means followed by the same letter are not significantly different at 5% level of probability by DMRT. [y]Score: 1 = light, 5 = serious.

Table 3. Yield and fruit characteristics of new open-pollinated AVRDC breeding lines, May to September 1987.

Variety	Growth habit[z]	Days to flowering	Fruit characteristics			Yield
			Shape	Size (g)	Solid (t/ha) °Brix	
CL 5915-206D4-2-2-0	SP+	28	Cylindrical	51	5.3	21.2
CL 5915-206D4-2-4-0	SP+	26	Cylindrical	51	5.8	8.7
CL 5915-206D4-2-5-0	SP+	27	Cylindrical	52	5.9	17.0
CL 5915-39D4-1-2-0	SP+	21	Globe	45	6.6	26.6
CL 5915-93D4-1-0	SP+	22	Globe	51	5.4	28.3
CL 5915-223D4-2-1-0	SP+	26	Globe	51	5.6	22.6
CLN 65-349D5-2-0	SP+	24	Globe	45	5.2	26.3
CLN 95-280D5-1-7-0	SP+	24	Deep Oblate	63	5.3	20.0
Floradel (ck)				–	–	–
				Unable to set fruit		

[z]SP+ = indeterminate, SP = determinate.

AVRDC's best breeding lines. Hopefully, a new processing tomato variety better than the popular and commercially used ones will be released soon.

Chinese Cabbage

In 1987, trials were concentrated on the on-farm evaluation of Hybrid 62 (ASVEG 1) in different parts of Thailand. A total of 79.2 kg of Hybrid 62 provided by AVRDC were divided into smaller packages and distributed for evaluation to the agricultural institutes located in different regions of Thailand. Seeds were also distributed to farmers who have experience in growing Chinese cabbage for the evaluation of farmers' preference as well as the marketability of this variety in the summer season.

Questionnaires were also sent out for information on the cultivation practices adopted, the problems met as well as other observations made during the growing period until marketing. Responses were received from 14 farmers in different regions; nine from the central, three from eastern and one each from the southern and northeastern regions.

Responses from these farmers showed that off-season Chinese cabbage was usually grown on a flat area of about 150 to 500 m^2. Most of these farmers used direct seeding by sowing 1-2 seeds/hill with spacing of approximately 30 × 40 cm. Irrigation was done everyday by pumping water from a canal through plastic pipes.

Most of the farmer respondents failed to grow Chinese cabbage due to heavy rain during the young stage. The other constraints were insects and some diseases, such as diamondback moth, soft rot and downy mildew. These farmers also reported that Hybrid 62 had more rapid growth than any other commercial cultivar and matured earlier at 42.5 days after sowing. Average head weight was about 500 to 800 g. In summer, average yield was 20.6 t/ha, but in the rainy season the yield might be lower depending upon the planting density. The product was also acceptable to traders in Nakhon Pathom who bought it at US$.32/kg. However, Chinese cabbage with longer head shape (cylindrical) was more acceptable.

These on-farm trials also showed that Hybrid 62 can be grown well in central and southern Thailand. It has a good head formation and is high yielding compared to the local cultivar, especially in the summer season. Furthermore, its production cost is lower due to its rapid growth and early maturity.

A new set of trials, both experimental and on-farm, of some promising AVRDC Chinese cabbage lines commenced last October 1987 in coordination with the training program. Results of these trials will be included in next year's report.

Sweet Potato

Nine sweet potato cultivars from AVRDC and one local check were evaluated for yield and horticultural characters under short growth duration in the experimental field of TOP in Kamphaeng Saen. Differences in yield potential, horticultural characters, eating quality and pest damage were statistically significant even at early harvest conditions. Results further indicated that sweet potato varieties Ungbuay, CN 1028-15 and PC#9 can be classified as early maturing and desirable. Taking all factors into account, CN 1028-15 came out best due to its good quality, tolerance to weevil and good agronomic characters (Table 4). This cultivar was previously classified as feed type; however, this study indicated that CN 1028-15 can be used for human consumption.

Table 4. Root yield of 10 sweet potato cultivars evaluated at TOP/KPS experimental field, 1987.

Cultivar	Marketable root			Cull root		Total root			Marketable
	t/ha	5%[z]	kg/plot	t/ha	kg/plot	t/ha	5%	kg/plot	Yield (%)
PC #9	21.45	a	7.15	5.25	1.75	25.20	a	8.40	85.1
CN 1028-15	19.74	ab	6.58	2.34	0.78	22.05	ab	7.35	89.4
PC #3	15.24	bc	5.08	2.04	0.68	17.25	c	5.75	88.3
CI 608-652	14.49	bc	4.98	3.54	1.18	18.45	bc	6.15	82.5
CN 942-47	13.14	c	4.38	3.00	1.00	16.41	cd	5.38	82.4
AIS 35-2	11.25	cd	3.75	3.06	1.02	14.34	cd	4.78	78.5
CI 431-12	10.56	cd	3.52	2.04	0.68	12.60	de	4.20	84.9
I 591-51	7.8	d	2.60	1.86	0.62	9.66	e	3.22	80.6
I 166	7.8	d	2.60	1.74	0.58	9.45	e	3.15	83.5
Ungbuay	22.74	a	7.58	3.15	1.05	25.86	a	8.62	87.8

[z]Means followed by the same letter are not significantly different at 5% level of probability by DMRT.

Soybean

In late rainy season of 1986, two additional trials were conducted in the TOP field but their results were not included in last year's report. These were yield evaluation trial of soybean lines introduced from AVRDC and a resistance trial on soybean pod borer.

Based on yield and yield components of all 12 soybean lines and varieties (Table 5), AGS 270 and AGS 208 gave higher yield than both check cultivars. AGS 208 also had large seed size, 17 g/100

Table 5. Yield and yield components of 12 soybean varieties grown in late rainy season, 1986.

Lines or varieties	Yield (kg/ha)	Plant stand at harvest (plant/m^2)	Number of pods/plant	Number of seeds per pod	100-seed weight (g)
AGS 270	1657 a[z]	22.0 abc	29.3 b	2.02 c	12.4 c
AGS 208	1558 ab	25.0 ab	22.9 c	1.95 c	17.0 b
AGS 129	1308 bc	25.1 a	27.3 bc	2.21 b	10.7 de
AGS 217	1297 bc	23.5 abc	30.4 b	2.13 b	12.9 c
AGS 299	1207 c	24.2 abc	28.2 bc	2.14 b	10.8 d
AGS 160	1097 c	24.5 ab	29.4 b	2.17 b	9.6 e
AGS 162	1007 c	19.9 abcd	26.5 bc	2.16 b	12.3 c
AGS 324	985 c	23.4 abc	38.0 a	2.27 b	4.7 f
AGS 124	619 d	24.1 abc	13.0 d	2.54 a	10.3 de
AGS 65	595 d	19.7 bcd	23.2 c	2.21 b	9.9 de
OCB	1016 c	15.1 d	22.5 c	2.09 bc	18.9 a
SJ 5 (ck)	1107 c	19.1 cd	30.3 b	1.94 c	11.0 d
CV (%)	19.36	14.47	14.30	5.45	5.52

[z]Means followed by the same letter are not significantly different at 5% level of probability by DMRT.

seeds, and can be used as vegetable. Correlations between yield and yield components across all varieties showed that plant stand at harvest, number of pods per plant and 100-seed weight were positively correlated, whereas number of seeds per pod was negatively correlated. In reference to desirable agronomic characters, reactions to diseases, insects and seed quality, OCB was found only as the second early-maturing cultivar, yet it had the highest susceptibility to downy mildew (Tables 6-7). Although neither rain nor relative humidity was a problem during harvest, seed quality of the varieties was rather poor. AGS 324 and AGS 124, the earliest and the latest maturing varieties from AVRDC, respectively, had the worst seed quality.

Results of the trial on soybean pod borer resistance indicated that although there were large differences in yield among varieties, it was not significant as the CV of the experiment was also high. Significant differences were noted in 100-seed weight, plant height, disease reaction and total insect damage. However, resistance in some lines, such as OCB, was partly due to the escape nature as it was the earliest cultivar tested. Coefficients of variation of all traits studied were extremely high in this experiment. However, those are common with insect experiments of this type.

Some of the activities conducted in 1987 were: testing of AVRDC lines, other introduced lines, vegetable soybeans, as well as the incorporation of resistant genes from AVRDC lines into the Thai recommended cultivar, Nakhon Sawan 1.

Fifteen AVRDC soybean lines were tested twice in 1987 (dry and rainy seasons). Results showed that AGS 270, 208, 129 and 217 were among the susceptible lines with average yields of 1.7, 1.6, 1.3 and 1.3 t/ha, respectively. AGS 208 can be used as vegetable soybean since it has large seeds of over 17 g/100 seeds. AGS 129 is highly resistant to both downy mildew and bacterial pustule — the most important diseases of soybean grown in central Thailand.

A downy mildew resistant gene from the line will be incorporated into Nakhon Sawan 1 (NW 1), the cultivar newly released by the Thai Department of Agriculture, to reduce the latter's susceptibility to *Peronospora manshurica*. Furthermore, this cross will hopefully also increase the resistance of NW 1 to bacterial pustule disease.

Soybean lines from other international agencies, such as the International Institute of Tropical Agriculture (IITA) in Nigeria, were introduced into the program and evaluated against the Thai recommended cultivars during both dry and wet seasons in 1987. The promising lines from this set of 12 will be combined with AVRDC elite lines and the Thai recommended cultivars to form a set of treatments to be evaluated in 1988. Superior lines from these latter trials will soon be extended for on-farm trials in central and eastern Thailand.

With the increasing demand for vegetable soybean, 15 vegetable soybean cultivars introduced from AVRDC were tested against NW 1. Evaluation was carried out in cooperation with Chiang Mai

Table 6. Agronomic characters of 12 soybean varieties grown in late rainy season, 1986.

Varieties	Emergence	Days to flowering	Maturity	Plant height (cm)	No. of nodes/ plant	No. of branches/ plant	Lodging	Shattering
AGS 270	5	31	91	36.0	9.2	1.57	1	1
AGS 208	5	31	85	40.0	9.4	2.23	1	2
AGS 129	5	31	88	59.9	14.4	1.10	1	1
AGS 217	5	31	89	48.2	10.9	1.30	1	3
AGS 299	5	31	83	59.4	10.9	1.85	1	1
AGS 160	5	32	84	52.1	11.0	2.75	1	1
AGS 162	5	31	87	48.8	11.4	1.23	1	2
AGS 324	5	31	78	60.6	13.3	4.02	2	1
AGS 124	5	29	94	71.3	15.1	1.35	2	1
AGS 65	5	32	90	53.5	13.3	2.85	3	1
OCB	5	29	80	54.2	9.7	2.00	1	1
SJ 5	5	32	94	52.0	10.6	2.30	1	1

Table 7. Disease, insect pest and seed quality ratings of 12 soybean varieties grown in late rainy season, 1986.

Varieties	Rust	Downy mildew	Anthracnose	Bacterial blight	Bacterial pustule	Soybean mosaic	Bean fly	Leaf-eating insects	Seed quality
AGS 270	221	1.6	2.2	1.0	1.0	1	2	1	2
AGS 208	331	1.0	2.6	1.0	2.3	1	3	1	1
AGS 129	221	1.0	1.9	1.0	1.0	1	2	2	2
AGS 217	331	1.0	3.3	1.8	2.0	1	2	2	2
AGS 299	342	1.0	1.8	1.0	1.5	1	3	2	2
AGS 160	331	1.0	3.1	1.2	2.0	2	2	2	2
AGS 162	331	1.0	2.7	1.2	2.3	1	3	1	3
AGS 324	332	1.0	4.1	2.1	2.0	2	3	1	4
AGS 124	321	1.0	2.7	1.2	1.5	1	2	2	4
AGS 65	322	1.0	3.8	1.2	1.5	2	4	1	3
OCB	321	3.0	2.0	2.1	2.8	1	4	1	1
SJ 5	321	1.6	2.0	1.0	1.3	2	2	1	2

Field Crops Research Center and some other stations of the Department of Agriculture. Results from the rainy season experiment revealed that Vesoy #4, Vesoy #1, 7016 and NW 1 gave reasonable and acceptable yield. However, they had small seeds which were not up to export standard.

Mungbean

Several trials which dealt not only on varietal evaluation but also on the effect of fertilizer and flower removal and behavior of several mungbean varieties were conducted in 1986, but were not reported since data collection ended on December 1986.

Results of the 14th IMN conducted at the TOP field from September to November 1986 showed that few lines were able to give significantly higher yield than VC 1973A (KPS 1)(Table 8). However, most of these lines had lower seed weight than VC 1973. Seed size is as important as the yielding ability for Thai farmers to accept newly introduced mungbean varieties. VC 3012B, the highest yielding line, yielded 1.87 t/ha, but was among those with smallest seed size. VC 2755A and VC 2768A were comparable to VC 1973A in both yielding ability and seed size. These two lines need further evaluation.

The evaluation of selected sublines from VC 1973A (KPS 1) and VC 2778A (KPS 2) revealed that lines extracted from VC 1973A were rather uniform and showed no variation in any trait measured (Table 9). However, lines extracted from VC 2778A displayed some variation in yielding abilities and other agronomic characters, e.g. seed weight, number of seeds per pod, number of pods per plant and reaction to Cercospora leaf spot. Not one line displayed overall superiority compared with the mass selected Kamphaeng Saen 1 and 2. Lines with higher yield than the mass selected population

Table 8. Average yield and some agronomic characters of 20 mungbean lines at 14th IMN, late rainy season.

Variety or pedigree	Yield (t/ha)	1000-seed wt. (g)	Seeds/ pod	Pods/ plant	Plt. ht. at harvest (cm)	Days to 1st flowering	Days to 1st ripe pod
V 2010	1.05 f[z]	72.9 ab	13.6 a	9.28 e	73.9 ab	37.32 a	53.60 a
V 2984	1.09 a-e	50.5 i	12.1 ab	17.90 a	70.7 abc	33.50 f	48.50 f
V 3476	1.40 de	60.7 fgh	12.6 ab	13.30 abc	65.2 d-g	35.06 b-f	50.30 de
V 3726	1.30 def	66.8 b-f	9.95 b	9.25 e	64.3 efg	33.80 ef	49.80 ef
V 1628A	1.58 b-e	63.9 d-g	12.6 ab	13.20 abc	68.2 b-g	34.50 c-f	51.00 cde
V 1973A	1.42 cde	70.5 a-d	11.9 ab	10.90 cde	76.5 ab	35.00 b-f	52.00 a-d
VC 2750A	1.66 a-d	62.6 efg	12.1 ab	12.90 a-d	72.9 a-e	36.50 ab	52.80 abc
VC 2754A	1.64 a-e	65.0 def	10.9 ab	11.80 b-e	70.8 a	35.50 a-e	53.00 ab
VC 2755A	1.60 a-e	73.8 a	12.1 ab	11.60 b-e	79.3 a	35.00 b-f	51.30 b-e
VC 2764A	1.75 a-e	63.3 efg	11.9 ab	11.70 b-e	76.4 ab	35.50 a-e	52.30 abc
VC 2764A	1.83 abc	65.7 c-f	13.3 a	15.20 a	76.9 ab	30.30 def	51.30 b-e
VC 2768A	1.65 ab	71.8 abc	12.2 ab	10.50 de	63.6 fg	36.30 abc	52.50 abc
VC 2771A	1.54 a-e	69.0 a-e	12.3 ab	12.60 a-d	65.9 c-g	35.80 a-d	52.50 abc
VC 2802A	1.31 a-e	57.8 h	12.2 ab	13.10 a-d	59.6 g	36.00 a-d	52.30 abc
VC 3004A	1.43 ef	62.6 fg	12.2 ab	13.10 a-d	65.8 e-g	35.80 a-d	52.30 abc
VC 3012A	1.55 cde	53.6 i	12.9 ab	15.00 a	69.7 b-f	36.00 a-d	52.02 a-d
VC 3012B	1.87 a	55.9 b	12.7 ab	14.10 ab	69.8 b-f	35.82 a-d	51.00 de
VC 3061A	1.63 a-e	57.9 h	13.1 ab	11.60 b-e	73.8 a-d	36.00 a-d	52.80 abc
VC 3178A	1.52 b-e	67.2 a-f	11.9 ab	11.70 b-e	67.2 c-g	35.80 a-d	52.80 abc
VC 3301A	1.49 cde	55.9 h	12.7 ab	13.30 abc	65.3 d-g	36.30 abc	51.80 bc
CV %	14.46	7.36	16.51	14.05	7.78	3.09	2.20

[z]Means followed by the same letter are not significantly different at 5% probability level by DMRT.

Table 9. Average yield and some agronomic characters of 16 mungbean lines, early rainy season, 1986.

Variety name or pedigree	Yield (t/ha)	1000-seed wt. (g)	Seeds/ pod	Pods/ plant	Plant ht.	Days to 1st flowering	Lodging	CLS
VC 1973A Sel#1	1.28 b	72.3 ab	10.6 b	14.5 b	62.9 ab	34.5 ab	3.33 ab	2.67 ab
VC 1973A Sel#3	1.26 b	76.0 ab	10.8 ab	14.8 b	64.9 ab	35.5 ab	1.67 ab	2.33 b
VC 1973A Sel#4	1.23 b	70.7 b	12.4 ab	12.2 b	65.8 ab	35.5 a	3.67 ab	2.00 b
VC 2778A Sel#1	1.31 b	73.8 ab	12.2 ab	16.9 ab	59.3 ab	33.3 b	1.83 b	2.67 ab
VC 2778A Sel#2	1.85 ab	70.6 b	11.5 ab	18.8 ab	54.4 ab	33.0 b	1.67 b	1.67 ab
VC 2778A Sel#4	2.11 a	67.8 b	12.6 a	19.4 ab	65.6 ab	33.7 b	1.17 b	2.00 b
VC 2778A Sel#5	1.98 ab	75.1 ab	12.6 a	20.6 a	61.7 ab	33.0 b	1.67 b	2.67 b
VC 2778A Sel#9	1.26 b	75.8 ab	11.5 ab	16.3 b	55.9 ab	33.0 b	1.67 b	1.00 b
VC 2778A Sel#10	1.56 b	74.9 ab	11.2 ab	18.0 ab	60.5 ab	33.8 ab	2.67 ab	1.33 b
VC 2778A Sel#11	1.32 b	70.3 b	12.2 ab	15.8 ab	56.6 ab	34.3 ab	2.17 b	1.67 ab
VC 2778A Sel#12	1.10 b	65.6 b	11.4 ab	13.2 b	50.0 b	38.3 b	1.00 b	2.33 b
VC 2778A Sel#13	1.70 ab	79.8 a	11.3 ab	13.8 b	64.3 ab	33.8 ab	2.50 ab	1.00 b
VC 2778A Sel#14	1.03 b	80.8 a	12.1 ab	14.6 b	49.0 b	34.0 ab	2.00 b	3.17 a
KPS #1	1.06 b	75.0 ab	10.1 b	11.9 b	56.2 ab	34.2 ab	2.82 ab	2.67 a
KPS #2	1.68 ab	65.1 b	11.8 ab	19.9 ab	62.8 ab	33.3 b	2.83 ab	2.00 b
Uthong 1	0.72 c	72.4 ab	11.2 ab	16.0 ab	74.8 a	35.2 ab	4.00 a	3.00 b
CV %	25.14	17.99	6.92	17.99	17.90	2.63	33.76	28.49

[z]Means followed by the same letter are not significantly different at 5% probability level by DMRT.

were inferior in other aspects. It is also possible that variation among the selected lines was not real since the coefficients of variation (CV) of some characters were abnormally high. Thus, the mass selected materials could be employed as base population for future purification and expansion of the cultivars.

Application of foliar fertilizer and honey did not result in any differences among the treatments. However, both Hao and Honey hormones tended to increase seed weight of VC 2778A (KPS 2). The

succeeding fertilizer trials using different rates and kinds of fertilizers did not extract any real response from both KPS 1 and KPS 2, perhaps since the experimental plots were heavily applied with complete fertilizer in previous years.

In a physiological study conducted on removal of flowers, it was found that later flower removal seemed to produce smaller seeds compared to earlier flower removal or no removal at all. It is rather normal for mungbean to set smaller seeds at later flush of flowering.

The AVRDC-TOP mungbean program for 1987 focused on the following trials: 1) maintenance of KPS 1 and KPS 2, 2) evaluation of new AVRDC lines against the established local varieties (15th IMN) and insect resistance trials, 3) establishment of experiments and demonstration plots for the Second International Mungbean Symposium held 16-20 November 1987 in Bangkok.

KPS 1 and KPS 2 had gained more and more popularity among Thai farmers. Although both government and private sectors are supplying some amount of seeds to farmers annually, the quantity is still small compared to seeds from other cultivars (Uthong 1 and some local varieties). The latter cultivars contaminate and reduce the potential of KPS varieties. In this regard, a program to maintain their genetic purity was set up since the release of these two cultivars in 1985. The pure line method of selection is employed and the resulting seeds are used for research purposes and distributed free to farmers.

Preliminary results of the 15th IMN showed that no new entries could outperform VC 1973A (KPS 1) in terms of yield and seed size, which are the two most important characters for Thai farmers' acceptance. Of the 10 mungbean lines reported resistant to several insects at AVRDC, none displayed any superiority over KPS 1 and KPS 2 in terms of insect resistance in Thailand.

As mentioned earlier, one of the activities of the program was the setting up of experiment and demonstration plots to be used as show window for the participants of the Second International Symposium on Mungbean. These experimental plots were on the planting date responses of KPS 1 and KPS 2 and also on their responses using different spacings and number of plants per hill. Three additional demonstration plots were also established to show the fertilizer responses of KPS 1 and KPS 2, the mungbean-sugarcane intercropping system and the mungbean varietal and germplasm collection at TOP/AVRDC.

In these varietal collection plots, a set of good agronomic and "fancy" mungbean introduced from AVRDC and various places in Thailand were grown. This drew attention not only from the participants but also from students, local and international scientists who visited the TOP field. Requests for seeds from the program have been steadily increasing since these are excellent materials for genetic studies.

New Variety Released in 1987

A new mungbean variety was officially released by the Department of Agriculture of Thailand in September 1987. This variety, a cross of VC 1178/MG50-10H/Y and ML-6 was released under the local name of 'Chainat 60'. This is an F_3 generation of one of the 30 crosses sent to the Department of Agriculture by AVRDC for field testing in different locations in Thailand. It is early maturing, in fact, the earliest maturing among all mungbean varieties available in Thailand. First harvest could be made 55 days after sowing and yield response can be increased from 200,000 to 600,000 plants/ha. It is erect and has a compact plant canopy. Average experimental yield was 1.38 t/ha while yield in farmers' fields ranged from 1.10 t/ha to 1.37 t/ha. It has good nutritional quality and good agronomic characteristics, such as 45% starch content, 20.6% protein content, 11 to 12 pods per plant, 9 to 10 seeds per pod, shiny green coat, white hilum, 33 days to first flowering, 47 days to first ripe pod, 50.5 cm plant height, and 51 g 1000-seed weight.

Home Garden

Several home garden patterns were developed in 1987. These patterns were extended to some areas in cooperation with the Department of Agricultural Extension (DOAE). A training for extension agents from different agricultural extension offices will be conducted in 1988. They will be trained on home gardening technologies using the KPS model and developed patterns. Expansion of the home

garden trials were carried out in cooperation with Chiang Mai University. The KPS model was modified to suit the particulars of the locality as well as the preference of the local people. A technoguide on home gardening was also developed this year, and it will be updated and supplemented with new data from developed models in other locations in Thailand.

Aside from the 25-m^2 plots for production of the different kinds of vegetables following the developed model, bigger plots were also established for vegetable seed production. The seeds will be given to DOAE for further multiplication and distribution to different agricultural extension offices for their on-farm home gardening activities. To cope up with the increasing demand for seeds of these home garden vegetables, multiple cropping, cropping rotation and other efficient methods for a fast turnover were adopted.

In these 25-m^2 plots which consisted of three 1 m × 5 m beds, more than 30 kinds of vegetables (leafy, fruit and beans) were grown, giving good yield and high market returns. Three garden plots also served as demonstration plots for students, farmer visitors and researchers, giving them insights on the most effective way of maintaining a productive home garden. Table 10 shows the kind of vegetables grown in TOP home garden in KPS and the total monthly production.

Table 10. Total yield (kg) of various kinds of vegetables from home garden plots (25 m^2) at TOP/KPS, 1987.

Crop	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Chinese radish KU#1	1.25	6.43	4.61	-	-	-	4.71	-	-	-		10.01
Chinese kale	1.99	4.93	-	3.91	0.91	-	2.94	-	-	2.49	-	3.20
Green onion	-	14.70	0.38	11.00	-	1.57	-	1.86	-	-	-	
Green Kwang Futsoi	21.24	-	-	9.46	-	-	-	7.82	-	6.63	-	1.81
Chinese cabbage	-	-	-	-	-	-	-	-	-	-	4.06	-
Water convolvulus	12.40	-	-	10.88	12.50	9.78	-	5.89	9.56	12.32	11.39	6.48
Coriander	-	-	0.38	0.85	-	-	-	0.27	-	-	-	-
Chinese chive	1.12	1.57	2.31	2.70	1.16	3.62	2.57	2.16	1.59	0.28	0.70	0.15
Amaranthus	-	-	-	-	-	-	5.52	6.43	-	-	-	-
Yardlong bean	-	0.30	3.98	0.44	-	-	-	-	-	3.06	5.89	-
Cucumber	1.56	2.87	0.32	1.41	0.48	-	3.01	6.40	-	-	0.37	8.43
Bitter gourd	-	-	-	2.22	3.38	-	1.88	13.13	8.61	3.50	-	-
Snapbean (pole)	-	-	-	-	-	-	-	-	-	-	0.44	-
Lemon grass	-	-	1.63	0.78	1.09	1.90	1.28	0.83	1.14	0.26	0.26	
Hot pepper	-	-	0.11	0.10	0.15	0.16	0.08	0.16	0.03	0.05	0.16	-
Sacred Basil	0.63	0.49	0.58	0.73	0.52	0.86	0.79	0.58	0.65	1.28	0.87	-
Hoary Basil	0.14	0.33	0.15	0.23	0.18	0.21	0.11	0.24	0.54	0.27	0.26	-
Sweet Basil	0.49	0.26	0.18	0.32	0.32	0.23	0.22	0.22	0.28	0.52	0.34	-

Other Activities Related to Vegetable Production and Research/Symposia, Workshops, etc.

Workshops/Symposia

One of the major activities undertaken by the AVRDC-TOP in 1987, in addition to its regular research and training activities, was the conduct of the Second International Symposium on Mungbean held in Bangkok from 16-20 November 1987. This workshop, which was attended by around 260 scientists from 30 countries all over the world, was recognized as a great success. During this workshop, the participants were able to discuss the latest developments on mungbean research and development, and various problems and possible solutions met by different participants in their mungbean research and production activities.

The AVRDC-TOP, in cooperation with the government of Thailand, KU, DOAE and DOA, were responsible for all the local arrangements. One of the highlights of this symposium was the presentation of three papers from China, which reported on the recent progress of mungbean research and development work using AVRDC mungbean materials. Presentation of these papers was made possible through the efforts of AVRDC-TOP. One paper which summarized the history, current status and

benefits of research cooperation on the mungbean crop between AVRDC and Thailand was presented at the Symposium by an AVRDC-TOP scientist.

Other Cooperative Works

As part of the cooperative work with the Food and Agriculture Organization (FAO), a demonstration plot of 1 ha, where six experiments designated to demonstrate various phases of seed production technologies on mungbean, soybean and peanut were established in the TOP field. This will be used as observation fields by the trainees of the FAO-KU seed production training course which will commence February 1988 and the Sixth Regional Training Course.

Regional Programs

The Africa Vitamin A Gardening Project

Objectives

The main objective of the project is to increase production and consumption of vitamin A garden crops in the Sahelian region of West Africa. This is to be accomplished through collaborative garden research in Africa, village testing of a prototype vitamin A garden system, workshops, conduct of training in gardening for selected Africans from Sahelian countries, and follow up support of graduates of the training program.

The project is initially funded for three years (FY 1986-89) by the Office of Nutrition of the Agency for International Development (AID), Washington, D.C., U.S.A.

Year One Accomplishments

During the first year, the following activities had been accomplished: site selection; setting up of project administration; establishment of collaborative contacts; hiring, orientation and placement of project staff; negotiation of a Memorandum of Understanding; acquisition of equipment and supplies in Taiwan and at the Africa project site; establishment of a mechanism for an independent project evaluation; organization of training center and preparation of a curriculum for the training program; initiation of needs assessment; and establishment of reporting procedures. At the end of the year, one site was prepared by the Africa project staff and observation trials were begun on 14 garden crops.

Site Selection

The criteria for site selection were prepared and two site selection trips were taken to Africa during the year. The one located in Niger was selected to be the project site. The site houses the project's collaborative and host organization — the Institut Pratique de Developpement Rural (IPDR), Kolo, Niger.

Project Administration

At AVRDC, arrangements were made for staff salaries, a managerial structure was charted, a process for local and international purchases was initiated, budgetary procedures were established, and international travel arrangements were made.

In Africa AVRDC began working with IPDR and USAID/Niamey in establishing various procedures: hiring local staff; identifying the processes for cooperation with the Government of Niger (GON), USAID/Niamey, PVOs and NGOs; scheduling staff travel and clearances; and establishing the extent of assistance to the project from USAID/Niamey.

Collaboration

A collaborative network was started during the year to encourage more Africans to get involved in the project, to provide a future vehicle for information exchange, to facilitate getting local, national and regional assistance in needs assessment and to get assistance in the gardens research and development (R & D), training, and outreach phases of the project. Contacts were made with AID's Regional Economic Development Support Office for West and Central Africa (REDSO/WCA),

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USAIDs in the Sahelian region, Office de Recherches sur L'Alimentation et la Nutrition Africaine (ORANA), ICRISAT-Sahelian Center, International Institute for Tropical Agriculture (IITA), the Government of Niger (GON), Peace Corps, AFRICARE, Helen Keller International (HKI), United Nations Children's Educational Fund (UNICEF), World Health Organization (WHO), International Board for Plant Genetic Resources (IBPGR), Cooperative for American Relief Everywhere (CARE), Japanese International Cooperation Agency (JICA), and a number of additional private voluntary organizations (PVOs) and nongovernment organizations (NGOs).

Project Staff

Job descriptions and work assignments were prepared for staff positions. Taiwanese and expatriate candidates were recruited, interviewed and hired. The hired staff underwent a period of orientation at AVRDC and began their work, either at AVRDC or at the project site in Niger. During the last quarter of the year, some Nigeriens were interviewed, and two were hired for local positions.

Memorandum of Understanding

The Memorandum of Understanding (MOU) was first drafted in January 1987. Since then subsequent drafts were written with inputs from AID, AVRDC and IPDR. A final draft was accepted by all parties in June. Copies signed by AVRDC were sent to USAID/Niamey; one copy was sent to the Minister of Agriculture, Niger.

Early in July USAID/Niamey requested AVRDC to send a project person to Niger to take care of further negotiations concerning the MOU. Jack Gershon went to Niger in July to obtain the signatures and conduct final negotiations. As of September 1987, most MOU signatures and acknowledgment letters had been obtained. Still to be obtained are MOU attachments for customs and duty exoneration, and exoneration from a new value added tax, ranging from 17% to 24%, on all imports and local purchases. Once the specific GON Ministries sign these attachments, the project can then get the necessary signed paper(s) and allow the project staff to plan and initiate activities in Niger.

Equipment and Supplies

Equipment and supplies for both AVRDC and the IPDR site were ordered and purchased. Small air shipments and one large sea shipment were sent to Niger. As soon as exoneration papers are cleared, they will be released for use by the project. Most of these items were shipped to Niger in July 1987. As of November they still have not been cleared through customs.

Project Evaluation

Under the terms of the project grant, an independent evaluation shall be undertaken to determine whether the project met its goals, and to decide on future funding and project extension. REDSO/WCA has agreed to conduct midpoint and final evaluations for AVRDC and for AID.

Needs Assessment

A needs assessment was started this first year to gather information on what the project staff needs to know to give focus on gardens R & D, village testing of the gardens, the type of trainees to recruit, the training program itself, workshops, and backstopping of trainees after they graduate. A limited amount of information had been gathered. More will be obtained when the MOU is completely signed; thus, allowing project staff to officially interact with Nigeriens.

Training Center/Training Curriculum

The facilities at IPDR were inspected and found to be basically adequate for project needs. IPDR is essentially a training facility for extensionists in the GON service. It has sufficient classrooms and dormitories. Food facilities are in place. IPDR also has staff experienced in administration and implementation of agricultural training programs, as well as a library, audiovisual section, and reprographic and printing facilities.

As part of the IPDR/AVRDC collaborative arrangements spelled out in the MOU, the project will cooperate with IPDR in an exchange of staff to assist in respective activities.

A training curriculum outline was drafted in 1986. It is based on AVRDC's experience in training on gardening, and on two FAO publications on food, nutrition and agriculture — guidelines for curriculum content for agriculture training. One publication focuses on Africa; the other on Southeast Asia. The training curriculum will be modified and finalized to reflect the results of the gardening research and the needs of people in the Sahelian region of West Africa.

Reporting Procedures

During the first year a project reporting procedure was scheduled. This was necessary because, as an AID/Washington project grant to AVRDC, conducted at a host institution (IPDR) in an African country (Niger), with the sanction of that country's USAID Mission, and evaluated by an AID regional office (REDSO/WCA), there are reports to be written for each of these institutions. In addition, IPDR had requested that the project provide them with copies of all relevant reports to all the other institutions. IPDR communicates only in French.

As of September 1987, the total number of reports to be submitted in both French and English is 58. The breakdown is as follows: annual reports, 2; assessment report, 1; evaluation reports, 3; final report, 1; projected yearly budget, 2; quarterly budget estimates, 10; quarterly progress reports to USAID/Niamey, 10; schedule of activities and work plans, 2; training program reports, 4; trip reports, 20; workshop reports, 3.

Research

Near the end of year one, the Africa project staff initiated garden research. Observation plots were started at two locations having different soil characteristics. Fourteen garden crops were selected for planting based on: (1) presence and/or popularity in local diets, (2) β-carotene content and (3) minimal requirements for cultivation (i.e. seed gathered or saved from previous crop, drought tolerant and tolerant of other environmental stresses). Some are semiwild species which are gathered during the rainy season.

The following crops will be planted for observation trials: *Hibiscus sabdariffa*, *Amaranthus* (various sources: local, U.S.A., Taiwan), *Corchorus olitorius* and *C. tridens*, *Gynandropsis gynandra*, *Portulaca oleracea*, *Talinum triangulare*, *Cassia fetide* and *C. occidentalis*, *Basella rubra*, tomato (AVRDC lines plus local sources); carrot (BETA III and locally available varieties); squash (local, orange-fleshed); and sweet potato (only white-fleshed varieties available).

Conclusion

The project has experienced a number of constraints during its first year of operations. Site selection took longer than anticipated; the MOU is still being negotiated; equipment and supplies are not in the hands of the project staff; and protocol in Niger is, and will continue to be, a time-consuming process. As a result, the project is one year behind schedule.

In September 1987 the Africa project was visited by Dr. Nick Luykx, Acting Director, Office of Nutrition, AID/Washington, to assess the reasons for the delays and to provide oversight on the project. The results of Luykx's visit showed that the delays were outside of AVRDC's control, and that USAID/Niamey and IPDR are strongly interested in completing the startup phase of the project, and in getting the research and training initiated. The GON is still interested in 'greening' Niger with edibles, and has released funds for horticultural activities.

The Office of Nutrition has notified AVRDC of its willingness to accept a modified project proposal and work plan that will extend the project to adjust for lost time. The modified proposal should include incremental increases in the budget to adjust for justifiable and unforeseen expenditures associated with the project's startup, additional costs of training, and additional costs as a consequence of the proposed time extension.

A final draft of the modified proposal, work plan and budget were submitted to AID/Washington in May of 1988.

Thailand Regional Training and Research Program

Fourteen training scholars completed the Fifth Regional Training Course on Vegetable Production and Research on 26 February 1987, bringing to 64 the total number of scholars who had undergone this training course. These scholars came from China, Indonesia, the Philippines, Sri Lanka, Thailand and Vietnam. As a requisite for the completion of the training course, a trainee was asked to conduct an experiment on a crop of importance to his national program. Data obtained from these trials are also being used in various crop improvement/production programs of AVRDC.

After a series of negotiations and recruitment for 1987-88, 19 trainees were accepted to the Sixth Regional Training Course, which started last October 1987. In this batch were six Chinese, one Filipino, three Sri Lankans, two Thais and seven Vietnamese. Aside from lectures, practicum and field trips, trainees also conducted field or laboratory research on AVRDC priority vegetable crops.

For the remaining years of the ADB support to the program, a series of in-country workshops will be conducted in different countries around the region. The main objective of the workshops is to enhance adaptation and extension of the results of the training program, as well as effect a fast technology transfer in response to the needs of vegetable research and production of the respective country.

With more support from other donor agencies, more training scholars are expected during the seventh training course in 1988.

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Genetic Resources and Information Services

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Genetic Resources and Seed Unit

Goals of the Genetic Resources and Seed Unit

The Genetic Resources and Seed Unit (GRSU) aims to promote the utilization of AVRDC's collections through evaluation and comprehensive documentation, build up a base and active collection of vegetable species popular in the tropics, strengthen AVRDC's cooperation within the international network of genebanks, and ensure that incoming and outgoing seed samples are free of pests and diseases.

Germplasm Introduction

Introduction

In 1987, the GRSU acquired a total of 5,954 accessions of 21 crop genera. The most important batches are the collections of 4,313 *Capsicum* from the United States Department of Agriculture, the Central Institute for Genetics and Research on Cultivated Plants (German Democratic Republic), Tropical Agricultural Research and Training Center (CATIE, Costa Rica), Malaysian Agricultural Research and Development Institute (Malaysia), Rural Development Administration (Korea), Bruinsma Selectiebedrijven Hybrid Seed Company (Netherlands) and Research Center for Agrobotany (U.S.A.), and the 813 accessions of 12 crop genera collected in Nepal by Professor M. Iizuka.

The different introductions are summarized in Table 1. The breakdown by genus of the two collecting missions of Professor M. Iizuka in Nepal is shown in Table 2.

Current Status

***Brassica* species.** A total of 231 accessions were introduced from five countries (Table 3). The 210 accessions from Nepal consist of 133 Tori, 17 Sarshum, 20 Rayo, 2 mustard, 1 cauliflower and 37 unknowns. These represent a range of variation including a potential black rot resistance material from Japan.

***Capsicum* species.** After naming *Capsicum* as one of the principal research crops, the GRSU acquired 942 accessions in 1986. In 1987 the number of accessions reached 4,313, including variations from all the domesticated and some wild species, i.e. *C. annuum*, *C. annuum* var. *longum*, *C. annuum* var. *grossum*, *C. baccatum*, *C. baccatum* var. *pendulum*, *C. baccatum* var. *baccatum*, *C. cardenasii*, *C. chinense*, *C. chacoense*, *C. eximium*, *C. frutescens*, *C. galapogense*, *C. microcarpum*, *C. pubescens*, *C. praetermissum* and *C. schottianum*. A summary of the introduction by country is shown in Table 4.

The accession Criollo de Morelos 331 (TC 3191) was indicated by the donor, Bruinsma Seed Company, to be resistant to *Phytophthora capsici* L. It was confirmed by the AVRDC pathologist.

***Glycine* species.** A total of 99 introductions were received from three countries (Table 5). The materials from Nepal are *G. max* collected from an area with an altitude of up to 2,800 m above sea level. The acquisition from the U.S.A. consisted of three *G. argyrea* and 12 accessions of *G. canescens*.

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Table 1. New germplasm introductions at AVRDC, 1987.

Source	No. of entries[z]							Total
	Glycine spp.	*Vigna* spp.	*Brassica* spp.	*Lycopersicon* spp.	*Ipomoea* spp.	*Capsicum* spp.	Others	
Australia	–	10	–	1	–	–	–	11
China	–	–	–	–	5	106	–	111
India	–	173	–	–	–	201	–	374
Japan	1	–	17	–	1	29	–	48
Macau	–	–	1	–	–	–	–	1
Madagascar	–	1	–	–	–	–	–	1
Malaysia	–	–	–	–	–	176	6[y]	182
Nepal	83	308	210	–	–	9	209[x]	819
Nigeria	–	–	–	–	10	12	–	22
Panama	–	–	–	6	–	13	–	19
Papua New Guinea	–	–	–	–	30	–	–	30
Peru	–	–	–	–	6	95	–	101
Philippines	–	359[w]	–	–	–	60	–	419
Puerto Rico	–	–	–	10	15	10	–	35
Syria	–	–	–	20	–	7	–	27
Taiwan	–	3	2	2	74[v]	33	–	114
Thailand	–	–	–	20	–	69	–	89
USA	15	1	–	39	1	285	–	341
USSR	–	–	1	–	–	56	–	57
Unknown	–	–	–	–	1	83	–	84
Others	–	–	–	–	–	3,069	–	3,069
Total	99	855	231	98	143	4,313	215	5,954

[z]All entries are still temporarily numbered. [y]*Amaranthus* (1), *Solanum* (1), *Cucurbita* (Pumpkin) (1), *Mamordica* (Bitter Gourd) (1), *Hibiscus* (1) and *Cucumis* (Cucumber) (1). [x]*Pisum* (56), *Lens* (28), *Dolichos* (68), *Cicer* (13), *Vicia* (5), *Lathyrus* (4), *Cajanus* (7), *Phaseolus* (27) and *Solanum melongena* L. (Eggplant) (1). [w]Selections from four *V. radiata* var. *sublobata*, TC 2208, TC 2209, TC 2210 and TC 2211. [v]Two varieties from Taiwan already given permanent accession numbers and 70 clones from interspecific crosses by Dr. Iwanaga.

Table 2. Germplasm collected in Nepal.[z]

Species	First batch[y]	Second batch[x]	Total
Brassica	163	44	207
Cajanus	7	0	7
Capsicum	0	7	7
Cicer	13	0	13
Dolichos	53	15	68
Glycine	83	0	83
Lathyrus	4	0	4
Lens	28	0	28
Phaseolus	27	0	27
Pisum	56	0	56
Vicia	5	0	5
Vigna	263	45	308
Total	702	111	813

[z]Collections by Professor M. Iizuka. [y]Received on 4 December 1986. [x]Received on 18 November 1987.

Table 3. New *Brassica* species introduced in 1987.

Source	No. of entries	Remarks
Japan	16	Radish (3), *B. campestris* (13)
	1	Cabbage, black rot resistance
Macau	1	*B. campestris* ssp. *chinensis*
Nepal	207	*B. campestris*
	3	Mustard (2), cauliflower (1)
Taiwan	2	*B. napus*
U.S.S.R.	1	*B. campestris* var. *oleifera*
Total	231	

Table 4. *Capsicum* species collection.

Country	No. of entries	Country	No. of entries
1. Afghanistan	18	40. Jamaica	1
2. Algeria	1	41. Japan	29
3. Angola	1	42. Kenya	2
4. Argentina	32	43. Korea	146
5. Austria	22	44. Lebanon	3
6. Belgium	2	45. Libya	10
7. Belize	7	46. Malaysia	176
8. Bolivia	14	47. Mexico	252
9. Brazil	77	48. Nepal	9
10. British Indian Ocean Territory	1	49. Netherlands	103
11. British Virgin Islands	1	50. Nicaragua	6
12. Bulgaria	105	51. Nigeria	12
13. Canada	25	52. Pakistan	10
14. Chile	7	53. Panama	13
15. China	106	54. Paraguay	2
16. Colombia	23	55. Peru	95
17. Costa Rica	200	56. Philippines	60
18. Cuba	10	57. Portugal	9
19. Czechoslovakia	32	58. Puerto Rico	10
20. Denmark	5	59. Romania	38
21. Ecuador	8	60. Singapore	1
22. Egypt	10	61. South Africa	1
23. El Salvador	87	62. Spain	54
24. England	31	63. Sri Lanka	1
25. Ethiopia	55	64. Sudan	2
26. Fiji Islands	1	65. Switzerland	9
27. France	43	66. Syrian Arab Republic	7
28. Germany, Democratic Rep.	28	67. Taiwan	33
29. Germany, Federal Rep.	23	68. Thailand	69
30. Ghana	1	69. Trinidad	3
31. Greece	5	70. Tunisia	10
32. Guatemala	129	71. Turkey	395
33. Honduras	84	72. Uruguay	4
34. Hungary	245	73. U.S.A.	285
35. India	201	74. U.S.S R.	56
36. Indonesia	8	75. Venezuela	3
37. Iran	52	76. Yugoslavia	491
38. Israel	7	77. Zambia	6
39. Italy	107	Unknown	83
Total			4,313

Table 5. New *Glycine* species introduced in 1987.

Source	No. of entries	Remarks
Japan	1	Vegetable soybean
Nepal	83	*G. max*
U.S.A.	15	*G. argyrea* (3), *G. canescens* (12)
Total	99	

***Ipomoea* species.** A total of 143 entries were introduced from nine countries. The 13 entries from Papua New Guinea and one from U.S.A. are true botanical seed samples for long-term storage at AVRDC. There are six accessions of wild species consisting of one diploid *I. trifida*, one tetraploid *I. trifida*, one hexaphord *I. trifida*, one *I. hederifolia*, one *I. nil* and one *I. setosa*. Seventy clones

from interspecific hybridization between *I. batatas* and *I. trifida* (by Dr. Iwanaga) were selected for conservation. The remainder are clones from China, Puerto Rico, Papua New Guinea (lowland form), International Potato Center (CIP, Peru) and the International Institute of Tropical Agriculture (IITA, Nigeria) (Table 6).

The introductions from CIP and IITA are in *in vitro* form.

***Lycopersicon* species.** A total of 98 entries were introduced. Most of the entries were specific genetic stock. Many had already several important agronomic genes combined together. The only batch of land races were the 20 entries from Syria (Table 7).

***Vigna* species.** A total of 855 entries were introduced. The most important batch was the collection from Nepal, consisting of 5 mungbean, 105 black gram, 45 rice bean, 29 adzuki bean, 83 cowpea, etc. and 41 unidentified species (Table 8).

Table 6. New *Ipomoea* species introduced in 1987.

Source	No. of entries	Remarks
China (Beijing Agr. University)	5	Cultivar
Japan	1	Cultivar
Nigeria (IITA)	10	Already in present collection (*in vitro*)
Papua New Guinea	13	True seeds of open-pollinated populations
(Laloki Agr. Res. Station)	17	Cultivars (lowland forms)
Peru (CIP)	6	Cultivars (*in vitro*)
Puerto Rico (Tropical Agr. Res. Station)	15	Cultivars (tubers)
Taiwan	70	Selection of interspecific crosses at AVRDC (Dr. Iwanaga)
(Chiayi)	4	Cultivars (2), *I. nil* (1), *I. setosa* (1)
U.S.A.	1	True seeds (Dr. Jones)
Unknown	1	*I. hederifolia*, transferred from Breeding Department to GRSU
Total	143	

Table 7. New *Lycopersicon* species introduced in 1987.

Source	No. of entries	Remarks
Australia	1	Bacterial wilt resistance
Panama	6	Bacterial wilt resistance
Puerto Rico (Tropical Agr. Res. Sta.)	10	Cultivars
Syria	20	Landraces
Taiwan	2	F_1 processing tomato
Thailand	20	Tomato yellow leafcurl (TYCL) resistance
U.S.A. (UC Davis)	24	Resistant to *Verticillium* I, *Fusarium* I & II, or bacterial speck resistance
(Campbell Co.)	15	Heat tolerance
Total	98	

Table 8. New *Vigna* species introduced in 1987.

Source	No. of entries	Remarks
Australia	10	*V. radiata* (9), wild *V. mungo* (1)
India	173	*V. radiata*, *V. mungo*, etc.
Madagascar	1	Wild *V. mungo*
Nepal	308	*V. radiata*, *V. mungo*, *V. umbellata*, etc.
Philippines	359	*V. radiata* (1), *V. radiata* var. *sublobata* (358)
Total	855	

Germplasm Conservation

Current Status

The current status of germplasm maintained at AVRDC, totaling 27,599 accessions, is shown in Table 9. After activating the long-term stores in mid-1985, 5,186 accessions have been placed in base storage (Table 10). Efforts are concentrated on the principal crops, namely, tomato, Chinese cabbage, mungbean, soybean, sweet potato and pepper.

Pepper was made a principal research crop in 1986. To date, 4,313 accessions of pepper have been acquired, including accessions from all of the major collections in the U.S.A., Costa Rica, German Democratic Republic, Thailand, Malaysia, etc. Batches of these accessions are being characterized and evaluated to support utilization work. Accessions for base and active collections are multiplied in net-houses.

The sweet potato *in vitro* storage was not maintained continuously due to the resignation of the staff working on this project. The IBPGR/AVRDC joint project on 'Introduction, virus indexing, conservation and distribution of the Asian and Pacific sweet potato germplasm, Phase II' has been extended starting 1 December 1987.

A batch of tubers which includes most of the accessions is now under testing for storage ability.

Table 9. Germplasm maintained by AVRDC's GRSU in 1987.

Crop	Accessions	Missing	Available	Temporarily numbered accessions	Suspected duplicates[z]
AVRDC principal crops					
Soybean	12,505	835	11,670	99	2,111 (9,034)
Mungbean	5,274	167	5,107	612[y]	985 (5,112)
Tomato	5,484	138	5,346	617	40 (4,734)
Sweet potato	1,241	32	1,209	157	9 (1,200)
Chinese cabbage	856	42	814	217	–
Pepper	3,042	30	3,012	1,271	–
Subtotal	28,402	1,244	27,158	2,973	3,145 (20,080)
Other crops					
Adzukibean	125	–	125	25	–
Amaranth	86	–	86	–	–
Black gram	158	–	158	183	–
Rice bean	72	–	72	50	–
Subtotal	441	–	441	258	–
Total	28,843	1,244	27,599	3,231	3,145 (20,080)

[z]Figures in parentheses indicate the total number of accessions from which the suspected duplicates were counted. [y]Including 356 accessions (lines) of wild black gram purified from four populations.

Table 10. Current status of base collections in long-term storage at AVRDC.

Crop	Accessions stored (no.)	Total accessions (%)	Storage room (units)	Seeds/[z] accession (no.)	Moisture content (%)
Soybean	2,620[y]	22.45	5	4,000	8.0
Mungbean	1,437[x]	28.14	5	4,000	8.0
Tomato	713	13.34	5	12,000	5.0
Chinese cabbage	341[w]	42.41	5	12,000	5.0
Pepper	75	3.04	5	12,000	5.0

[z]Recommended number of seeds per accession. [y]Non-USDA accessions. [x]Another 3,000 accessions (58.7%) will be stored in early 1988. [w]Open-pollinated varieties.

Germplasm Characterization

The status of characterization and the characters evaluated are summarized in Tables 11 and 12, respectively.

Germplasm Documentation

The GRSU, with the assistance of the AVRDC Computer and Statistical Services, is developing an AVRDC genetic resources data base using the MINISIS software. Presently, all passport as well as characterization data obtained for mungbean, sweet potato, non-USDA soybean and open-pollinated Chinese cabbage have been entered. The current status of documentation is given in Table 13.

Table 11. Characterization of AVRDC's principal crops.

Crop	No. of morphological and physiological characters characterized		Chemical characters characterized
	IBPGR descriptor list	Additional	
Mungbean	23	13	Protein, starch and fiber
Soybean	26	1	Protein, fat, starch and fiber
Chinese cabbage	66[z]	–	–
Pepper	37	2	Capsaicin
Sweet potato	27	9	Protein, sugar, starch, fiber and dry matter
Tomato	36	2	% brix

[z]AVRDC/IBPGR descriptor list (IBPGR/AVRDC 1987).

Table 12. Status of AVRDC germplasm characterization in 1987.

Crop	Morphological and physiological characters		Chemical characters	
	Accessions characterized	% of total	Accessions characterized	% of total
Mungbean	4,945	96.8	4,945	96.8
Soybean	2,672[z]	22.9	2,622	22.5
Chinese cabbage	315[y]	39.2	–	–
Pepper	508[x]	20.6	–	–
Sweet potato	1,168	98.4	734[w]	61.8
Tomato	1,250[x]	22.8	–	–

[z]Non-USDA accessions. [y]Open-pollinated cultivars. [x]Ongoing in fall 1987. [w]Accessions flowering at AVRDC.

Table 13. Current status of documentation at AVRDC's GRSU in 1987.

	Soybean (%)	Mungbean (%)	Tomato (%)	Chinese cabbage (%)	Sweet potato (%)	Pepper (%)
Passport data entry	100	100	100	100	100	100[z]
Characterization data entry	25	97	0	37	98	0
Germplasm catalog	Spring 1988	Fall 1987	–	1986 (for OP[x])	Summer 1988	–
Seed inventory data input	0[y]	0[y]	0[y]	100	0[y]	0

[z]New crop in temporary numbers. [y]Will be completed in spring 1988. [x]OP = Open-pollinated.

Seed Distribution

A total of 12,183 seed samples of both germplasm and breeding lines were distributed to 305 cooperators in 95 countries and territories in 1987 (Table 14). The 305 germplasm recipients in 1987 are listed in another section of this report.

The summary of the internal seed distribution is given in Table 15. There were two big batches of requests; one was for the Entomology Department to screen against beanflies in soybean and the other for the Pathology Department to screen against Cercospora leaf spot in tomato.

Germplasm Utilization and Evaluation

Summary

The utilization and evaluation of mungbean, soybean and sweet potato since 1973 are summarized here. The important parents for the improvement of these crops at AVRDC were identified. The useful

Table 14. External seed distribution of germplasm and breeding lines in 1987.

Country	Seed packets		Total
	6 AVRDC crops	Other crops	
Thailand	2,435	100	2,535
Philippines	1,454	2	1,456
Japan	1,076	0	1,076
U.S.A.	766	5	771
Indonesia	655	2	657
India	535	9	544
Korea	392	0	392
Nigeria	356	0	356
Brazil	280	0	280
Vietnam	252	0	252
Others[z]	3,665	199	3,864
Total (95)	11,866	317	12,183

[z]Includes 84 countries and territories: Anguilla, Argentina, Australia, Bahrain, Bangladesh, Barbados, Belgium, Belize, Bhutan, Brunei, Burma, Canada, Cape Verde Islands, Chile, Cocos Islands, Colombia, Cook Islands, Costa Rica, Cuba, Dominica, Dominican Republic, Egypt, England, Ethiopia, Fiji Islands, France, Germany (Democratic Republic of), Germany (Federal Republic of), Ghana, Guadeloupe, Guam, Netherlands, Honduras, Iran, Iraq, Israel, Jamaica, Jordan, Kenya, Kiribati, Lebanon, Liberia, Madagascar, Malawi, Malaysia, Maldives, Marshall Islands, Mauritius, Mexico, Namibia, Nepal, Niger, Niue Islands, Pakistan, Panama, Papua New Guinea, Peru, Polynesia (French), Portugal, Saipan, Salvador, Samoa (American), Saudi Arabia, Senegal, Seychelles, Singapore, South Africa, Sri Lanka, St. Lucia, Swaziland, Switzerland, Syria, Tahiti, Taiwan, Tanzania, Togo, Trinidad, Turkey, Uganda, Vanuatu, Yemen, Yugoslavia, Zaire, Zambia and Zimbabwe.

Table 15. Internal seed distribution of germplasm materials in 1987.

Department	Soybean	Mungbean	Chinese cabbage	Tomato	Sweet potato	Pepper	Others	Total
Plant breeding	269	18	6	217	0	76	0	586
Entomology	5489	36	0	0	31	4	1	5561
Pathology	17	34	22	4997	18	321	0	5409
Physiology	0	0	0	4	1	0	0	5
On-station testing	0	0	0	1	0	0	0	1
Total	5775	88	28	5219	50	401	1	11562

germplasm identified through years of screening and evaluation are listed. These summaries form a very useful set of reference information.

Introduction

The entire AVRDC collection is being screened and evaluated continuously by AVRDC scientists for specific traits; 149,487 seed packets had been used for varietal improvement since 1975. Cooperation with scientists from national programs in the screening of germplasm for specific characteristics is also encouraged. During the same period, a total of 237,237 seed packets had been shipped to cooperating scientists in 174 countries and territories. The distribution of AVRDC materials in the last decade has resulted in the release by local authorities in 35 countries of 118 cultivars of the five principal crops, i.e. Chinese cabbage, sweet potato, tomato, mungbean and soybean.

The systematic exploitation of the germplasm at AVRDC has resulted in an average of 8.11% of the collections being utilized for crop improvement by AVRDC breeders (Table 16). Many of the identified traits for biotic and abiotic stress, adaptability and yield had been combined together.

Mungbean Utilization and Evaluation

From 1972 to 1985, 4,200 crosses were done by the AVRDC mungbean breeders. Of these, 114 elite crosses have been selected which involved 39 accessions in their parentages.

The 10 best female parents in descending order are: V 2773, V 2272, V 3476, V 1947, V 1411, V 1945, V 1944, V 1380, V 2184 and V 2273 while the 10 best male parents are: V 2773, V 2184, V 3476, V 2273, V 2272, V 1394, V 1400, V 1945, V 1947 and V 1411. The best parents in descending order are: V 2773 (16.93% of the total number of times represented), V 2272 (8.47%), V 3476 (8.47%), V 2184 (8.24%), V 1947 (5.72%), V 2273 (5.72%), V 1411 (5.26%), V 1945 (5.26%), V 1944 (4.35%), V 1394 (4.11%) and V 1400 (4.11%).

The materials from the Philippines are represented 251 times (57.4 %) out of a total of 437 and that from India 167 times (38.2%). The rest (U.S.A., China, Korea, Taiwan and Sri Lanka) were represented minimally. The best parent, V 2773, from India occupies 16.9% of the total number of times represented.

Table 16. Number of accessions and percentage of each collection used in AVRDC breeding programs.

Crop	Period	Total crosses	Number of accessions used			
			As female	As male	As female or male	% of collection
Mungbean	1972-85	4,200	262	274	343	6.72
Tomato	1972-85	6,045	–	–	373	6.98
Soybean	1973-86	2,487	–	–	501	4.29
Sweet potato	1973-87	1,875	132	92	135	11.37
Chinese cabbage	1973-87	374	–	–	90	11.19

Since V 5000 (Shanhua 1) was selected from V 2773, the combination of V 2773 and V 5000 is 19.2%. V 2272 (ML-5) and V 2273 (ML-6), both from India and probably related, represent 14.4%. Also, both V 1381 and V 1944 which represent 6.6% are progenies of MG50-10A except for seed color difference, which is green and yellow, respectively. V 1945 and Glabrous *3, a progeny of MG50-10A (V 1381 and V 1944), represent 11.9%. The top 11 parents account for 76.6% of the elite gene pool.

In general, the Indian materials provided the disease resistance for the elite crosses gene pool, and the materials from the Philippines provided yield potential, earliness, uniform ripening and photoperiod insensitivity.

At AVRDC the germplasm are constantly being evaluated for specific genes so that breeders can broaden the base of the breeding gene pool. Since 1972, a series of accessions were identified for pest and disease resistances and good agronomic characters. The results are summarized in Table 17. Some of these genes were very successfully combined by breeders at AVRDC resulting in several named cultivars.

Table 17. Potential accessions from the world mungbean collection (extracted from AVRDC Annual and Progress Reports, 1974 to 1986).

Character	Accession (V)	Sources	Country/Inst. Reporting
Cercospora canescens resistance (CLS)	1445, 1471, 2272, 2757, 2773, 3274, 3276, 3279, 3501, 4679[z], 4706, 4717[z], 4718, 5036	Afghanistan India, Indonesia Korea	AVRDC, several years
	3417, 4483	India	India Punjab, 1979
Cercospora cruenta[y] resistance	1276, 1353, 1483	France, India, Indonesia	Tanzania, 1980
Erysiphe polygoni resistance (PM)	1104, 2159, 3911, 3912, 4186, 4189, 4207, 4574, 4584, 4631, 4658, 4662, 4668, 4679, 4717[z], 4799, 4883, 4966, 4967, 4990	Afghanistan, Australia, India	AVRDC, several years
Rhizoctonia solani[y] resistance (damping off)	1103, 1446, 1877	India Indonesia	AVRDC, 1976 AVRDC, 1977
Macrophomina phaseolina[y] resistance (Charcoal rot)	3404, 3476, 3484	Pakistan, Philippines, Thailand	Sri Lanka, 1979
Pseudomonas phaseolicola[y] resistance (Halo-blight)	1042	Thailand	Ethiopia, 1982
Xanthomonas campestris[y] pv. *phaseoli* resistance (Bacterial leaf spot)	2089, 2164, 2165	Australia	AVRDC, 1974
Leaf crinkle virus (LCV)[y]	3417, 4483	India	India Punjab, 1979
Mungbean yellow mosaic[y] virus (MYMV)	2273, 2773, 3404, 3417, 3484, 3485, 3486, 3487, 4483	India, Pakistan, Thailand	Bangladesh Noakhali, 1978 Bangladesh BARI, 1980 Bangladesh, 1979 India Punjab, 1979
	1729, 1735, 2366, 2500, 2551	India	India ICRISAT, 1974
Mungbean cucumber mosaic[y] virus (MBCMV)	1868, 2010, 2040, 2043, 2357, 2650, 2866, 2867, 2984, 3476, 3686, 4184, 4842	China, India, Korea, Philippines, USA	AVRDC, 1985
Mungbean mottle virus[y]	1114, 1133, 1153, 1227, 1337, 1353, 1562, 1595, 1672, 1673, 1682, 1693, 1696, 1745, 1811, 1831, 1878, 1972, 1976, 2082, 2194, 2260, 2310	Afghanistan, China, France, India, Iran, Philippines, Taiwan, USA	AVRDC, 1985
Aphis craccivora (cowpea aphids)	1381, 1944, 2184	Philippines	AVRDC, 1976
Ophiomyia species resistance (beanflies)	2396, 3495, 4281, 1160 (V. glabrescens)	India, Philippines	AVRDC, several years
Maruca testulalis resistance (podborer)	2135 (V. mungo)	Australia	AVRDC, 1979

Table 17. Continued.

Character	Accession (V)	Sources	Country/Inst. Reporting
Callosobruchus chinensis resistance (Bruchid)	VM 2011, VM 2164 (both *V. mungo*)		AVRDC, 1980
Meloidogyne incognita resistance (Root-knot nematode)	1133, 1412, 1709, 2010, 2179, 2744, 2773	China, India, Iran, Philippines	AVRDC, 1978 AVRDC, 1979
Early and uniform maturity	6027, 6037, 6078, 6080, 6083	India, USA, USSR	AVRDC, 1982
Photoperiod insensitive	1381, 3726	Philippines, India	AVRDC, 1983
Better compatibility with black gram	4997, 6085, 6099	India	AVRDC, 1982
Possible flood tolerance	1968, 2984, 3092, 3372	India, Korea, USA	AVRDC, 1978
Possible cold tolerance	2984, 1968	Korea, USA	New Zealand, 1979
Possible drought tolerance	1281, 1947, 2013, 2984, 3372, 3388, 3404, 3484	India, Korea, Pakistan, Philippines, Taiwan, USA, Thailand	AVRDC, 1978 Bangladesh, 1979
High yield potential	1380, 1381, 1388, 1776, 1944, 1948, 1968, 2007, 2010, 2013, 2184, 2272, 2273, 2773, 2808, 2984, 3092, 3388, 3404, 3476, 3484, 3726, 4956	China, India, Iran, Korea, Philippines, Pakistan, Taiwan, Thailand, USA	Different countries
Multifoliate leaf (9 leaflets)	5926	Philippines	Philippines, 1979
Lobed leaf	1270, 1834, 1837, 1840, 1841, 1869, 1870, 1871, 1910, 1922, 1937, 2216, 2939, 3030, 4183, 5108	India, Korea, Philippines	AVRDC, 1984

[z]Tested in Indonesia, Korea, Philippines, Taiwan and Thailand. [y]Reported to have tolerance or resistance.

Soybean Utilization and Evaluation

From 1973 to 1986, 2,487 crosses were done by AVRDC soybean breeders. Of these, 326 AGS lines were selected which involved 119 accessions in their parentages.

The 10 best female parents in descending order are: G 02120, G 00057, G 00086, G 00038, G 00069, G 01994, G 00016, G 01322, G 00067 and G 00017. The 10 best male parents are: G 02120, G 00057, G 00015, G 00044, G 02042, G 00086, G 02038, G 00038, G 01322 and G 00008. The best parents in descending order are: G 02120 (10.23% of the total number of times represented), G 00057 (6.27%), G 00086 (5.44%), G 00038 (4.12%), G 01322 (3.79%), G 02042 (3.46%), G 00069 (2.97%), G 01994 (2.8%), G 00058 (2.31%), G 00015 (2.14%), G 00044 (2.14%) and G 02038 (2.14%).

The most represented parent is G 02120 (1039) from Indonesia. It is small-seeded with high-yielding potential but it is very sensitive to photoperiod. Through mutation breeding, the breeders were able to select 24 not so photoperiod-sensitive AGS lines from this accession.

The materials from Taiwan (including 25 improved cultivars and other local cultivars, e.g. Shih Shih) play a very important role in the improvement of soybean at AVRDC. Together, they represent 239 times out of a total of 606 or 39.46% of the parentages. The other group of significant importance is the improved cultivars from the U.S.A. which represent 17.82% of the parentage. The top 12 parents account for 47.81% of the elite gene pool.

It is also very interesting to note that the list of parents identified in 1976 (Table 18) eventually accounted for 43.36% of the elite parent gene pool.

Table 18. Parents used in the soybean hybridization program AVRDC, 1976.

AVRDC acc. no.	Plant characteristics
G 00038	Early, resistance to downy mildew and soybean mosaic virus (SMV)
G 00057	Soybean rust tolerance, high yield
G 00086	High yield, wide adaptability, nonshattering
G 00215	Early, photoperiod insensitivity, medium stable yield
G 01322	Early, photoperiod insensitivity, medium stable yield
G 02042	Resistance to SMV, tolerance to soybean rust, good yield
G 02120	High yield, short internodes, profuse acute branches, good root system
G 02134	Adapted high yielding in Indonesia G 02502 Early, photoperiod insensitivity
G 02506	High yield, narrow leaf, three-seeded pods, good seed quality
G 05088	Early, photoperiod insensitivity, large seed
G 05092	Short internode, large seed size
G 07484	Early, photoperiod insensitivity, good seed quality
G 07485	Early, photoperiod insensitivity, good seed quality
G 07958	Reported as resistant to soybean rust in India
G 08586	Moderate resistance to soybean rust, good seed quality
G 08587	Moderate resistance to soybean rust, good seed quality

Sweet Potato Utilization and Evaluation

From 1973 to 1987, 1,875 crosses were done by the sweet potato breeders. From these crosses, 210 elite clones were selected, involving 60 accessions in their parentages. Out of the 60 accessions only 40 were used as female and 42 as male.

The three most important parents are: I 0057 (Tainung No. 57 from Taiwan), I 0117 (Fatena - PI 344129 from Papua New Guinea) and I 0122 (B-6708 from U.S.A.) which account for 10.45%, 15.05% and 16.26% of the total elite parent gene pool, respectively. Together, they represent 41.76% of the total. They were equally used both as female and male parents. The other important accessions utilized as parents are: I 0010 and I 0015 which are the H-D-K clones from Laos; I 0152 and I 0157 from Taiwan; and I 0232, I 0306 and I 0307 from Japan.

The seven important female parents in descending order are: I 0117, I 0122, I 0057, I 0306, I 0152, I 0015 and I 0361. The important male parents are: I 0057, I 0017 and I 0122.

Evaluation in 1987

I. Tomato

Summary

A total of 5,071 entries from 5,031 accessions were screened for resistance to Cercospora leaf spot as described in the report of Dr. E. M. Saadaoui on "Screening of the AVRDC tomato germplasm collection for resistance to Cercospora leaf spot (*Cercospora fuligena*)".

The disease reaction was classified into five categories as follows: (1) resistant (r), (2) moderately resistant (mr), (3) moderately susceptible (ms), (4) susceptible (s) and (5) highly susceptible (hs). The variation in reaction of the AVRDC tomato collection to this disease is shown in Table 19. Most of the germplasm are susceptible to this disease. However, about 11% indicated certain levels of resistance. The 37 accessions classified as resistant are listed in Table 20. About half of this group are wild species. The 42 highly-susceptible accessions are listed in Table 21. Precaution should be observed when using this highly susceptible group of materials in breeding for tropical tomato.

Table 19. Reaction of AVRDC's tomato collection to Cercospora leaf spot (*Cercospora fuligena*).

Disease reaction category	R[z]	MR	MS	S	HS
Number of entries	37	549	656	3,787	42
% of total	0.7	10.8	12.9	74.7	0.8

[z]R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible and HS = highly susceptible.

Table 20. List of accessions resistant against Cercospora leaf spot (*Cercospora fuligena*).

AVRDC acc no.	Name/PI no.	Species	Origin/Source
L00733	PI 127827	Hirsu	Peru
L00734	PI 127828	Peruv/humi	Peru
L01064	PI 134417	Hirsu	Ecuador
L01065	PI 134418	Hirsu	Ecuador
L01352	PI 180721	Escu	Germany
L01533	PI 205012	Pimp	Peru
L01558	PI 205037	Escu	USA
L01668	PI 224580	–	USA
L01688	PI 224710	Pimp	Mexico
L01696	PI 231257	Chees-min	Calapagos Islands
L01731	PI 250124	Escu	Netherlands
L01777	PI 254655	Escu	Canada
L02102	PI 270432	Escu	Mexico
L02116	PI 270446	Pimp	Mexico
L02119	PI 270449	Pimp	Mexico
L02120	PI 270450	Pimp	Mexico
L02851	PI 287109	Escu	Canada
L02888	PI 289212	Escu	Hungary
L02926	PI 289250	Escu	Hungary
L03050	PI 296363	Escu	USA
L03233	PI 306814	Escu/peruv	USA
L04034	(7879 x Atom) F7	Escu	Australia
L04089	Macero	Escu	Taiwan
L04143	Malintka	Escu	USA
L04167	LA 1591	Pimp	USA
L04220	PI 378994	Escu	Peru
L04253	PI 379039	Chees	Ecuador
L04405	PI 390699	Pimp	Peru
L04414	PI 390708	Pimp	Peru
L04455	PI 390751	Pimp	Peru
L04506	PI 406770	Escu	Costa Rica
L04569	PI 406867	Escu	Honduras
L04765	UC x 100-15-2 F7	Escu	USA
L04815	Z 1072 - NE 4	–	USA
L04930	PI 419092	Escu	China
L05184	PI 433120	Escu	China
L05235	PI 433171	Escu	China

II. Chemical Analysis of Sweet Potato

Summary

Tubers of 734 entries from the AVRDC sweet potato germplasm collection (1985/86 season) were analyzed for dry matter, fiber, protein, starch and sugar contents with a Near-IR analyzer. Wide variations were found in all the tuber chemical characters studied. I 362 had starch content up to 78%, I 954 had dry matter content of about 42%, I 963 had protein content of 11.08% and I 122 had sugar content of 27.14%. I 498 had a low sugar content of 8.78% only.

Table 21. Accessions highly susceptible to Cercospora leaf spot (*Cercospora fuligena*).

AVRDC acc no.	Name/PI no.	Species	Origin/Source
L00061	(TRxVC 48-1)-13-1-1 F5	Escu	Philippines
L00087	VC 6-1-1 P	Escu	Philippines
L00194	LA 403	Escu	Peru
L00532	PI 118785	Escu	Venezuela
L00647	PI 126452	Escu	Peru
L00658	PI 126915	Escu/pimp	Peru
L00660	PI 126917	Escu	Peru
L00702	PI 127795	Escu	Peru
L00703	PI 127796	Escu	Peru
L00785	PI 128257	Escu	Bolivia
L01128	PI 143522	Pimp	Peru
L01343	PI 179367	Escu	Iraq
L01420	PI 193421	Escu	USA
L01540	PI 205019	Escu/pimp	USA
L01577	PI 206967	Escu	Turkey
L01583	PI 208837	Escu	Cuba
L01605	PI 212415	Escu	USA
L01621	PI 212432	Escu	USA
L01893	PI 262173	Escu	Germany
L01903	PI 262930	Escu	USSR
L01955	PI 269512	Escu	W. Pakistan
L01957	PI 269514	Escu	W. Pakistan
L02129	PI 271382	Escu	India
L02145	PI 272630	Escu	El Salvador
L02190	PI 272679	Escu	El Salvador
L02548	PI 273038	Escu	El Salvador
L02583	PI 273073	Escu	El Salvador
L02756	PI 283914	Escu	Czechoslovakia
L03400	PI 330336	Escu	Japan
L03424	PI 339328	Escu	Turkey
L03427	PI 339331	Escu	Turkey
L03680	PI 365900	Escu	Ecuador
L04047	Rideaw	Escu	India
L04340	PI 390490	Escu	Ecuador
L04521	PI 406800	Escu	El Salvador
L04601	PI 406899	Escu	Honduras
L04602	PI 406900	Escu	Honduras
L04851	PI 407438	Escu	Australia
L04852	PI 407439	Escu	Australia
L04857	PI 407445	Escu	Bulgaria
L04889	PI 408971	–	India
L05064	PI 433000	Escu	China

Introduction

Sweet potato has good yield potential and is an important source of both starch and vitamin A (β-carotene). With the changing emphasis on the use of sweet potato tuber both as food and feed, it is, therefore, important to analyze the variations in the chemical constituents of each accession. This will provide the sweet potato scientists with reference information.

Materials and Methods

Tubers of 734 entries from the 1985/86 cropping season were sent to the Chemistry Department for analysis of dry matter, fiber, protein, starch and sugar contents with a Near-IR analyzer.

Results and Discussion

The distribution of dry matter, fiber, protein, starch and sugar, expressed in percentage of dry weight, are shown in Figure 1. The mean, coefficient of variation, range, skewness and kurtosis are given in Table 22. The correlations between the characters are shown in Table 23.

Wider variations were present in all the tuber chemical characters analyzed. Accession I 362 (Sta. Fe from Indonesia) had a starch content of up to 78%, I 954 (K 9 from Papua New Guinea) had a dry matter content of about 42%, I 963 (W-154 from U.S.A.) protein content of 11.08% and I 122 (B-6708 from U.S.A.) a sugar content of 27.14%. I 498a & Nik (5-Mun) from Papua New Guinea had low sugar content (8.78%).

The 20 accessions with high dry matter content in descending order are: I 954, I 361, I 578, I 489, I 579, I 723, I 715, I 440, I 450, I 711, I 745, I 840, I 387, I 879, I 579, I 861, I 607, I 872, I 596 and I 867.

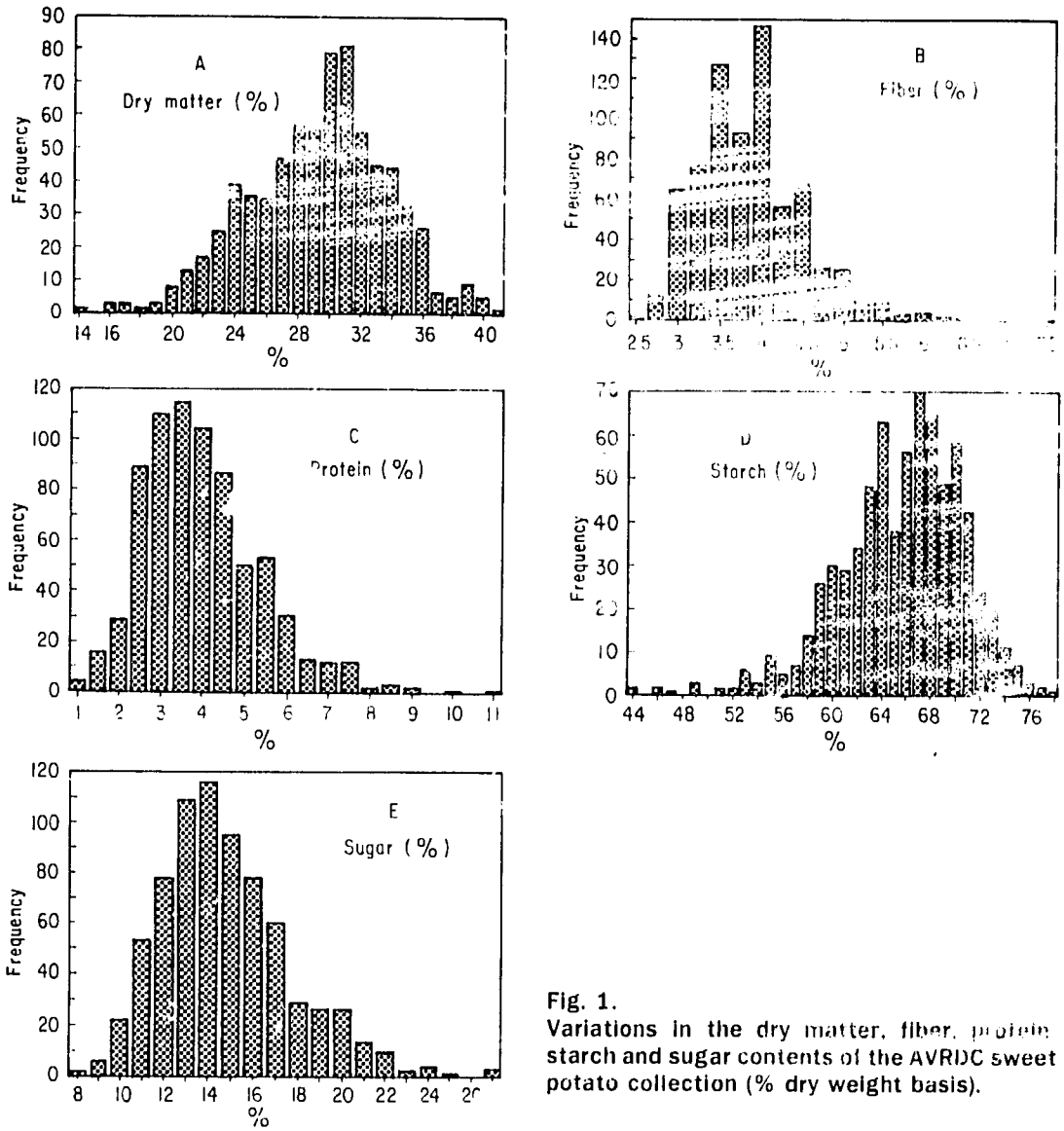

Fig. 1.
Variations in the dry matter, fiber, protein starch and sugar contents of the AVRDC sweet potato collection (% dry weight basis).

The 20 accessions with low fiber content in ascending order are: I 585, I 281, I 381, I 552, I 559, I 819, I 89, I 155, I 338, I 755, I 772, I 861, I 1039, I 1156, I 158, I 204, I 274, I 282, I 283 and I 322.

The 20 accessions with high protein content in descending order are: I 963, I 684, I 1104, I 1, I 122, I 867, I 121, I 940, I 35, I 1186, I 841, I 1125, I 447A, I 933, I 961, I 146, I 870, I 144, I 214 and I 264.

The 20 accessions with high starch content in descending order are: I 362, I 723, I 302, I 204, I 1029, I 872, I 263, I 871, I 585, I 274, I 338, I 414, I 276, I 202, I 874, I 552, I 559, I 94, I 159 and I 281.

The 20 accessions with high sugar content in descending order are: I 122, I 1010, I 349, I 1069, I 119, I 121, I 984, I 470, I 82, I 1080, I 36, I 1104, I 324, I 1117, I 177, I 1071, I 822, I 60, I 395 and I 1076.

The 20 accessions with low sugar content in ascending order are: I 498, I 587, I 86, I 872, I 354, I 90, I 63, I 216, I 150, I 151, I 970, I 123, I 585, I 66, I 1198, I 94, I 451, I 155, I 362 and I 53.

The correlation study indicated that protein may not be linked to sugar and dry matter content. However, high protein materials may have higher fiber and lower starch content. High sugar content materials have low starch and dry matter content. As in protein, high sugar content clones probably also have higher fiber. High starch clones have low fiber and high dry matter content. High fiber clones probably have lower dry matter content.

Further studies have to be carried out to estimate the variation between seasons and years.

Table 22. Descriptive statistics of chemical constituents of sweet potato tubers in AVRDC sweet potato collection.

Characters	Mean	CV[7]	Minimum	Maximum	Skewness	Kurtosis
Dry matter	29.87	14.79	14.79	41.98	-0.27	0.02
Fiber	3.99	16.39	2.70	7.60	1.00	2.26
Protein	4.22	33.33	1.34	11.08	0.91	1.43
Starch	66.08	7.71	44.59	78.02	-0.78	1.30
Sugar	15.26	19.53	8.78	27.14	0.81	0.95

[7]Coefficient of variation.

Table 23. Correlation between the tuber constituents in the AVRDC sweet potato germplasm (all correlation coefficients are significant at p = 0.0001 level).

	Sugar	Starch	Fiber	Dry matter
Protein	0.20712 0.0001	-0.55628 0.0001	0.62675 0.0001	-0.23538 0.0001
Sugar		-0.75882 0.0001	0.61363 0.0001	-0.73777 0.0001
Starch			-0.84921 0.0001	0.62436 0.0001
Fiber				-0.51407 0.0001

Germplasm Recipients

Anguilla (UK)

Corito Trading Co., Ltd.

Argentina

Agrotecnica Trebol Sur S.R.L.
Instituto Nacional de Tecnologia Agropecuaria
Universidad Nac. de Tuc.

Australia

Gatton Redland Horticulture Research Station
Horticulture Research Station
Pacific Seeds
Redlands Horticultural Research Station

Bangladesh

BARI
MCC
Institute of Postgraduate Studies in Agriculture

Barbados

CARDI

Belize

CARDI

Bhutan

Centre for Agricultural Research and Development
Department of Agriculture

Brazil

EMBRAPA-CENARGEN
EMBRAPA-UAPNPBS-RIO de Janeiro
University Federal de Viçosa

Brunei

Ministry of Development

Burma

UNDP
IRRI/Burma Program

Cambodia

Church World Service

Canada

Agriculture Canada
Plant Gene Resources of Canada
University of Guelph

Cape Verde Islands

Instituto Nacional de Investigãçao Agraria (INIA)

Chile

FAO

Colombia

Agrotrading Import & Export Corp. (ATRIMEXCO)
CIAT

Cook Islands

Totokoitu Research Station

Costa Rica

Centro de Asesoria e Investigación Biologica y Agricola
Coalicion Costarricense de Iniciativas de Desarrollo (CINDE)
Finca Selvamar
Mision Technica Agricola De Taiwan
San Joaquin de Flores Heredia

Cuba

Instituto Nacional de Ciencias Agricolas (INCA)

Dominica

Agricultural Technical Mission

Dominican Republic

Centro Sur de Desarrollo Agropecuario (CESDA)
Enda - Caribe

Egypt

Field Crops Research Institute
Minufiya University

El Salvador

Agricultural Technical Mission

Ethiopia

Bako Research Centre
JOCV/Ethiopia
Nazrek Agricultural Research Station

Fiji Islands

Legalega Research Station
Ministry of Primary Industries
Sigatoka Research Station
Vuda Garden Ltd.

France

Andre Blondeau Selectionneur-Obtenteur
Clause Seed Company
Ecole nationale superieure agronomique
INRA

Germany, Democratic Rep. of

Zentralinstitut für Genetik und Kulturpflanzenforschung

Germany, Federal Rep. of

Bayer AG
Biologische Bundesanstalt für Land und Forstwirtschaft
University of Bonn

Ghana

Agricultural Services Co-operative Society Ltd.
Nyankpala Agricultural Experiment Station
Tanyigbe Atidze Community Farms

Guadeloupe (France)

Centre de recherches agronomiques des Antilles et de la Guyana

Guam (USA)

University of Guam

Honduras

Oficina de la Mision Tecnica del Japon
La Escuela de Agricultura

India

Aligarh Muslim University
Ankur Agricultural Research Laboratory
Assam Agricultural University
AT & PO Bonand
Central Agricultural Research Institute
Central Experiment Station
Coromandel Indag Products India (P) Ltd.
Department of Genetics & Plant Breeding
Family Planning Association of India
Farm & Home Consultancy Service
Farm Seeds
Fredrick Institute of Plant Protection and Toxicology
Haryana Agricultural University
I/C, Scheme for Research on Vegetable Crops
IARI
Institute of Advanced Studies, Merrut
ISNAR
Lakhnu Pura Rural Integrated Project
Nath Seeds Private Ltd.
NBPGR
National Pulses Research Centre
PAK-College of Agriculture
Punjab Agricultural University
Regional Research Station/TNAU
Rural Leprosy Trust
Sheetal Hybrid Seeds Company
Tagore Society for Rural Development
The University of Agricultural Sciences

Indonesia

AARD/ISNAR
Agricultural Technical Mission
Akademi Farming Semarang
Balittan Sukamandi (SURIF)
Centre for the Application of Isotopes and Radiation
Horticulture Research and Development Centre, Lembang
Indonesia/AVRDC Bilateral Project
Lembang Horticultural Research Institute (LEHRI)
Malang Research Institute for Food Crops (MARIF)
Nutrition Research and Development Centre
Sub Balai Pasar Miring
Universitas Merdeka Madium
University of Merdeka

Iran

Seed and Plant Improvement Institute

Iraq

Agriculture and Water Resources Research Centre

Israel

NIRIT Co.

Jamaica

FAO
Irwin
University of the West Indies

Japan

Agricultural Research Center
Fukuoka Pref. Federation of Agricultural Cooperatives
Ibaraki-Ken Horticultural Experiment Station
Kagome Co., Ltd.
Kagoshima Agricultural Experiment Station
Kochi University
Morioka Branch, Vegetable & Ornamental Crops Research Station
Nagano Chushin Agriculture Experiment Station
Nagasaki Agricultural Association
Ogasaware Sub-Tropical Agricultural Center
Okinawa Sekiyu Seisei Co., Ltd.
Sakata Seed Co., Ltd.
Taiyo Consultants Co., Ltd.
Takarazuka Research Center
The University of Tokyo
Tokyo Agricultural University
Tsukuba International Agricultural Training Center, JICA

Jordan

Eastern Company

Kenya

National Dryland Farming Research Station

Kiribati

Engelhardt Training Centre

Korea, Rep. of

Cheju National University
Chon-Buk Rural Development Administration
Dongwon Nongsan Seed Co.
Gyeongsang National University
Horticultural Experiment Station, Rural Development Administration
Jeju Provincial Office of Rural Development
Provincial Rural Development Administration (PRDA)
The Chonnam Provincial Rural Development Administration

Lebanon

American University of Beirut

Liberia

AVSPP/NCRDP
Lowland - NCRDP
NCRDP - Saolepea

Madagascar

Madagascar - IRRI

Malawi

Bvumbwe Research Station

Malaysia

Agriculture Research Centre
MARDI
Universiti Pertanian Malaysia

Maldives

Kandhu Edhuruge

Marshall Islands

Agricultural Technical Mission in Marshall Island

Mauritius

Farming Society

Mexico

Centro de Investigaciones Agrícolas del Golfo Centro
SARH, Inst. Nacional de Investigaciones Agrícolas

Namibia

Ju/wa Bushman Development Foundation

Nepal

HMG/FAO Vegetable Seed Production Project
Institute of Agriculture and Animal Sciences
PADCO
Rural Development Centre
Secretariat of National Agricultural Research
The United States Mission to Nepal
Tribhuvan University
Vegetable Development Division

Netherlands

Bejo Zaden B.V.
Bruinsma Seeds B.V.
Deruiter Zonen B.V.
Glasshouse Crops Research & Experiment Station
Royal Sluis B.V.
Sluis & Groot Research, Zaadunie B.V.

Niger

Institut pratique de development rural (IPDR)

Nigeria

Ahmadu Bello University
Anambra State University of Technology
IITA
Ministry of Agriculture and Natural Resources
Nosamag Farms (Nig.) Ltd.
Okapuala Cooperatives
Omorogbe Farms Ltd.
Shell Petrot-Dev. Corp. Nig. Ltd.
UNDP/FAO Project NIR/84/014

Niue Islands

Dept. of Agriculture & Fishery

Pakistan

Agricultural Research Institute
National Agricultural Research Centre
Nuclear Institute for Agriculture and Biology
STM International

Panama

Nestle Panama, S.A.

Papua New Guinea

Division of Primary Industry
Laloki Agricultural Research Station
Pacific Adventist College (PAC)

Peru

Estacion Experimental Agropecuaria
Estacion Experimental Baños del Inca

Philippines

Asian Farming Systems Network/IRRI
AVRDC/POP
Benguet State University
Bohol Agricultural Promotional Center
Don Mariano Marcos Memorial State University
Institute of Plant Breeding
IRRI
Mariano Marcos State University
Mindanao State University
Ministry of Agriculture and Food
Negros Forest & Ecological Foundation Inc.
Nestle Philippines, Inc.
Northern Mindanao State Institute of Science & Technology
Panay State Polytechnic College
Pangasinan State University
Phil-nut Product & Food Industry
Rizal College of Agriculture & Technology
Second Laguna de Bay Education Project, Reforestation Component
University of Eastern Philippines
University of the Philippines at Los Baños
Visayas State College of Agriculture

Polynesia, French

CIRAD

Portugal

Universidade de Evora

Saipan

Northern Mariana College

Samoa, American

American Samoa Community College

Saudi Arabia

Community Development Consultants (CDC)
Tabuk Agricultural Development Co. (TADCO)

Senegal

Institut senegalais de recherches agricoles

Seychelles

Grand'Anse Experimental Centre

Singapore

Eastreco (Pte.) Ltd.
World Farm Col, Ltd.

South Africa

University of Stellen Bosch

Sri Lanka

Agricultural Research Station
Israel Interests Section
Department of Agriculture
Development Alternatives, Inc.
Tea Research Institute
Tropical Sunblest Fruit Company

St. Lucia

CARDI

Swaziland

Agricultural Technical Mission
University of Swaziland

Switzerland

NeSTEC - TAGR.

Tahiti (France)

CIRAD

Taiwan, China

Academia Sinica
Chiayi Agricultural College
Fu Jen University
Hwalien DAIS
Known You Seed Company
National Chiayi Institute of Agriculture
National Chung Hsing University
National Taiwan University
Taichung DAIS

Tanzania

Ilonga Agricultural Research Institute
Kilombero Sugar Co. Ltd.

Thailand

Northern Regional Agriculture Development Centre
Chainat Field Crops Research Centre
Chia Tai Co., Ltd.
Chiangmai University
College of Agriculture
East-West Seed Company
Field Crops Research Institute
Kasetsart University
Maejo Institute of Agricultural Technology
Oxfam-Belgique
Prince of Songkhla University
Srisamrong Field Crop Experiment Station
Thailand Institute of Scientific and Technological Research TOP/AVRDC

Togo

Ecole sup. d'agronomie

Trinidad

Caribbean Chemicals and Agencies Ltd.
The University of the West Indies

Turkey

Cumhuriyet University

United Kingdom

L.W. Lambourn & Co.

USA

AID - Wyoming Team
Asgrow Seed Company
Campbell Inst. for Research and Technology
Eagle Seed Co.
Ferry Morse Seed Co.
Harris Moran Seed Co.
Heinz USA
Hort. Science Institute, USDA
Land O'Lakes, Inc.
Mississippi Agr. & Forestry Expt. Station
Northrup King Company
Oklahoma State University
Oregon State University
Peto Seed Co., Inc.
Richfield Packing Co., Inc.
Seedcrast, Inc.
University of California
University of Arizona, Tucson

Uganda

Luweero Rural Development Coop. Society Limited
Makerere University

Vanuatu

Matevulu College
Tagbe Agricultural School

Vietnam

University of Cantho

Yemen Arab Rep.

Ministry of Agriculture & Agrarian Reform

Yugoslavia

University E. Kardelj, Ljubljana

Zaire

Agriculture fruits et legumes, s.p.r.l.

Zambia

Mwapula Research Estates
National Irrigation Res. Sta.
Zambia Seed Co., Ltd.

Zimbabwe

Chiredzi Research Station

Information Services

Publications

The primary manner that the Office of Information Services (OIS) accomplishes its communication function is by publication of AVRDC's research and development work.The publication process consists of the following distinctive stages: (1) writing of the manuscript; (2) editing; (3) preparation of camera-ready copy for printing; (4) printing; and (5) distribution. During 1987 OIS completed the publication process for 42,622 copies of 29 different publications which contained a total of 2,062 pages (Table 1). This represents an increase of approximately 10% more output of the key indicator in publications, i.e. number of camera-ready pages, over 1986. By year-end two publications with 359 pages were prepared to the camera-ready stage and were ready to print; two publications with a total of 550 pages were through with the editing process; and the manuscripts were written for another four documents.

Journal Publication and Symposium Presentations

During 1987 a total of 13 journal papers, written by AVRDC scientists, were published and 11 articles were prepared for publication (Tables 2 and 3). Also during the year 24 symposium presentations were made by AVRDC scientists (Table 4). Other articles/items published are listed in Table 5.

Editing/Authoring Services

During 1987 OIS authored one issue of the *Centerpoint* newsletter and compiled the *1986 Progress Report Summaries*. It also edited 16 major documents, 3 issues of periodicals, 22 journal papers, 93 symposium presentations, 6 brochures and 40 informal documents (Tables 1, 2 and 3).

Publication Activities

- Copublication I: AVRDC had made a copublication arrangement with the Technical Centre for Agricultural and Rural Action (CTA) and the Agence de coopération culturelle et technique (ACCT) to publish AVRDC's *Sweet Potato Proceedings* in French. During the year the manuscript was typeset and was in press at year-end.
- Copublication II: In another copublication venture, a contract was signed between AVRDC and Wiley Eastern, Ltd., New Delhi to copublish N.S. Talekar's monograph entitled *Agromyzid Flies of Food Legumes in the Tropics*. The contract stipulates that Wiley Eastern, Ltd. will publish the work and distribute it through the John Wiley network worldwide; the author will be responsible for reviewing all editorial work done by the publisher; AVRDC will provide all graphics, check the quality of the materials to be utilized and purchase sufficient copies of the work for its own distributive network; and the royalties of the work will be equitably divided between the author and AVRDC.

Public Awareness

During 1987 many articles about AVRDC's activities appeared in the local press and in the press of many national programs which specialize on agricultural development issues. Much of the basic

Table 1. AVRDC publication schedule in 1987.

Author/ Editor	Publication	No. of copies	No. of pages	Total no. of pages	TVIS[z]	Quarter published
	Documents					
Lastimosa	1984 Progress Report	900	-	442,800		1st
McLean et al.	Soybean Cropping System (rev. ed.)	2,500		1,260,000		1st
Talekar	Insect Pests of the Sweet Potato Crop in Java (translation)	2,000	28	56,000		1st
Caldwell	TB 16 Assessing Rainy Season Vegetable Production Alternatives	1,500	40	60,000	x	2nd
Marlowe	AVRDC Accomplishments, Goals and Structure	500	27	13,5003		3rd
Yoon et al.	Int. Coop. Guide Chinese Cabbage Cultural Practices in the Tropics (rev. ed.)	1,500	6	9,000	x	3rd
P.L. Hwang et al.	Soybean Rust Bibliography: 1895-1986	1,500	112	168,000	x	3rd
Sundar, Lastimosa, Llemit	Soybean Varietal Improvement	1,500	104	156,000	x	3rd
Sundar/McLean	Abstracts, 2nd International Mungbean Symposium	330	48	15,840	x	4th
-	Notebook, 2nd International Mungbean Symposium	250	50	12,500	x	4th
Soderlund/ Mclean	1986 Progress Report Summaries	2,000	102	204,000	-	4th
Lastimosa	1985 Progress Report	900	473	425,700		4th
Llemit, Lastimosa	Gardening Nutritious Vegetables	-	100	-	-	--
Saadaoui et al.	Mungbean Bibliography	-	250	-	x	-
	Subtotal	15,380	1,340	2,823,340		
	Periodicals					
McLean/Llemit	AVRDC Newsletter (weekly)	200	216	43,200		1st-4th
McLean	TVIS News, Vol. 2, No. 2	1,500	86	129,000	x	2nd
Tschanz, Sundar, Llemit	Soybean Rust Newsletter, Vol. 8	1,500	24	36,000	x	2nd
McLean	Centerpoint, Vol. 6	8,200	8	65,600		4th
	Subtotal	11,400	334	273,800		
	Brochures/Announcements					
Sundar	Soybean & Mungbean Directory Questionnaire	3,000	3	9,000	x	1st
Castro	Comparative Technology Training Leaflet	500	3	1,500		2nd
Sundar	2nd Int'l Mungbean Symposium Final Announcement	350	3	1,050	x	2nd
Castro	Training Brochure	8,000	3	24,000		2nd-4th
McLean	Publication Lists		7	12,000		2nd-4th
Yoon	Chinese Cabbage Directory Questionnaire	2,600	3	7,800	x	3rd
Green	Tomato/Pepper Symposium Final Announcement	375	3	1,125		3rd
Green	Sweet Potato Phytosanitary Statement	200	2	400		4th
	Subtotal	15,025	27	56,875		
	Reprints					
-	Frontiers for Science & Technology in Vegetable	200	20	4,000		1st
-	International Cooperators' Guides	1,017	28	28,467		1st
-	Chinese Cabbage Proceedings	500	500	250,000	x	2nd
	Subtotal	1,717	548	282,467		
	Total	43,522	2,249	3,436,482		

[z]An x indicates that publication is part of the Tropical Vegetable Information Services (TVIS) project

information for these news items came from AVRDC's publicity activities, such as personal encounters with journalists, press releases and the *Centerpoint* newsletter. During the year OIS issued two press releases, one on the release of several new AVRDC-developed varieties, and the other on the Second International Mungbean Symposium and the five new AVRDC mungbean releases announced during the proceedings. OIS prepared hundreds of briefing kits for VIP visitors to the Center and continued to systematically prepare information kits for senior staff to use during overseas travel. These kits contain small quantities of the most recent *Centerpoint* newsletter, the new *Advanced Training Opportunities at AVRDC* brochure, upcoming symposia announcements, the VIP questionnaire, directory questionnaires, and the postcard used for the mailing list data base. OIS also ran the slide show in the auditorium for 117 groups of visitors during 1987.

Table 2. Journal articles published in 1987.

Author(s)	Title	Journal
S.-H. Choi, Green, D.-R. Lee and Yoon	Incompletely dominant single resistance gene for peanut stripe virus in soybean line AGS 129	Euphytica 40:193-197
S.K. Green Y.-J. Kuo and D.-R. Lee	Uneven distribution of two potyviruses (feathery mottle virus and sweet potato late virus) in sweet potato plants and its implication on virus indexing of meristem derived plants	Trop. Pest Mgt. 34(3): 298-302
S.K. Green, L.-L. Hwang and Y.-J. Kuo	Epidemiology of tomato mosaic virus in Taiwan and identification of strains	J. Plant Dis. Protection 94(4):386-397
B.C. Imrie and Sundar	Source of variation in yield in international mungbean trials	Field Crops Research
Kuo, H.-M Chen, B.-J. Shen, H.-C. Chen, Opeña	Associations between heat tolerance, water consumption, and morphological characters in Chinese cabbage	Euphytica 39:65-73
S.-H. Lai	Production of processing tomato in Taiwan (in Chinese)	Shin Nung Farm Magazine
E.M. Saadaoui	Cercospora blight of asparagus in Malaysia	Plant Disease Note 71:1146
N.S. Talekar	Host plant resistance to insects attacking soybean and mungbean in the tropics	Insect Sci. Appl. 8(4/5/6):777-782
N.S. Talekar	Influence of cultural pest management techniques on the infestation of sweetpotato weevil	Insect Sci. Appl. 8(4/5/6):809-814
N.S. Talekar	Resistance in sweet potato to sweetpotato weevil	Insect Sci. Appl. 8(4/5/6):819
N.S. Talekar	Feasibility of the use of resistant cultivars in sweetpotato weevil control	Insect Sci. Appl. 8(4/5/6):815-817
N.S. Talekar, K.-W. Cheng	Nature of damage and sources of resistance to sweetpotato vine borer (Lepidoptera: Pyralidae) in sweet potato	J. of Econ. Ent. 80:788-791
Yoon	Peppers and Chinese cabbage adaptation to the tropics	Span 30(2):64-66

- Journalists. OIS met with journalists from India, the Philippines, South Africa and Taiwan during 1987.
- OIS directed the filming at AVRDC of "Is Agricultural Research Keeping Pace with the March of the Billions?", commissioned by the German Agency for Technical Cooperation (GTZ) and taken by the CRW, Filmproduktion crew which premiered on World Food Day (16 October 1987) in Frankfurt. The 30-minute film includes segments on the work of the International Center for Maize and Wheat Improvement (CIMMYT), the International Livestock Center for Africa (ILCA) and AVRDC. Copies of this German language film are available for viewing in Beta and VHS formats from the growing OIS video film library.

Table 3. Journal articles prepared in 1987.

Author(s)	Title	Journal
G.C.J. Fernandez, H.-K. Chen	Effects of temperature and photoperiod on reproductive development of reduced photoperiod-sensitive mungbean genotypes: A quantitative model	J. Amer. Soc. of Hort. Sci.
S.K. Green	Occurrence of peanut stripe virus (PStV) on soybean in Taiwan — Effect on yield and screening of resistance	Trop. Pest Mgt.
S.K. Green, Y. Sulyo, D.E. Lesemann	Leaf curl virus on tomato in Taiwan	FAO Plant Protection Bul.
B.A. Kratky, J.E. Bowen, H. Imai	Observations on non-circulating hydroponic system for vegetable production	HortScience
Kuo, H.-M. Chen B.-J. Shen and L.-H. Ma	Changes in plant hormones of tomato pistil during fruit set in hot and cool seasons	J. Amer. Soc. Hort. Sci.
N.S. Talekar, Y.-H. Lee	Biology of *Ophiomyia centrosematis* (Diptera: Agromyzidae), a pest of soybean	Ann. Ent. Soc. Amer.
N.S. Talekar, Y.-H. Lee, Suharsono	Resistance of soybean to four defoliator species in Taiwan	J. Econ. Ent.
N.S. Talekar	Characteristics of *Melanagromyza sojae* (Diptera:Agromyzidae) damage in soybean	J. Econ. Ent. Section C
N.S. Talekar H.-C. Yang, Y.-H. Lee	Morphological and physiological traits associated with agromyzid (Diptera: Agromyzidae) resistance in mungbean	J. Econ. Ent. Section C
N.S. Talekar, Y.-H. Lee	A procedure for mass-rearing of beanfly (Diptera: Agromyzidae) in the laboratory	J. Econ. Ent.
A. Sajjapongse, M.-H. Wu, Y.-C. Roan	Effect of planting date on growth and yield of sweet potatoes	J. Amer. Soc. of Hort. Sci.

The IARC Center Directors have established a "Public Awareness Committee" to enhance support for international agricultural research and assigned their respective information officers to participate. AVRDC has attempted from the beginning to direct the Committee toward support for the entire IARC system. At the Committee's most recent meeting in Washington, D.C. in late October, AVRDC presented the specially-drawn map (see p. 482) which first appeared in the *AVRDC Accomplishments, Goals and Structure* pamphlet. It was suggested that all Centers which formally join the Committee should appear on such a map which could be utilized in the members' general publications, such as annual reports, general brochures, etc. In this way the entire IARC system is strengthened with, hopefully, eventual concomitant donor support to the participating Centers.

Data Base

Mailing List

The mailing list is a data base that now contains useful up-to-date information including crop interests, telephone and telex numbers and is accessible for keyword search through any HP terminal

Table 4. Symposium/Workshop presentations in 1987.

Author(s)	Presentation	Symposium/Workshop
Chen C.-Y., Tsou, H.-H. Wang	Utilization patterns of mungbean in Chinese diet	2nd Int. Mungbean Symp. Bangkok, 16-20 Nov.
Fernandez	Current strategies for conservation of sweet potato germplasm at AVRDC	CIP Sweet Potato Workshop, Lima, Peru, Feb.
Fernandez	Status of the sweet potato collection at AVRDC	CIP Sweet Potato Workshop, Lima, Peru, Feb.
Fernandez, Sundar	The AVRDC mungbean breeding program: Past, present and future	2nd Int. Mungbean Symp., Bangkok, 16-20 Nov.
Green	The virus elimination and virus indexing scheme for sweet potato at AVRDC	CIP Sweet Potato Workshop, Lima, Peru, Feb.
Iwanaga, Yoon, Talekar, Y. Unemura	Evaluation of the breeding value of 5x interspecific hybrids between sweet potato cultivars and 4x *I. trifida*	Int. Sweet Potato Workshop, ViSCA, Philippines 20-26 May
Kratky, Y.-C. Roan	A steel-reinforced, concrete-filled PVC pipe shelter for vegetable seedlings	20th Nat. Agr. Plastics Congress, USA, Aug.
Opeña, Takagi, Tsou	AVRDC sweet potato improvement program	Int. Sweet Potato Workshop, ViSCA, Leyte, Philippines, 20-26 May
Opeña, Sun	AVRDC sweet potato research program	Workshop on Sweet Potato Improvement in E. Africa, CIAT/ CIP/IITA, 28 Sept. to 2 Oct.
Opeña, Sundar, Fernandez, Yoon, Takagi, Tschanz, Green	Vegetable germplasm at AVRDC and its utilization in crop improvement with reference to disease resistance breeding	IBPGR Workshop on Germplasm Resouces of East Asia, Tsukuba, Oct.
Sajjapongse	Effect of weed competition and metribuzin on transplanted tomatoes	11th Conf. Asian-Pacific Weed Sci. Soc., Taipei, Nov.
Sajjapongse	Weed management in vegetable fields	11th Conf. Asian-Pacific Weed Sci. Soc., Taipei, Nov.
Sundar	Genetic improvement of annual oilseed	Int. Bot. Congress, Berlin
Sundar	Seed production and management of soybean and mungbean	IRRI, Philippines
Sundar, Tsou	Filling the yield gap in soybean — strategies and methodologies	CGPRT Workshop on Soybean Improvement, Bogor, Feb.
Talekar	Insect pests of sweet potato in the tropics	Plant Protection Congress Manila, Sept.
Talekar	Biology, damage and control of bruchid pests of mungbean	2nd Int. Mungbean Symp., Bangkok, 16-20 Nov.
Takagi, Opeña	Sweet potato breeding at AVRDC to overcome constraints in production	CIP Sweet Potato Workshop, Lima, Peru, Feb.
Tay	Present status, management and utilization of tropical vegetable genetic resources at AVRDC	Int. Workshop on Crop Gen. Res. in E. Asia, Tsukuba, 10-13 Nov.

Table 4. Continued.

Author(s)	Presentation	Symposium/Workshop
J.L. Tickoo, C.-S. Ahn, H.-K. Chen, Sundar	Utilization in India of genetic variability from AVRDC mungbean germplasm	2nd Int. Mungbean Symp. Bangkok, 16-20 Nov.
Tschanz	Disease problems, varietal resistance and chemical constraints in soybean and mungbean in the tropics	Plant Protection Congress, Manila, Sept.
Tsou, K.-K Kan, S.-Y. Wang	Biochemical studies on sweet potato for better utilization at AVRDC	Int. Sweet Potato Workshop, ViSCA, Philippines 20-26 May
Tu S., Tsay	Recent development of rice paddy field farming in Taiwan	Farming Systems and Management in Asia Workshop, Philippines, 22-28 June

Table 5. Other articles/items published in 1987.

Author(s)	Title	Publication
	Newsletters	
Imai, C.-H. Ma, Tsay, Sundar	Maximum yield trials of soybean at AVRDC	Better Crops International
S.-H. Lai	Tomato World (in Chinese) (translated from "The California Tomato Grower")	Shin Nung Farm Magazine
S.-H. Lai	AMITOM (in Chinese) (translated from the "Second International Symposium on Processing Tomatoes")	Shin Nung Farm Magazine
S.H. Lai	Production of processing tomato in Taiwan (in Chinese)	Shin Nung Farm Magazine
McLean Sundar	AVRDC adds pepper as new principal crop Screening for soybean rust resistance in perennial glycine	*Capsicum* Newsletter Soybean Rust Newsletter, Vol. 8
Opeña, Tschanz	Bacterial wilt resistance breeding program on tomato at AVRDC	ACIAR Bacterial Wilt Newsletter
Tay	Characterization and evaluation work at AVRDC — an example with *Brassica campestris*	IBPGR/SEAP Newsletter
Yoon, S.-S.-M Lin, C.-S. Hung, Tsou	The evaluation of early vegetative generations of sweet potato clones in a polycross breeding nursery	IBPGR Regional Committee for Southeast Asia Newsletter (1987):24-27
	Chapter in Book	
Sundar, J.-M. Poehlman	Genetics and breeding of mungbean	A.S. Mandal and Bahl, eds. Genetics, Cytogenetics and Breeding of Crop Plants
Takagi	Genetic resources handbook	Kodansha Scientific Co.Ltd. (in Japanese)
Talekar	Insect pests of soybean in tropical to subtropical asia	Soybeans for the Tropics, John Wiley and Sons
	Book	
Talekar	Agromyzid Flies of Food Legumes in the Tropics	John Wiley Eastern of New Delhi & AVRDC

in the Center. The current status of this data base is provided in Table 6. AVRDC continues to save resources with no qualitative reduction in communicating its activities by the recent mailing list update. Savings of nearly US$1,800 in postage charges were made by updating the mailing list.

During 1987 a complimentary library address data base was established to hold and aid in the analysis of information gained from the library survey (see distribution section).

Table 6. Mailing list data base, 1983-87.

Date	Number of listings		
	Total	Libraries	VIP
April 1983	4,785	404	na[1]
December 1984	5,999	538	na
December 1985	6,975	718	270
November 1986	4,697	546	168
December 1987	5,016	573	440

[1]not available.

OIS Slide File

As noted in the *1986 Progress Report*, the previous system of an open OIS slide file, supplemented by large collections of slides in the diverse departments, was inadequate with the best slides often borrowed and never returned to the OIS file. Slides taken by OIS for various departments are sometimes treated as 'personal' collections and taken by departing scientists, thereby permanently removing them from the Center. To ensure that all slides taken by OIS remain in its file, it was decided that departments should make requests for duplicates.

Photo Services

The photographic unit took over 16,000 photographic records of the scientific work in progress during 1987 in over 1,000 separate photographing sessions in the fields, laboratories or studio. A total of 5,364 of these black and white prints and blue slides were also developed at AVRDC in the OIS darkroom.

The senior photographer performed the first overseas photographic service for AVRDC when he traveled to document the Second International Mungbean Symposium in Bangkok. In addition to fully recording the multifaceted activities during the Symposium, he spent several days photographing for OIS and TOP, as well as holding a workshop for TOP Thai colleagues and providing technical assistance on making blue slides.

Art Services

The art services unit processed 116 requests for a total of 230 figures, tables, posters, book covers, etc. during 1987. Among these numerous assignments are many extremely creative challenges such as the design of five original book covers, seven wall posters and the final illustrations for the 87 figures for the forthcoming *Second International Mungbean Symposium Proceedings*.

Purchase of the Electronic Typesetter

To increase efficiency, reduce costs and improve turn-around times during the preparation of camera-ready copies, OIS proposed evaluating the feasibility of leasing electronic typesetting equipment

in 1986. After an exhaustive evaluation, it was decided that OIS purchase the same typesetting equipment utilized by AVRDC's commercial printers.

The decision to purchase the Compugraphic MCS 8000 typesetter with interactive terminal was taken in January and the purchase order was issued on 6 February with shipment arranged for 12 March 1987. Delivery did not occur until 7 April and the key MCS 8000 typesetter was damaged en route. After repeated attempts to repair this precision piece of equipment failed, a new, perfectly functioning typesetter was delivered on 10 July.

To catch up on typesetting work owing to late delivery of the equipment, a day and a swing shift were implemented seven days a week beginning in August. Work schedules were rearranged to allow two noncampus resident staff to regularly exchange a normal workday for Saturday or Sunday and keep the typesetter in operation during the day shift seven days a week. OIS staff who live in the campus alternated to work the swing shift seven days a week while earning compensatory leave. Table 7 lists the work accomplished on the photocomposition machine in 1987, worth US$20,880. Of this amount, US$12,480 are receipts toward the purchase of the equipment and US$8,400 represent direct savings in the core budget.

Table 7. Work accomplished on typesetter, 1987.

Publication		No. of typeset pages
A. TVIS Project		
- Soybean Rust Newsletter, No. 8		24
- TVIS News, Vol. 2, No. 2		86
- Soybean Rust Bibliography		110
- Soybean Varietal Improvement Workshop		87
- Mungbean/Soybean Directory Questionnaire		3
- Chinese Cabbage Directory Questionnaire		3
- Mungbean Symposium Final Announcement		3
- Mungbean Symposium Abstract		45
- International Cooperator's Guide — Chinese cabbage		6
- Mungbean Bibliography		250
- Mungbean Symposium name/registration cards		37
	Subtotal	654
B. Tomato & Pepper Symposium		
- Final Announcement	Subtotal	6
C. AVRDC		
- Centerpoint, Vol. 6		8
- 1985 Progress Report		483
- Insect Pests of Sweet Potato in Java		15
- 1986 Progress Report Summaries		33
- AVRDC Accomplishments, Goals & Structure		27
- Publication lists		8
- Tschanz's & Talekar's IRRI Proceedings Articles		28
- Comparative Technology Leaflet		3
- Three Training Brochures		6
- Sweet Potato Phytosanitary Statement		2
- Forms		10
- Publication Lists		7
	Subtotal	630
	Grand total	1,290

Distribution

An Update on the 1986 Proposal

In the proposal entitled "Towards a Cost-Effective Publication Policy" made at the 1986 Progress and Planning Workshop, OIS noted that the question of "how to **reduce** distribution costs of AVRDC's research achievements while **increasing** the impact through a superior quality of distribution?" had been clearly posed by the force of events: 23% increase in postal rates; 27% decrease in local purchasing power of US$ budget; and a sharp reduction in the amount of US dollars allocated for the distribution of publications.

Several measures were suggested to meet the challenge above:

- Monitor postage expenditures of publications;
- Subsidize cost of automatic distribution;
- Reduce the number of addressees receiving automatic free distribution;
- Utilize postal tariffs fully; and
- Increase sales.

The overall progress in implementing this distribution proposal is given below.

Monitor Postage Expenditures of Publications

OIS was provided with a budget for distribution of publications for the first time in 1987. This provided the basis for OIS to carefully plan and utilize the limited funds available. All postal expenditures were categorized as:

- automatic complimentary (i.e. libraries, bilateral projects, etc.),
- complimentary on request,
- promotional (distributors, book reviews, etc.), or
- for sale.

The 1987 postal expenditures are itemized in Table 8. One new element is that the postage utilized to make a sale is deducted from the sales receipts and credited back to the postage fund, thereby allowing the extremely limited funds to be utilized for the automatic and selective complimentary distribution.

Table 8. OIS postal expenditures for documents, 1987.

Category	OIS (NT$)	TVIS (NT$)
Automatic complimentary	286,628	139,392
Automatic on request	21,372	–
Promotional	30,833	–
By sales	-53,694	
	285,139 (US$8,911)*	139,392 (US$4,356)

*Exchange rate of US$1.00 = NT$32.

Subsidize Cost of Automatic Distribution

Two different avenues were pursued. First, the local authorities were approached concerning reduced postal rates. Although there is provision for a reduction in postal rates for periodicals, the complexity of meeting all requirements and the frequency of AVRDC's periodicals made pursuit of this avenue, under the current regulations, unfeasible.

As proposed in 1986, an "AVRDC Publication Distribution Fund" was established in 1987 and a dozen potential donors were approached for contributions. One donor, the Technical Centre for

Agricultural and Rural Cooperation (CTA), pledged a US$5,000 contribution for 1988 to be used to cover the postal charges for publications sent to the African, Caribbean and Pacific (ACP) states and European Community (EC) nations.

Reduce the Number of Addressees Receiving Automatic Free Distribution

Over the last decade, AVRDC has provided complimentary copies of most of its publications automatically upon publication to selected libraries and VIP addressees in its mailing list. OIS has reduced the total number of these addressees by about 38% (from 988 in 1985 to the current 714) through the mailing list update. However, as pointed out in 1986, before further reducing the number of libraries which function as AVRDC repositories of publications, "it is essential that OIS conduct a serious study, utilizing future planned mailings, to contact these libraries to obtain information on this important question and also cooperators in the universities/national programs, who use the libraries, to verify the librarians' responses." With the information from this survey, AVRDC will be in a position to select key libraries which make its publications available and are unable to obtain them in any other manner except by complimentary subscriptions. AVRDC can then substantially reduce the number of libraries which receive free publications.

Two questionnaires were developed, one for the library and the other for library users, in the first quarter of 1987. The library questionnaire was designed to determine the perceived value of AVRDC's publications to the respective collection, the availability and use by readers of previously deposited AVRDC publications, the publication(s) AVRDC receives in exchange, and the libraries' willingness and ability to purchase AVRDC publications in the future. The library user questionnaire simply requested the selected users to search the shelf and card catalog to verify the information solicited on the same six AVRDC publications as in the library questionnaire.

The library questionnaire was sent to 571 libraries at the beginning of the third quarter of 1987. To ensure a serious response from the maximum number of libraries, this questionnaire was sent together with six newly published AVRDC books/periodicals whose sales price totaled US$63.00. The librarians were informed that there would be no future deposits of AVRDC publications until their questionnaires were returned duly answered. By year's end one-third of the questionnaires were returned.

A general consideration, based on a preliminary examination of the returned questionnaires, is that AVRDC will have ample information to utilize in judiciously reducing the number of libraries which currently act as AVRDC repositories.

It was much more difficult to first identify and second obtain tenable information from selected library users to corroborate the librarians' responses. Only a few of the 30 library users surveyed responded with useful information. This is a perennial problem according to Terry Lindeman (World Bank) and Taco Bottema (ESCAP/CGRRT Centre) who are responsible for publication distribution and have attempted similar verifications.

Utilize Postal Tariffs Fully

The utilization of postage-saving techniques, such as consolidated mailings, was discussed in the 1986 distribution proposal of OIS. Because of the prevailing tariff structure, AVRDC pays the same amount to send a single copy of the 40-page Technical Bulletin No. 16, which weighs 110 g, as the 102-page 1986 Progress Report Summaries, which weighs 240 g to the Philippines. OIS has actively implemented measures in 1987 to: (1) design AVRDC's publications to remain within the upper limit of the tariff utilized and (2) utilize consolidated mailings to substantially reduce postage costs over the former practice of distributing each publication individually.

Custom designing AVRDC publications. During 1987 publication typesetting 'tricks', such as using 1/2 point reduction in character size to comfortably include more lines of text per page and, thereby, reduce overall number of pages/weight, were implemented by AVRDC's own typesetters. The slight reduction in paper weight from 100 lb to 80 lb reduced the overall weight of publications such as the *1986 Progress Report Summaries* (240 g) and the *Soybean in Tropical and Subtropical Cropping Systems*, revised edition (960 g) enough to bring them down from the bottom of the higher tariff category to the top of the adjacent lower tariff category. This practice obtained a substantial savings from 29% to 45% in postage charges for individual mailings.

Consolidated mailings. OIS consolidated its entire automatic complimentary distribution in 1987 into two mailings (Table 9). The *Centerpoint*, Vol. 6 is an example of a publication which obtained substantial savings from both consolidated mailing and publication "tricks". Instead of preparing two 4-page *Centerpoint* newsletter issues as proposed in the 1987 publication schedule, one 8-page issue was prepared, thereby, consolidating mailing costs. However, to keep the weight within the minimum 20 g tariff, a substantially lighter magazine paper was utilized. Although this paper is more expensive, an overall savings of US$1,200 in postal charges was obtained by bringing the weight down to the minimum tariff.

Increase Sales

The desirability of increasing the volume of sales of AVRDC publications was pointed out in the proposal "Towards a Cost Effective Publication Policy" by OIS in 1986. However, it is not easy to sell AVRDC publications. Considerable effort was invested by OIS in 1987 to bring about a more conducive sales environment.

Total sales of AVRDC publications in 1987 were US$7,522 (Table 10); well over four times the total sales of 1986.

Table 9. OIS automatic consolidated complimentary publication distribution, 1987.

Publication	Weight (g)
July Surface Distribution	
1984 Progress Report	1,110
Insect Pests of Sweet Potato in Java	65
TVIS News, Vol. 2, No. 2	285
Soybean Rust Newsletter, Vol. 8	100
Rev. Soybean in Trop. & Subtrop. Cropping Systems (rev. ed.)	960
Library Questionnaire & Publication List	10
Technical Bulletin No. 16	98
Packaging	168
Total	2,770
December Air Mail Distribution	
Centerpoint, Vol. 6	18
Publication List	1
Total	19

Table 10. Sales of AVRDC publications, 1987.

Source	Sales (US$)
Headquarters	4,476
-Mungbean Symp. Display	617
-Weed Science Society Display	125
Subtotal	5,218
Distributors	
-Australia (& Oceania)	36
-Germany (Europe)	504
-India	331
-Indonesia*	–
-Japan	330
-Kenya*	64
-Malaysia	64
-Taiwan	194
-Thailand	64
-U.S.A. (North America)	717
Subtotal	2,304
Grand Total	7,522

*Just becoming active distributor

Distributor network. During the first half of 1987, the distributors who enlisted at the October 1986 Frankfurt International Book Fair began active distribution of AVRDC publications. By the end of 1987, OIS had extended the network to include Australia (Oceania), Indonesia and Kenya. Although the volume of sales in India was not great, it should be noted that these US$331 represent the first time AVRDC publications have ever been sold in the Subcontinent.

Sales profile. Of the 13,125 publications distributed in 1987, 1,689 were distributed through sales. (Of these, 443 were either of the 10th anniversary monograph series, technical bulletin series or newsletters which were not even for sale in 1985.) The 'AVRDC 10 Best Sellers' are listed in Table 11. Many of these sales resulted from specific sales initiatives undertaken by OIS during the course of the year.

Table 11. AVRDC 10 best sellers, 1987.

Rank	Publication	No. of copies sold
1	1985 Progress Report Summaries	170
2	Soybean in Tropical & Subtropical Cropping Systems (Revised ed.)	61
3	Diamondback Moth Management	44
4	Tropical Tomato	38
5	Vegetable Technology in Asia	27
6	Chinese Cabbage	23
7	Guidelines for Diagnostic Work in Plant Virology	21
8	1st Mungbean Symposium	20
9	Breeding Field Vegetables	19
10	2nd Mungbean Symposium	18

Best Seller No. 1. The *1985 Progress Report Summaries* became the "best seller" because of a lack of postage funds. This document is the single most useful AVRDC publication to bring scientists into contact with the Center's research work, as evidenced by the number of requests for reprints of sections of the Progress Report (Table 12) obtained from the postcard in the Summaries. Most of the 260 requests for journal paper reprints and the 148 requests for international cooperators' guide sheets originated from the publication list in the Summaries. Since there is a direct correlation between reprint requests and breadth of distribution, the decision was taken to distribute the *1985 Progress Report Summaries* to the entire 4,697 mailing list addressees. Unfortunately, the postal funds were exhausted after only 3,000 copies were sent. Since none of the 660 U.S.A. addressees had been sent the Summaries, OIS sent postcards to them offering the document at a deeply discounted price. A total of 146 addressees took advantage of this offer and, in effect, paid for the material publication costs and postage costs of the publication.

Best Seller No. 2. A sizable portion of the sales of *Soybean in Tropical and Subtropical Cropping Systems* (rev. ed.) is due to the publicity obtained from book reviews. OIS began to systematically send book reviews and, on request, copies of newly-published books to specialized journals/newsletters in 1987. Of a total of 95 selected publications which were sent reviews, eight published book reviews.

Best Seller No. 3. At least one-third of the sales of the *Diamondback Moth Management* Workshop Proceedings was the result of one selected book review which OIS was able to place in the *Infoletter* newsletter.

Best Seller No. 10. The *Second International Mungbean Symposium Proceedings* will not be published until the end of 1988, yet, through a special prepublication offer made to the participants at the Symposium, this work is already on the best seller list. A total of 39, as yet unpublished, books were purchased as a result of this prepublication offer. This technique will be refined and applied more frequently in the future.

Table 12. Requests for progress report reprints, 1984-85.

Section	No. of requests	
	1984*	1985**
Chinese Cabbage		
Breeding	24	93
Entomology	24	72
Pathology	19	71
Physiology	21	77
Sweet Potato		
Breeding	46	95
Entomology	38	78
Pathology	30	69
Physiology	27	93
Tomato		
Breeding	51	150
Entomology	41	97
Pathology	36	118
Physiology	37	126
Mungbean		
Breeding	48	118
Entomology	40	79
Pathology	34	81
Physiology	31	99
Soybean		
Breeding	57	129
Entomology	58	98
Pathology	50	101
PSP		
Agricultural Economics	21	61
Chemistry	8	40
Crop Management	57	168
Garden Program	36	104
New Vegetable Crops	39	94
Soil Science	29	91
Others	24	844
Total	926	3,246

*1,000 copies of 1984 Progress Report Summaries were sent to mailing list addressees.
**3,140 copies of 1985 Progress Report Summaries were sent to mailing list addressees.

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Publications Available

How to Order

All of the publications listed below can be ordered from the Office of Information Services (OIS), AVRDC. The following list of distributors in the highly-developed countries (HDC) and less-developed countries (LDC) have many of these publications available for sale in local currency.

The prices quoted below include surface postage. If airmail delivery is required the additional postal charges will be added to the invoice. All charges should be paid with a US dollar check (**payable by a bank in the USA**) made out to AVRDC, or with Unesco coupons.

HDC Distributors

Select Books Pte. Ltd.
19 Tanglin Rd.
Singapore 1024
Republic of Singapore

Publishers International Corp.
2nd Floor, Newfield Building
42-3 Ontsuka 3-chome
Bunkyo-ku, Tokyo 112
Japan

Agribookstore
1611 N. Kent Street, Suite 600
Arlington, VA 22209
USA
(Orders for North America)

TRIOPS: Tropical Scientific Books
Toeche-Mittler Distribution
6100 Darmstadt
Hindenburg Str., 33
Fed. Rep. of Germany
(Orders for Europe)

LDC Distributors

World Universities Press
B-5/132, Safdarjung Enclave
New Delhi - 110 029, India

Publications Section
CGPRT Centre
Jalan Merdeka 145
Bogor 16111, Indonesia

Africa Book Services, Ltd.
Quran House
Mfangano Street
P.O. Box. 45245
Nairobi, Kenya

University of Malaya Co-Operative
Bookshop, Ltd.
P. O. Box 1127
Jalan Pantai Baru, 59.700
Kuala Lumpur, Malaysia

National Book Store, Inc.
Library Services Center
701 Rizal Ave.
Manila, Philippines

INDEX, Book Promotion &
Service, Ltd.
Ploenchit Road, Pathumwan
Bangkok 10500, Thailand

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Annual Progress Reports

1983 Progress Report. 444 p.
1984 Progress Report. 480 p.
1985 Progress Report. 471 p.
1986 Progress Report. 541 p.
(All issues of Progress Reports cost HDC $20.00; LDC $15.00)

Progress Report Summaries

1985 Progress Report Summaries. 96 p.
1986 Progress Report Summaries. 94 p.
1987 Progress Report Summaries. 98 p.
(All issues of Progress Report Summaries cost HDC $7.50; LDC $4.00)

Symposium Proceedings

AVRDC. 1977. Vegetable Technology in Asia. Proceedings of the workshop on pre- and post-harvest. 156 p. (HDC $12.00; LDC $8.00)

Cowell, Robert (ed.). 1978. Tropical tomato: Proceedings of the first international symposium. 290 p. (HDC $18.00; LDC $10.00)

Talekar, N.S. and T.D. Griggs (eds.). 1981. Chinese cabbage: Proceedings of the first international symposium. 489 p. (HDC $25.00; LDC $15.00)

Villareal, R.L. and T.D. Griggs (eds.). 1982. Sweet potato: Proceedings of the first international symposium. 481 p. (HDC $28.00; LDC $15.00)

Shanmugasundaram, S., E. Sulzberger and B.T. McLean (eds.). 1986. Soybean in Tropical and Subtropical Cropping Systems. Revised ed. 485 p. (HDC $25.00; LDC $18.00)

Talekar, N.S. and T.D. Griggs (eds.). 1986. Diamondback Moth Management: Proceedings. 483 p. (HDC $25.00; LDC $18.00)

Shanmugasundaram, S., P. Lastimosa and N. Llemit (eds.). 1987. Soybean Varietal Improvement: Proceedings of the international workshop. 93 p. (HDC $7.50; LDC $4.00)

Lastimosa, Pura J. and Norma V. Llemit (eds.). 1987. Gardening Nutritious Vegetables: Proceedings of the Vegetable Improvement Gardening Workshop. 136 p. (HDC $10.00; LDC $6.00).

Technical Bulletins

TB 1 Menegay, M.R. 1975. Taiwan's specialized vegetable production areas: An integrated approach. 17 p. (HDC $4.00; LDC $3.00)

TB 2 Menegay, M.R. 1976. Farm management research on cropping systems. 19 p. (HDC $4.00; LDC $3.00)

TB 3 Calkins, P.H. 1976. Four approaches to risk and uncertainty for use in farm management extension. 18 p. (HDC $4.00; LDC $3.00)

TB 4 Calkins, P.H. 1977. Farmers' viewpoint of sweet potato production in Taiwan. 44 p. (HDC $5.00; LDC $3.50)

TB 5 Calkins, P.H. 1978. Vegetable consumption in five cities of Taiwan. 24 p. (HDC $4.00; LDC $3.00)

TB 6 Huang, S.Y. and P.H. Calkins. 1978. Summer tomato production in Taiwan. 29 p. (HDC $5.00; LDC $3.50)

TB 7 Huang, K.R. and P.H. Calkins. 1978. Vegetable production in Taiwan; A survey of 300 farmers. 36 p. (HDC $5.00; LDC $3.50)

TB 8 Calkins, P.H. 1978. Why farmers plant what they do: A study of vegetable production technology in Taiwan. 92 p. (HDC $7.50; LDC $4.00)

TB 9 Calkins, P.H. and H.M. Wang. 1978. Improving the marketing of perishable commodities: A case study of selected vegetables in Taiwan. 65 p. (HDC $6.00; LDC $3.50)

TB 10 Calkins, P.H. and S H. Tu. 1978. White potato production in Taiwan: A farm survey. 29 p. (HDC $4.00; LDC $3.00)

TB 11 Calkins,P. H. 1978. Soybean production in Taiwan: A farm survey. 28 p. (HDC $4.00; LDC $3.00)

TB 12 Riley, J.J. 1978. Evaluation of environmental parameters in the humid tropics for crop scheduling purposes. 31 p. (HDC $4.00; LDC $3.00)

TB 13 Shanmugasundaram, S. 1979. Varietal development and germplasm utilization in soybeans. 36 p. (HDC $5.00; LDC $3.50)

TB 14 Caldwell, J.S. and D.W. Newsom. 1984. Vegetable consumption and production in two municipalities in Ilocos Norte, Philippines. 24 p. (HDC $4.00; LDC 3.00)

TB 15 Green, S.K. 1984. Guidelines for diagnostic work in plant virology. 43 p. (HDC $5.00; LDC $3.50)

TB 16 Caldwell, J.S. 1987. Assessing rainy season vegetable production alternatives: A case study in 'upstream' farming systems research. 50 p. (HDC $5.00; LDC $3.50)

TB 17 Opeña, R.T., C.G. Kuo and J.Y. Yoon. 1988. Breeding and seed production of Chinese cabbage in the tropics and subtropics. 92 p. (HDC $7.50; LDC $4.00)

Bibliographies

Talekar, N.S., H.C. Yang, S.T. Lee, B.S. Chen and L.Y. Sun (comps.). 1985. Annotated Bibliography of Diamondback Moth. 469 p. (Gratis, limited stock distributed selectively)

Hwang, P.L., F.C. Chen and C.C. Wei (comps.), Saadaoui, M., A.T. Tschanz and J. W. Soderlund (eds.). 1987. Soybean Rust Bibliography. 103 p. (HDC $7.50; LDC $5.00).

AVRDC. 1988. Disease and Insect Pests of Mungbean and Black Gram: A Bibliography. 254 p. (HDC $17.50; LDC $10.00)

Monographs

Bressani, R. 1982. World needs for nutrition and the role of vegetables and legumes. 22 p. (HDC $4.00; LDC $3.00)

Chandler, R.F. 1983. The potential for breeding heat tolerant vegetables for the tropics. 10 p. (HDC $3.00; LDC $2.00)

Choudury, B. 1984. Vegetables and the quality of life in the year 2000. 7 p. (HDC $3.00; LDC $2.00)

Innes, N.L. 1983. Breeding field vegetables. 34 p. (HDC $5.00; LDC 3.50)

Liu, M.S. and P.C. Ma. 1983. Postharvest problems of vegetables and fruits in the tropics and subtropics. 14 p. (HDC $3.00; LDC 2.00)

Wittwer, S.H. 1983. Frontiers for science and technology in vegetable production. 19 p. (HDC $4.00; LDC $3.00)

Miscellaneous

AVRDC. 1987. Accomplishments, Goals and Structure. 23 p. (Gratis)

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TVIS News — This journal is prepared by the Tropical Vegetable Information Service (TVIS) through AVRDC and published twice a year. It provides a platform of exchange of information for scientists working with mungbean, soybean and Chinese cabbage. (HDC $4.00/issue; LDC $2.00/issue)

Soybean Rust Newsletter — This annual newsletter is published by the International Working Group on Soybean Rust through the TVIS project of AVRDC. (HDC US$5.00/issue;LDC US$2.00/issue)

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Appendices

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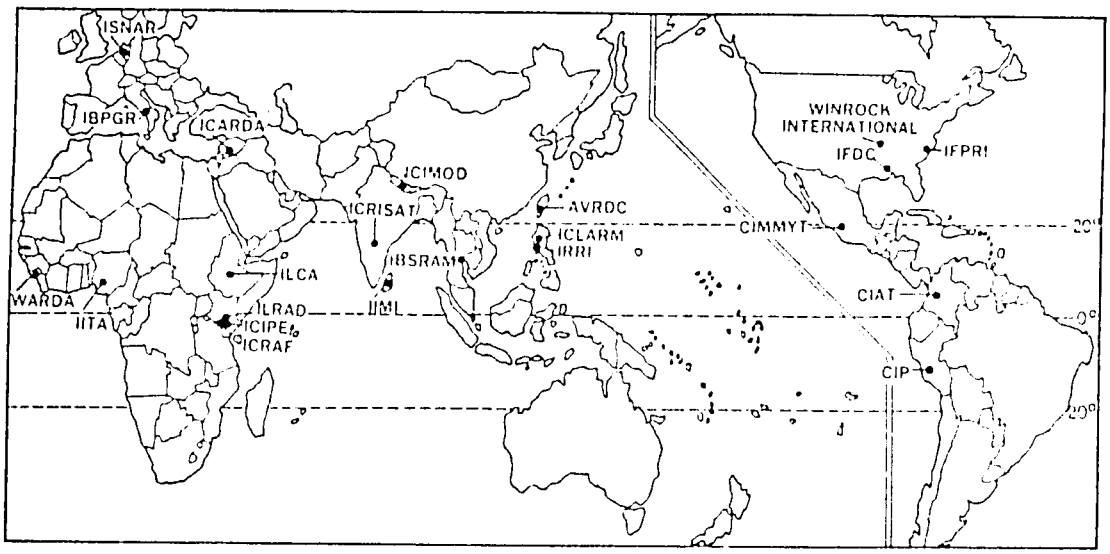

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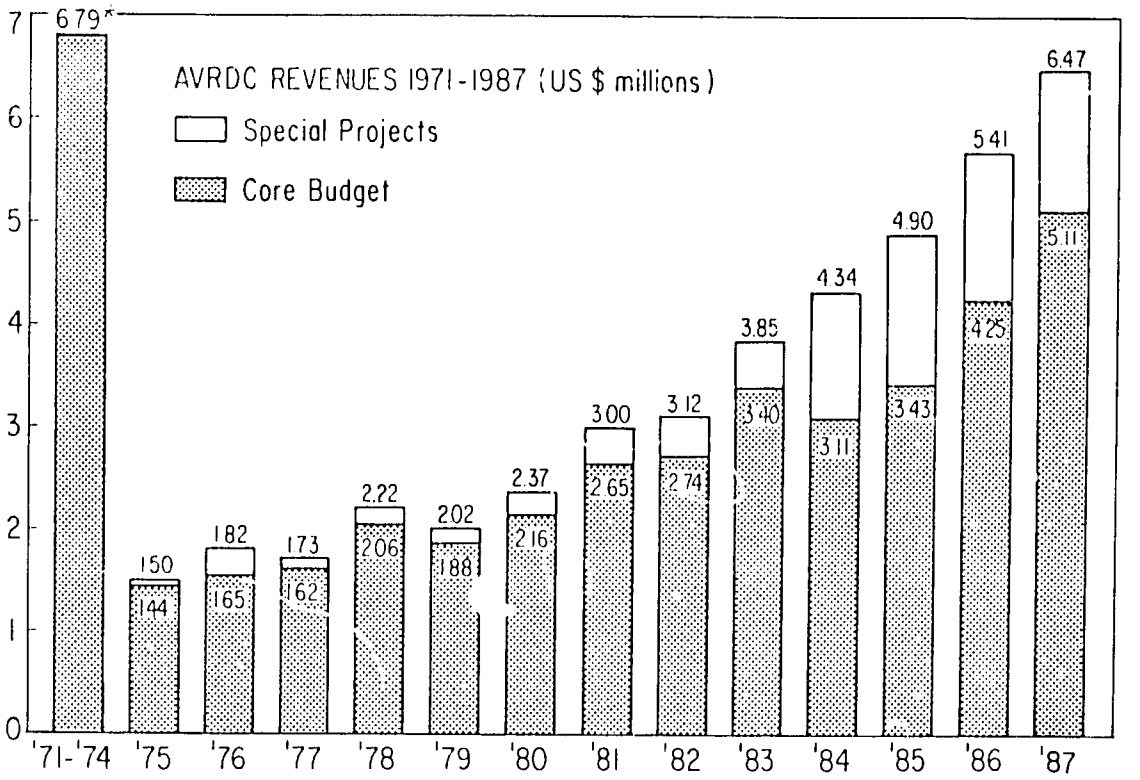
- International Food Policy Research Institute (IFPRI)
- International Institute of Tropical Agriculture (IITA)
- International Irrigation Management Institute (IIMI)
- International Laboratory for Research on Animal Diseases (ILRAD)
- International Livestock Centre for Africa (ILCA)
- International Rice Research Institute (IRRI)
- International Service for National Agricultural Research (ISNAR)
- West Africa Rice Development Association (WARDA)
- Winrock International Institute for Agricultural Development (WINROCK INTERNATIONAL)

Finances

AVRDC's projected budget for 1987 was US$5,400,000 compared with an actual income of US$6,466,535 and expenditures of US$5,944,984. In 1987 AVRDC received support from the following governments:

- the Republic of China
- the United States of America
- Japan
- the Kingdom of Thailand
- the Republic of Korea
- the Federal Republic of Germany
- the Republic of the Philippines
- The French Republic

Grants and other forms of assistance were also received from: the Asian Development Bank (ADB), the Swiss Development Corporation, the International Development Research Centre (IDRC), the Agency for International Development (AID), the International Board for Plant Genetic Resources (IBPGR), the Council of Agriculture (ROC), the Sasakawa Peace Foundation, the Technical Center for Agricultural and Rural Cooperation (CTA), the Australian Centre for International Agriculture Research (ACIAR), the United Nations ESCAP CGPRT Centre, the German Ministry for Economic Cooperation (BMZ), and the General Administration for Development Cooperation (Belgium).



*US $ 4.2 million for capital expenditures 1971-74