AVRDC Report 1999

Asian Vegetable Research and Development Center

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Foreword

AVRDC is the only international institute dedicated to vegetable research and development in the tropics and subtropics. Our mission is to enhance the nutritional well-being of people and raise the incomes of farmers in the target zones through improvement of key vegetables and their cultivation technologies. These improved plant materials and technologies are adapted by AVRDC and its many collaborators and then disseminated to our ultimate clients, farm families.

Our mission and strategy are detailed in a publication entitled *Vegetables for poverty alleviation and healthy diets: a plan for 1998-2002*. Working from this plan, AVRDC scientists elaborated 133 activities under 12 projects and 47 subprojects. Each project, subproject, and activity has been built around a logical framework that articulates overall goal, objectives, and expected outputs, as well as potential pitfalls. The work of management and planning is made more efficient through use of a computer-based project management system developed in 1999, easily accessible to all scientists and staff via the inter/intranet.

Most activities are moving forward, producing valuable materials, technologies, and information. Some activities, however, have been slowed due to lack of human resources, the result of an unexpected shortfall in the Center's revenue. Despite this funding challenge, which is hardly unique to AVRDC, the Center is making good progress delivering outputs detailed in its action plan.

AVRDC Report 1999 is the second annual report under the current five-year plan. Most of the projects are now halfway or far more than halfway toward achieving their objectives. The progress detailed in this report makes us confident that we can achieve our stated objectives within the remainder of the plan period.

Samson C S Tsou
Director General

Board

[a] Left during 1999
[b] Assumed office during 1999

Program I

Vegetables in cereal-based systems

Program I focuses on production systems that include vegetables in cereal-based farming. The overall goal of the program is to increase the efficiency of cereal-based vegetable production systems through the development of improved sustainable cereal–vegetable cropping systems that enhance returns to land, labor and capital, and at the same time protect the environment.

The mechanism involves the application of strategic research to develop improved technologies and innovative research methodologies that are important to national agricultural research systems. Improved technologies include improved breeding materials or production techniques. Methodologies might include practical means to screen plant populations for disease and insect resistance or nutrient content. The major shift in the approach is to look not only at the production system but also at the marketing and consumption systems. The key is integration of available and new technologies following a systems approach.

The objectives of Program I are to:

- increase production per unit of land area through intensified cropping
- help ensure cropping system sustainability through crop rotation, recycling of unused plant parts, and reduction in the use of agrochemicals
- make available more vegetables for human consumption, especially in off seasons
- diversify incomes, regularize cash flow and reduce risk
- make more efficient use of labor and other resources
- provide a catalyst for infrastructure development and growth of local service industries

Project 1. Off-season tomato, pepper and eggplant

Project 1 encompasses most of AVRDC's research on solanaceous vegetables. It has two main purposes:

- to increase tomato and sweet pepper yields in hot-wet and hot-dry environments
- to increase and stabilize chili and eggplant yields

In the hot-wet season, high temperature, flooding and numerous disease and insect problems drastically reduce tomato yield. Improved tomato lines with heat tolerance and multiple disease resistance, coupled with effective and economical management practices, must be developed in order to overcome these constraints and extend tomato production into the hot-wet season. Management of bacterial wilt of tomato has received considerable research attention at AVRDC because of the importance of this disease in the hot-wet season.

In hot-dry environments, production of tomato is limited by tomato yellow leaf curl virus infection and production of sweet pepper is constrained by high temperatures.

In contrast to tomato and sweet pepper, chili and eggplant are extensively grown in the off-season, even in hot-wet and hot-dry conditions, but pests and diseases often make yields low and unstable. For eggplant, a long-term project output is identification of lines/accessions resistant to major insect pests (particularly eggplant fruit and shoot borer) and bacterial wilt. For chili, AVRDC plans to increase yield and yield stability by developing improved chili lines and management practices designed to overcome numerous disease problems, especially cucumber mosaic virus, chili veinal mottle virus, tobamoviruses, phytophthora blight and anthracnose.

TYLCV-resistant Tomato lines

Tomato yellow leaf curl virus (TYLCV), a heterogeneous complex of whitefly-vectored gemini viruses, is a serious production constraint of tomato worldwide, but particularly in hot-dry environments. In 1996, the AVRDC tomato unit made crosses to develop TYLCV-resistant, determinate lines with good fruit quality and resistance to bacterial wilt (BW), tomato mosaic virus (ToMV), and fusarium wilt (FW). The TYLCV resistance source was tomato line H24, bred in India by Dr. G. Kalloo. TYLCV resistance in H24 was derived originally from *L. hirsutum* f. sp. *glabratum* accession B6013, and is associated with an introgression mapped to the bottom of chromosome 11 (*AVRDC Report 1998*). The following double crosses (CLN indicates an AVRDC cross code number) were made in 1995 to achieve the above objectives:

- CLN2114=(CL5915-93D4 × H24) × (PT4671A × CRA84-58-1)
- CLN2116=(CL5915-93D4 × H24) × (CRA84-58-1 × UC204A)
- CLN2121=(CL5915-93D4 × HM3075) × (PT4719A × H24)
- CLN2123=(CL5915-93D4 × Orion) × (PT4719A × H24)
- CLN2131=(CL5915-93D4 × CRA84-58-1) × (PT4664A × H24)

CL5915-93D4 is a small-fruited, heat tolerant line. CRA84-58-1 is a large-fruited, BW-wilt resistant line bred in the French West Indies by the National Institute for Agronomical Research. UC204A, HM3075, PT4719A, Orion, and PT4664A are firm-fruited processing tomato lines or varieties. From the F_2–F_6 generations, the populations were screened at AVRDC for TYLCV resistance by exposing them to viruliferous whiteflies; resistant plants were transplanted to the field and among them individual plants were selected based on good fruit-set and fruit quality. In addition, evaluation for BW resistance was done in the F_3, F_4, and F_7 generations. In 1999-2000, about 30 promising F_7 lines are being tested for yield potential, fruit quality, and resistance to BW and FW, and the best 10–15 will be increased for international distribution.

Contact: Peter Hanson

Genetic diversity of whitefly-transmitted geminiviruses in South and Southeast Asia

Knowledge of the genetic diversity of the geminiviruses affecting tomato in Asia is important for implementation of effective integrated pest management (IPM) programs, resistance-breeding strategies, and, ultimately, development of breeding lines with stable resistance. Therefore, molecular characterization of geminiviruses infecting tomato, chilli, other economically important crops, and common weeds continues to be a high priority.

Fresh or dried leaf samples from plants showing symptoms of geminivirus infection, such as vein clearing, yellowing, curling, blistering, and stunting, were obtained from Malaysia, Laos, Vietnam, Myanmar, Sri Lanka, Bangladesh, Indonesia, Nepal, and the Philippines. DNA extracts from these samples were subjected to polymerase chain reaction (PCR) analysis, then cloned and sequenced (as described in *AVRDC Report 1998)*. Each confirmed geminivirus was sequenced and compared with the sequences of all geminiviruses reported to infect tomato, chili, tobacco, okra, and *Croton* and *Ageratum* species in South and Southeast Asia, as described in the National Center for Biotechnology Information database.

Table 1 lists the geminiviruses cloned and sequenced at AVRDC in 1999, and the most closely related geminivirus based on sequence similarity. As a rule, sequence similarities of >90% indicate that the viruses are strains of the same virus, while sequence homology <90% indicate the viruses are distinct. Based on this definition, the geminiviruses from Indonesia, Laos, and Vietnam are distinct.

Two distinct tomato geminiviruses were identified in Bangladesh: TLCV-BD1, showed 89% sequence homology with TLCV-Ban3 from south India; the other, TLCV-BD2, showed low sequence homology with other reported tomato and pepper geminiviruses (Table 2). TLCV-BD2 did, however, show close homology (>95%) with BD1 in the pre-coat protein (PCP) and coat protein (CP) regions (Table 2), indicating that perhaps one of these two viruses (BD1) might have been derived as a result of genetic recombination with another distinct geminivirus in the area.

Two geminiviruses were obtained from Malaysia, one from tomato and the other from chili. The two are distinct from each other, with sequence similarities of 74, 78, 80, 73, and 69% of the whole genome, the PCP, CP, C_1, and C_4 open reading frames (ORFs), respectively. The chili-infecting was found to be closely related to, or a strain of, the Thailand pepper leaf curl virus (PLCV-TH). PLCV-TH is distinct from the Thailand tomato yellow leaf curl virus (TYLCV-TH) with which it shares sequence homologies of only 79, 80, 74, 84, 84, 84, and 90% of the whole genome, the PCP, the CP, the C_1, C_2, C_3, and C_4 ORFs, respectively. The tomato geminivirus from Myanmar was found to be identical to, or a strain of, TYLCV-TH, with sequence homologies of 94, 97, 93, 94, 97, and 96% of the whole genome, the PCP, CP, C_1, C_2, C_3, and C_4, ORFs, respectively. The geminivirus isolated from the common weed *Ageratum* sp. in Sri Lanka also

Table 1. *DNA Sequence Blast analysis of geminiviruses cloned and sequenced in 1999*

Country	Crop	DNA sequenced and used for comparisons[1]	% sequence similarity[2]	DNA-Sequence Blast: Virus	DNA-Sequence Blast: Genebank accession
Bangladesh	Tomato	A full (BD)	84	Papaya leaf curl virus (PLCV), (India)	Y15934
Indonesia	Tomato	A top (I8341)	71	Tomato yellow leaf curl virus, (Spain)	Z25751
Laos	Tomato	A full (LC2-1)	84	Ageratum yellow vein virus, (Singapore)	X74516
Malaysia	Pepper	A top (MP6)	95	Pepper leaf curl virus, (Thailand)	AF134484
	Okra	A top (Ma10K5)	95	Cotton leaf curl virus, (Pakistan), okra leaf curl strain	AJ002459
Myanmar	Tomato	A full (My2.1)	94	TYLCV-(Thailand), DNA A	X63015
Nepal	Croton sp.	A top (Nep Crot)	90	Papaya leaf curl virus, (India)	Y15934
Philippines	Tobacco	A top (Tob2)	86	Ageratum yellow vein virus, (Singapore)	X74516
Sri Lanka	Ageratum sp.	A full (SL7)	85	TLCV-Ban 3, (India)	U38239
Vietnam	Tomato	A full (V2)	82	TLCV-TW, (Taiwan)	U88692

[1] A full=Full length (~2.7Kb) DNA-A; A top=1.4Kb sequent of DNA, obtained by PCR using the primer pair PAL1v 1978/PAR1c 715; the AVRDC isolate designation is listed in parentheses.

[2] Sequence similarities >90% mean that the viruses are the same or closely related strains of the same virus. Sequence similarities <90% indicate that the viruses are different and not related.

appears to be a distinct new geminivirus, not related to the geminivirus infecting *Ageratum* sp. in Singapore and Malaysia.

Testing Lycopersicon *entries for resistance, tolerance*

Because of the vast genetic diversity among tomato-infecting geminiviruses, it is important to evaluate *Lycopersicon* entries in order to identify stable resistance/tolerance sources for breeding. At each location, 24 seedlings per entry were exposed at the 2-true-leaf stage for 40 days to viruliferous whiteflies in a screenhouse. The whiteflies were reared on tomato plants infected with the locally prevalent TYLCV. These plants were placed around the test entries. The test entries (except wild species) were then transferred to the field and exposed to natural disease pressure. They were rated by visual symptom observation and by DNA hybridization using appropriate digoxigenin-labeled probes.

Screening results (Table 3) showed that: 1) none of the commercial F_1 hybrids offered high levels of resistance, 2) some entries were resistant to some geminiviruses, 3) resistance to the bipartite geminiviruses, such as TYLCV-TH and the tomato mottle geminivirus (ToMoV) is not readily available. The three wild accessions, LA1777 (*L. hirsutum*), LA1969 (*L. chilense*), and LA1932 (*L. chilense*) appeared resistant to the monopartite and bipartite geminiviruses in the test. Results obtained from Bangladesh from two consecutive years of screening suggest that more than one geminivirus might be present.

In conclusion, most of the TYLCV/TLCV isolates from East and Southeast Asia analyzed constitute different species, not strains of the same viruses, with the exceptions of the Myanmar TYLCV, which is the same as TYLCV-TH; the Malaysian pepper leaf curl virus, which is the same as the Thailand pepper leaf curl virus; and the geminivirus infecting *Ageratum* sp. in Singapore and Malaysia. However, despite the great genetic diversity of the tomato geminiviruses in

Table 2. *DNA similarities between Bangladesh tomato geminivirus TLCV-BD2 other geminiviruses of Solanaceous crops and weeds in Asia and Australia*

Virus[1]	Crop	Country	Accession number[2]	% sequence homology						
				Whole genome	Pre CP	CP	C1	C2	C3	C4
TLCV-AU	Tomato	Australia	S53251	74	73	75	77	74	77	77
TLCV-BD 1	Tomato	Bangladesh		88	97	98	83	-[3]	-	87
TLCV-Ban 2	Tomato	India	Z48182	82	77	82	83	89	90	91
TLCV-Ban 3	Tomato	India	U38239	86	96	88	85	90	90	86
TLCV-Nde/Mld	Tomato	India	U15016	74	78	81	73	71	71	81
TLCV- Nde/Svr	Tomato	India	U15015	74	79	81	73	71	72	78
TLCV-ID	Tomato	Indonesia	AF189018	67	68	70	70	-	-	75
TLCV-LA	Tomato	Laos	AF195782	76	76	78	76	77	76	75
TLCV-MY-1-5	Tomato	Malaysia		76	76	80	76	-	-	74
TLCV-MM	Tomato	Myanmar		78	75	76	83	80	76	85
CLCV-NP	Croton sp	Nepal		89	94	95	69	-	-	65
TLCV-PH	Tomato	Philippines	AF136222	75	67	69	77	-	-	74
TobLCV-PH	Tobacco	Philippines		77	80	83	78	-	-	75
AYLCV-LK	Ageratum sp	Sri Lanka		82	83	84	83	83	84	86
TLCV-TW	Tomato	Taiwan	U88692	77	77	79	82	74	73	88
TYLCV-TH	Tomato	Thailand	AF141922	78	75	76	82	78	75	85
PLCV-TH	Chili	Thailand	AF134484	77	80	76	80	77	73	80
TYLCV-TH	Tomato	Thailand	AF141922	78	75	76	82	78	75	85
TLCV-VN	Tomato	Vietnam		79	83	77	82	77	78	85
AYVV	Ageratum	Singapore	X74516	78	82	79	79	75	78	74

[1] AYVV = Ageratum yellow vein virus; AYLCV = Ageratum yellow leaf curl virus; CLCV = croton leaf curl virus; PLCV = pepper leaf curl virus; ToLCV = tobacco leaf curl virus; TLCV = tomato leaf curl virus; TYLCV = tomato yellow leaf curl virus.
[2] Accession number of the US National Center for Biotechnology Information GenBank.
[3] - = data not available.

Asia, resistance genes exist that hold up against all or some of these viruses. This will be considered in AVRDC's resistance breeding program.

Contact: S K Green

Pyramiding of TYLCV resistance genes into tomato by marker-assisted selection

Tomato yellow leaf curl virus (TYLCV) is a serious production constraint of tomato in Asia, the Middle East, and the Americas. Several TYLCV tolerance/ resistance genes have been identified and pyramiding different TYLCV genes into a single variety might provide more durable resistance. Pyramiding multiple resistance genes is difficult using conventional methods, but molecular marker-assisted selection could facilitate this process. One tolerance gene, called *Ty*-1 and mapped to tomato chromosome 6, was derived from *Lycopersicon chilense* and introgressed into tomato by an Israeli group. A second resistance factor, derived from *L. hirsutum*, was mapped to chromosome 11 (see *AVRDC Report 1998*). The objective of the activity reported here was to develop inbred lines with both tolerance genes via marker-assisted selection.

Cultivated tomato line Ty52 (carrying Ty-1 gene) and CLN2116A (L. hirsutum introgression) were used as donor parents. Three inbred lines, CLN399, CH154, and CLN2026D, were crossed with each donor parent and then single crosses involving the same recurrent parent were crossed to create three double-cross populations. About 72 plants per

Table 4. *Identification of TYLCV genes in three double-cross populations*

Recurrent Parent	No. of plants: *L. hirsutum* gene	*Ty*-1 gene	Both genes
CLN399	25	12(+2)	12
CH154	27	12	12
CLN2026	18(+5)[1]	15	9

[1] Number of plants that carried incomplete introgression within tested marker. Twenty-seven plants were tested from each population.

Table 3. *Summary of reactions of selected entries with some Asian tomato geminiviruses*

Line	Origin	Disease reaction [1]: TLCV TW	TYLCV-Ban 2: A [2]	B [3]	C [4]	TYLCV [5] BD	TYLCV [6] PAK	TYLCV [7] TH	ToMoV [8]
TYKING F_1	NL	MS	S						S
FIONA F1	NL	MR	S	MS	MR	MR® S[9]	S	S	S
AVINASH F_1	India	MS	MR	S					(S)
L. e. TY 52	IS	(S)	(S)		R	R® (MS)	(S)		S
L. e. H 24	India	R	R	HR	HR	HR® R	HR	(MS)® S	S
L. *hirs.* LA 1777	IS	R	HR		HR	HR® (R)	HR	HR® (R)	R
L. *per.* VL 215	F	HR	HR	HR	HR	HR	HR	(R)® (MR)	(S)
L. *chil.* LA 1969	US	HR	HR	HR		HR	HR	(R)	R
L. *chil.* LA 1932	US	HR		R	HR		HR	(R)	R
L. e. FL 744-6-9	US	R	R	R	R	R® (MR)	(S)	(S)	(MS)
L. e. FL 736	US	S	S	MS	S	R® S	S	S	(MS)
L. e. FL 699	US	HR	R	R	HR	HR® (MR)	S	S	(MS)
L. e. FL 699 Sp+	US	R	R	R	HR	HR® (S)	S	(S)	(MS)
L. e. FL 776	US	MR	S	R	R	HR® (MS)	S	S	(MS)
L. e. FL 619	US		S				S	S	(S)
L. e. FL 805	US	MR	MS		R		NT	S	MR
L. e. FL 505	US	R	HR	MS		R® (S) R® (S)	S	S	(S)
L. e. TK70 (S. CK)	TW	S	S	S	S	S	S	S	S

[1] HR = highly resistant: 0% infection, negative hybridization test; R = resistant: 1-20% infection; MR = moderately resistant: 21-50% infection ; MS = moderately susceptible: 51-75% infection; S = susceptible; 76-100% infection; ( ) = mild to moderate symptoms

[2] Data provided by Dr. V. Muniyappa, Bangalore; [3] data by Dr. A.A. Deshpande, IIHR, Bangalore; [4] data by Sunseed; [5] data provided by Mr. Harun, BARI, Bangladesh; [6] data provided by Dr. Saif Khalid, NARC, Islamabad; [7] data provided by Ms. Kittipakorn Kruapan/Dr. Pissawan and Limagrain Seed Co.; [8] data provided by Dr. J.W. Scott, Florida; [9] MR® S = testing done in different years; first year reaction was MR, the second year reaction was S.

double cross were exposed to viruliferous whiteflies in an AVRDC nethouse. Symptomatic plants were discarded and 27 healthy plants per population were selected for DNA extraction and restriction fragment length polymorphism (RFLP) marker analysis. DNA was digested with six restriction enzymes (BstNI, DraI, ScaI, DraI, HindIII, and HaeIII), and blotted onto nylon membranes. Hybridization was carried out with probes TG97, TG297, and TG232 (on chromosome 6) and TG36, TG26, TG105A, and TG393 (on chromosome 11).

Scoring was based on presence of polymorphic bands generated by the donor parents (Figures 1 and 2), and the results are summarized in Table 4. Most healthy plants carried the L. hirsutum introgression, and about half of the tested plants carried Ty-1. The number of plants that inherited both genes was 12, 12, and 9 from populations generated from CLN399, CH154, and CLN2026, respectively. Plants carrying both genes and favorable horticultural traits will be backcrossed to their respective recurrent parents by the AVRDC tomato breeding unit.

Contact: C G Kuo

Evaluating wet season tomato lines

One preliminary yield trial of 13 F_6 determinate dual-purpose (fresh market/processing) tomato lines and three check varieties was conducted at AVRDC in 1998. Entries were sown on 12 August, transplanted 16 September, and harvested four times between 17 November and 29 December. Trial plots were single, 1.5-m beds with one 4.8-m-long row per bed. Mean maximum and minimum temperatures during the trial were 29.8 and 21.1°C, and total rainfall was 134 mm.

A separate greenhouse trial was conducted to estimate BW tolerance after drench inoculation with the BW pathogen. Yields and horticultural characteristics of the best entries are shown in Table 5.

The better entries in the trial were sister lines from AVRDC cross CLN2026, which is a double cross of (CRA84-58-1 × UC204A) × (CL5915 × NC82-162). Three entries yielded significantly greater than heat tolerant checks CL5915 and CLN1621C, and the processing tomato variety UC204A. In addition, three entries produced good internal red color

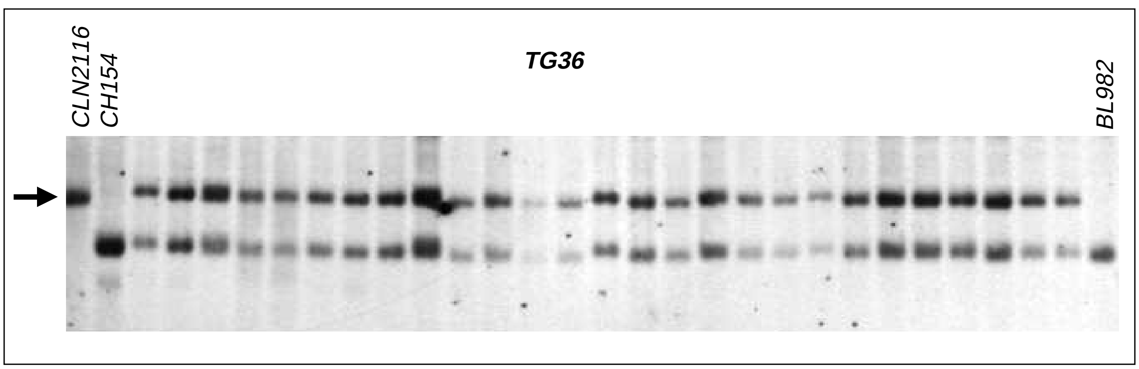

Figure 1. *RFLP probing of TG36 on 27 plants derived from double cross of (CH154 × CLN2116A) × (CH154 × TY52). Arrow indicates polymorphic band generated by hirsutum gene.*

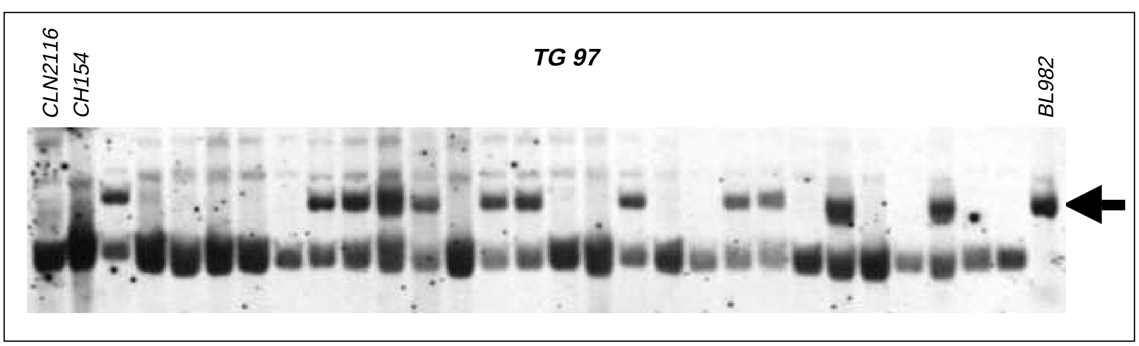

Figure 2. *RFLP probing of TG97 on 27 plants derived from double cross of (CH154 × CLN2116A) × (CH154 × TY52). Arrow indicates polymorphic band generated by Ty-1 gene.*

indicated by (a/b) scores greater than 2.0. All entries with the CLN2026 prefix carry multiple disease resistance.

Based on fruit yield and quality, entries CLN2026C, CLN2026D, and CLN2026E were selected for inclusion in the AVRDC determinate set for international distribution.

Contact: P Hanson

Variation in genotype and aggressiveness of *Ralstonia solanacearum* in tomato fields

Bacterial wilt, caused by race 1 strains of *Ralstonia solanacearum*, is the most important disease of tomato in the tropics and subtropics. Host resistance has been the main control strategy, as the pathogen is soil-borne and has a wide host range. The success of BW resistant tomato lines has, however, been limited by the location-specific nature of the resistance to bacterial wilt. Location-specificity could be due to large pathogen strain variation. Recent studies at AVRDC have shown that a population of *R. solanacearum* collected from tomato production fields in Taiwan is highly diverse in genotype and aggressiveness. It is not known, however, whether a similar degree of strain diversity is present in individual fields. The objective of this study was to examine the variation in genotype and aggressiveness of *R. solanacearum* present in single fields, and to determine possible selection factors acting on the pathogen population.

Populations of *R. solanacearum* were collected in 1996 from two fields in Taiwan. The first field was a BW-disease-screening nursery located in the Taiwan Seed Propagation and Improvement Station (TSS), located in central Taiwan. For determining the uniformity of strains within the field, the nursery was partitioned into five subfields (12 × 50 m each) and 15 wilted plants of L390 (susceptible) were collected from three plots per subfield for isolation. The second tomato production field, in Ilan County in northeast Taiwan (Ilan population), was sampled: a total of 15 wilted plants of tomato variety ASVEG#5 (moderately susceptible) were collected randomly from each subfield (14 × 20 m each) for isolation. Biovar, aggressiveness, and genomic fingerprint of each strain were determined. Aggressiveness was evaluated by inoculating 3-week-old seedlings of L390, L180-1 (resistant), and Hawaii 7996 (resistant), with each strain, using

Table 5. *Yield and horticultural characters of determinate fresh market/processing lines in a preliminary yield trial at AVRDC, August–December 1998*

Entry	My (t/ha)	Fruit set (%)	Fruit size (g)	Solids (Brix°)	pH	Acid (%)	Color (a/b)	BW (% surv.)	Disease resistance
CLN2026E	44	43	60	4.4	3.89	0.43	2.05	70.8	TMV, F-1, F-2, GLS
CLN2026L	43	35	73	3.9	4.15	0.30	1.81	52.9	TMV, F-1, F-2, GLS
CLN2026H	42	35	79	3.3	4.08	0.27	1.81	61.9	TMV, F-1, F-2, GLS
CLN2023B	40	36	63	4.1	4.00	0.38	1.79	66.7	TMV, F-1, F-2, GLS
CLN2026K	39	40	66	3.8	4.11	0.31	1.84	54.5	TMV, F-1, F-2, GLS
CLN2026C	38	40	68	4.1	4.00	0.37	2.11	70.4	TMV, F-1, F-2, GLS
CLN2026J	36	41	77	3.7	4.08	0.29	1.89	71.2	TMV, F-1, F-2, GLS
CLN2023C	36	34	69	3.8	4.00	0.37	1.80	70.8	TMV, F-1, F-2, GLS
CLN2023A	35	33	66	3.9	4.00	0.37	1.36	70.8	TMV, F-1, F-2, GLS
CLN2026F	34	41	69	4.1	4.00	0.39	1.93	74.6	TMV, F-1, F-2, GLS
CLN2026D	32	39	67	4.2	4.02	0.38	2.12	56.5	TMV, F-1, F-2, GLS
CL5915	31	41	37	4.3	3.87	0.48	1.86	40.8	TMV, F-1
CLN1621C	29	39	38	4.6	3.92	0.46	1.94	85.1	TMV, F-1
UC204A	25	37	76	nt	nt	nt	nt	Nt	F-1, F-2, GLS
CLN2001C	23	42	50	4.4	4.00	0.35	1.95	72.7	TMV
CLN2001B	23	39	55	4.1	4.03	0.33	1.98	81.4	TMV
Mean of all entries	34	39	63	4.0	4.00	0.36	1.88	62.6	-
LSD (0.05)	11	6	7	0.4	0.11	0.06	0.20	25.8	-
CV%	16	11	5	5.0	1.29	7.86	4.95	19.7	

ToMV = tomato mosaic virus, F-1 and F-2 = resistance to races 1 and 2, respectively, of the fusarium wilt pathogen, GLS = gray leaf spot soil drenching method at 28°C. Aggressiveness (mean final percent wilt on each tomato line or over lines) of strains from each population, subfield, or biovar was compared. Genomic fingerprint of each strain was determined by random amplified polymorphic DNA (RAPD) method with four random primers (OPAD1, OPAE1, OPAG6, and OPAG14). Haplotypic diversity (H; Nei's index) was calculated to indicate the degree of genetic diversity. Index of differentiation (G_{ST}) was calculated and analysis of molecular variance (AMOVA) was conducted to determine the differentiation at different hierarchical subdivisions.

Biovar 4 strains and biovar 3 strains were predominant in TSS and Ilan populations, respectively. Biovars were not randomly distributed within fields, according to the Fisher's exact test. Overall, the TSS population was more aggressive than the Ilan population with a mean final percent wilt over tomato lines of 53.9 ± 13.2% (variance = 175.3) and 41.3 ± 11.0% (variance = 120.5), respectively (Table 6). The smaller standard deviation and variance of the Ilan population indicated that the population was less diverse in aggressiveness than the TSS population. Aggressiveness of strains between biovars or subfields was similar in the Ilan population, but was significantly different in the TSS population. Overall, biovar 3 strains were more aggressive than biovar 4 strains, and their distribution in subfields was positively correlated with the mean aggressiveness in subfields. Both populations appeared to be highly diverse genetically (Table 6), but the TSS population was more diverse than the Ilan population. Genetic diversity was not similar among subpopulations of

Table 7. *Results on haplotypic differentiation analysis (G_{ST}) and analysis of molecular variance (AMOVA)*

Field	Level	G_{ST}	AMOVA	
			Within	Between
Ilan	Subfield	0.070	9.2%	90.8%
	Biovar	0.113	19.2%	80.8%
TSS	Subfield	0.085	11.4%	88.6%
	Biovar	0.013	5.0%	95.0%
Ilan + TSS [1]	All	0.051	7.8%	92.2%
	Biovar 3	0.050	9.7%	90.3%
	Biovar 4	0.130	16.5%	83.5%

[1] Strains collected from Ilan and TSS were combined (Ilan+TSS), then examined for differentiation between populations (Ilan vs. TSS) considering all the strains (All), biovar 3 strains (Biovar 3), or biovar 4 strains (Biovar 4), separately.

Table 6. *Variation in genotype and aggressiveness in two populations of* R. solanacearum *collected from Taiwan Seed Propagation and Improvement Station (TSS) and Ilan County*

Field	Level	Strain number[1]	Haplotype number	H [2]	Aggressiveness (%)[3]			
					L390	L180-1	H7996	Total
Ilan	Total	41(59%)	16	0.878	96.1	22.0	5.9	41.3
	Subfield1	11(55%)	5	0.764	1.7a	28.0a	0.8b	40.2a
	Subfield2	15(40%)	4	0.752*	96.1a	20.6a	5.6ab	40.7a
	Subfield3	15(80%)	11	0.933	99.4a	18.9a	10.0a	42.8a
	Biovar 3	24	12	0.815	97.2a	22.9a	8.3a	42.8a
	Biovar 4	17	6	0.743*	94.6a	20.6a	2.5b	39.2a
TSS	Total	60(37%)	39	0.964	97.2	48.3	16.1	53.9
	Subfield1	13(31%)	5	0.628*	98.7a	44.2bc	10.3b	51.1bc
	Subfield2	12(25%)	9	0.939	92.4b	36.8c	12.5b	47.2c
	Subfield3	14(29%)	9	0.901	100.0a	50.6ab	19.0ab	56.5ab
	Subfield4	12(42%)	10	0.970	96.5ab	51.4ab	20.1a	56.0ab
	Subfield5	9(67%)	8	0.972	98.1a	62.0a	19.4ab	59.9a
	Biovar 3	22	20	0.991*	99.6a	70.8a	28.4a	66.3a
	Biovar 4	38	19	0.912*	95.9b	35.3b	9.0b	46.7b

[1] Percentage of biovar 3 strains at each level is shown in parentheses.
[2] Value of Nei's haplotypic diversity index (H); * means that the H index at the sublevel is significantly different from the total H.
[3] Final percent wilting on each line or over lines (Total). Mean comparison was conducted among subfields and biovars of each population. Means with the same letter were not significant at P=0.05 by DMRT.

biovar or subfield within each population (Table 6). Biovar 3 strains were more diverse than biovar 4 strains. Subfield 2 strains of the Ilan population and subfield 1 strains of the TSS population were significantly less diverse than their entire respective populations. Results of G_{ST} and AMOVA (Table 7) pointed out that both populations were differentiated at the biovar and subfield levels. However, effect of biovar (19.2% of the total variation) was more important in differentiating the Ilan population, while the effect of subfield (11.4% of the total variation) was more important in differentiating the TSS population. Significant differentiation existed between the two populations (Table 7). However, only the biovar 4 subpopulation showed substantial differentiation. This indicates that biovar 4 strains might be more sensitive to the environmental differences between the two fields.

In conclusion, large variation in genotype and aggressiveness exists among strains in the same field. The Ilan population was less diverse than the TSS population, both in genotype and aggressiveness. This might be due to the different cropping systems in the two fields. In Ilan, tomato is planted after paddy rice, while green manure (*Sesbania* spp) is rotated with tomato in TSS. Paddy rice cultivation might cause significant drifting and result in a more homogeneous population. The effect of cropping system on strain variation of *R. solanacearum* needs to be studied further.

Contact: J F Wang

Screening for resistance to tomato fruitworm in *L. hirsutum*-based breeding progeny and *L. cerasiformae*

Tomato fruitworm (TFW), *Helicoverpa armigera* (Hübner), is a polyphagous pest that attacks a wide variety of crop species, including tomato, maize, cotton, mungbean, cowpea, chickpea, and others. In tomato, after feeding on leaves, where adults lay eggs, the larvae enter the fruit and feed inside before leaving to pupate in soil. Because it can feed on so many crops and because for most of its life cycle it is protected by a cover of plant tissue or soil, the tomato fruitworm is very difficult to control by conventional pesticide use. The pest has already developed resistance to a large number of commonly used chemical insecticides. At AVRDC, we have been working on breeding tomato cultivars resistant to TFW and have developed a few breeding lines with moderate levels of resistance to the pest—the resistance of which was derived from *L. hirsutum*. The fruits of these lines are too small to compete in the market with commercial cultivars, but the lines can be used as parents to impart resistance. In this field experiment, we tested these breeding lines and two accessions of *L. cerasiformae*, which are potential sources of resistance, to judge their suitability as parents.

Seeds of seven test lines and two susceptible checks were germinated in soil-compost mixtures in a greenhouse. One-month-old seedlings were transplanted in the field in 15-m-long and 1.5-m-wide, single-row plots; each entry in three randomly selected plots. Plant-to-plant distance was 1 m in each plot. The crop was grown using local cultural practices—weeding, irrigation, fertilizer, fungicide, but no insecticide. When most of the entries were in flower, we released an undetermined number of laboratory-reared TFW adults at irregular intervals in the planted area to increase ambient pest population pressure to assure uniform pest infestation. We observed tomato fruits for TFW damage three times before final harvest. Total fruits and damaged fruit from each plant in each entry were recorded and percent damaged fruit was calculated. We also recorded the number of plants in each entry showing pest damage in fruit. At each observation we plucked TFW-damaged fruit and scattered them in the field to

Table 8. *Tomato fruitworm damage, various entries, Spring 1999, AVRDC*

Entry designation	Fruit damaged (%)[1]	Plants damaged (%)[1]
UC204A	3.93	77.3
LA1320	0.98	47.2
CL5352C	2.49	69.1
CL5352B	4.80	91.5
CL5352A	3.09	80.4
CLN1466I	7.34	87.3
CLN1466J	8.37	85.1
LA1310	1.12	54.9
CL5915[2]	7.47	92.8
LSD	3.88	29.9

[1] Data are means of three observations, each with three replicates.
[2] Susceptible check.
Transplanting date: 28 October 1998. Damage observation dates: 12, 27 January and 11 February 1999.

increase pest population pressure. The mean fruit damage and mean plant damage data were compared by the test of Least Significant Difference (LSD).

The results are summarized in Table 8. Two *L. cerasiformae* entries, LA1310 and LA1320, were the least damaged, in terms of number of plants damaged and fruits damaged. Two test entries, CL5352A and CL5352C, were also significantly less damaged (number of plants) than the susceptible check CL5915. On a plant-damage basis, however, they were on par with the susceptible check. It must be pointed out that the plant-damage criterion is very severe: a plant with one damaged fruit earns the same rating as a plant with every fruit damaged. UC204A, a selection from a commercial cultivar, showed much less damage than the susceptible check. It has respectable fruit size. The *L. cerasiformae* entries had the smallest fruit. Some study with these two entries has indicated there is no relationship between fruit size and insect infestation, so these lines represent an important source of resistance to TFW.

Contact: N S Talekar

Late blight resistant tomato lines

Two fresh market tomato (*Lycopersicon esculentum* Mill.) inbred lines, CLN2037B and CLN2037E, possessing race-specific resistance to the late blight (LB) pathogen, *Phytophthora infestans* (Mont.) deBary, were developed at AVRDC. Resistance in the lines originated from AVRDC *L. pimpinellifolium* accession L3708, and was introgressed into cultivated tomato through backcrossing and selection. L3708 has expressed high resistance levels in multilocation field tests conducted over wide geographical areas. Late blight resistance in L3708 is conditioned by a single partially dominant allele, *Ph-3*, which has been mapped to tomato chromosome 9.

Plants of CLN2037B and CLN2037E are of determinate and indeterminate growth habit, respectively. The lines are green-stemmed due to the presence in homozygous state of the anthocyaninless of Hoffman (*ah*) allele; *ah* in these lines is linked to the Tobacco mosaic resistance-2^2 allele (*Tm*-2^2), conditioning resistance to multiple strains of tobacco mosaic virus (Stevens and Rick, 1986). Foliage cover of CLN2037B and CLN2037E were rated good and fair, respectively. Fruit of CLN2037B averaged 123 g, were globe to deep-globe shaped, contained 3-4 locules, and had smooth shoulders with slight fasciation. Fruit wall thickness averaged 0.7 cm. The blossom end scar was dot to small stellate. Unripe fruit were light green and fully ripened fruit were moderately soft, with good external color and fair

Table 9. *Yields, plant and fruit trials of the top 10 inbred lines in a spring preliminary yield trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Maturity (DAT)	Total yield (g/plant)	Biomass[2] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Harvest index (%)
PBC 197	83	123	1465	465	8.1	6.7	108	14	76
9852-190	81	122	1135	286	11.1	5.7	98	12	80
PBC 845	84	124	1089	405	7.8	6.1	80	14	73
9848-4840	80	117	1089	299	7.6	5.2	50	22	78
9848-5009	77	123	1031	365	7.5	4.6	41	25	74
9847-4704	90	123	1016	403	10.8	6.1	98	10	72
PBC 438	87	124	966	349	7.1	6.5	91	11	73
9847-4669-2	79	124	910	429	8.4	4.5	41	22	68
PBC 843	87	124	908	360	7.3	6.9	105	9	72
9847-4677	88	124	904	481	8.2	5.8	69	13	65
F_1 Andalus (ck)	83	122	869	291	11.8	5.7	91	9	75
F_1 Blue Star (ck)	88	122	522	174	9.9	5.9	82	6	75
Mean	83	126	586	317	7.3	4.6	45	17	64
Range	64-106	107-125	61-1465	53-643	4.0-11.3	2.0-6.9	8-98	4-36	9-83
$LSD_{0.05}$	10	10	368	222	1.5	1.2	21	19	14
CV (%)	6	2	32	34	10.5	13.0	24	56	11

[1] DAT = days after transplanting.
[2] Plant weight after all fruits removed.

internal color. CLN2037 fruit averaged 140 g, were deep globe shaped with three locules, smooth-shouldered with slight fasciation. Fruit wall thickness averaged 0.7 cm. The blossom end scar was dot to slightly dented. Unripe fruit were light green and fully ripened fruit were moderately firm, and showed good internal and external color. In a greenhouse BW evaluation trial using *R. solanacearum* strain Pss4, the percentages of healthy plants four weeks after inoculation for CLN2037B and CLN2037E were 20% and 60%, respectively, compared to 90% for resistant check H7996 and 0% for susceptible check L390. CLN2037B and CLN2037E are susceptible to gray leaf spot (caused by *Stemphyllium* sp.) and fusarium wilt (FW) race 1 (caused by *Fusarium oxysporum* f. sp. *lycopersici*). After seedling inoculation of CLN2037B and CLN2037E with FW race 2, 90% and 69% of plants, respectively, were rated resistant (no wilting, stunting, or vascular browning). Some seed samples of CLN2037B and CLN2037E are available from AVRDC upon request.

Contact: P Hanson

Heat tolerant sweet pepper lines

Sweet peppers are not widely grown in the subtropics and tropics because they lack heat tolerance and disease resistance. AVRDC is developing improved sweet pepper inbreds with heat tolerance and disease resistance for the hot and humid tropics to replace heat sensitive open-pollinated sweet pepper varieties, such as California Wonder, Early Calwonder, and Yolo Y. In addition, our goal is to extend sweet pepper production to new regions.

Two preliminary yield trials (same entries) were conducted (RCBD, two replications, 10 plants/plot, 30,000 plants/ha) to evaluate the yield potential of 121 breeding lines and accessions during the cool-dry season (planted 4 February) and the hot-wet season (planted 1 April). The cool-dry spring season was excellent for sweet pepper growth, while the hot-wet summer season was very stressful. Data for the top 10 lines from the spring and summer trials are shown in Tables 9 and 10, respectively. Only two lines, 9848-4840 and 9848-5009, were higher yielding in both trials, and entry by environment interactions were significant for every trait except fruit width.

Mean yield of the summer trial was 40% less than the spring trial due to a decrease in fruit number, especially among the larger-fruited varieties, and fruit size (primarily fruit length), which significantly lowered the mean fruit weight.

AVRDC started its International Sweet Pepper

Table 10. *Yields, plant and fruit trials of the top 10 inbred lines in a summer preliminary yield trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Maturity (DAT)	Total yield (g/plant)	Biomass[2] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Harvest index (%)
9847-4542	67	109	739	358	7.0	2.4	12	62	67
9848-4840	69	104	734	373	7.9	4.9	42	18	66
PBC 344	66	104	668	626	10.3	4.4	42	16	52
9848-4841	62	103	660	394	6.2	4.6	35	19	63
9852-131	66	105	631	378	9.1	3.6	33	19	63
9847-4757	57	103	630	250	5.0	4.3	23	27	72
PBC 235	66	103	571	473	6.4	2.9	12	50	55
9847-4661	67	107	570	330	7.4	3.3	22	26	63
9848-5009	69	107	548	414	5.5	4.2	28	20	57
9847-4510	69	107	520	665	6.0	3.6	21	25	44
F_1 Andalus	71	109	439	438	13.9	4.9	68	6	50
F1 Blue Star	70	106	378	295	9.9	5.7	90	4	56
Mean	68	106	356	353	6.4	4.2	32	15	50
Range	57-75	103-123	15-739	153-961	3.6-13.9	2.3-6.6	9-90	1-62	2-72
$LSD_{0.05}$	6	3	247	217	2.0	1.0	27	12	14
CV (%)	4	1	35	31	15.8	12.6	43	41	14

[1] DAT = days after transplanting.
[2] Plant weight after all fruits removed.
All mature and immature fruits were harvested at the same time to get an estimate of yield potential.

Nursery (ISPN) in 1999. The trial includes 10 inbred line entries, plus 1–2 local checks, inbreds or hybrids. During the hot, rainy season, the 1st ISPN was evaluated at AVRDC (RCBD, four replications, 10 plants/plot, 30,000 plants/ha, planted 1 April). The checks were commercial hybrids. Data for yield and horticultural characteristics are shown in Table 11. PBC 271 and PBC 344 yielded as well as commercial check, F_1 Andalus, and significantly higher than F_1 Blue Star. Disease reactions of ISPN entries in AVRDC greenhouse trials are presented in Table 12.

Contact: T G Berke

Table 11. *Yields, plant and fruit traits of the 1st International Sweet Pepper Nursery summer field trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Total yield (g/plant)	Biomass[2] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Harvest index (%)
9852- 14	66	206	193	6.5	2.7	10	22	52
9852- 37	66	214	306	6.9	3.8	17	13	41
9852- 64	67	186	153	4.1	3.7	15	13	55
9852-136	66	131	121	7.0	3.0	15	9	52
9852-140	65	215	236	5.2	4.4	22	10	48
9852-179	68	207	207	6.7	3.5	17	12	50
PBC 271	68	350	153	7.4	5.1	40	9	70
PBC 310	72	174	142	6.4	4.0	22	8	55
PBC 344	70	331	266	10.4	3.6	25	13	55
PBC 577	75	140	123	5.6	5.0	39	4	56
F_1 Blue Star	69	191	83	8.9	4.8	47	4	70
F_1 Andalus	71	352	153	13.8	4.6	53	7	70
Mean	69	225	177	7.4	4.0	27	10	56
LSD0.05	2	83	94	0.7	0.3	5	5	13
CV(%)	6	26	37	6.1	5.4	14	32	17

[1] DAT = days after transplanting.
[2] Plant weight after all fruits removed.
All mature and immature fruits were harvested at the same time to get an estimate of yield potential.

Table 12. *Disease reactions of entries in the1st International Sweet Pepper Nursery*

Code	ChiVMV	Pathotype 1 PB	Pathotype 2 PB	PVY	ToMV	CMV	BW
	Number of plants inoculated						
	12	24	24	12	12	12	36
	% susceptible						
9852- 14	16	0	83	0	100	100	85
9852- 37	75	0	8	16	100	100	97
9852- 64	0	0	50	0	100	100	100
9852-136	68	0	100	0	100	100	94
9852-140	33	0	92	0	100	100	67
9852-179	100	50	100	100	100	100	89
PBC 271	0	8	0	0	100	100	93
PBC 310	33	75	100	0	100	100	93
PBC 344	100	67	100	100	75	100	70
PBC 577	100	83	100	100	100	100	100
F_1 Blue Star	NT	100	100	NT	NT	100	92
F_1 Andalus	NT	NT	NT	NT	NT	100	98

BW = bacterial wilt; ChiVMV = chili veinal mottle virus; PB = phytophthora blight; PVY = potato virus Y; ToMV = tomato mosaic virus; CMV = cucumber mosaic virus

Molecular markers linked to genes of pepper for resistance to bacterial spot

Bacterial spot (BS), caused by *Xanthomonas campestris* pv. v*esicatoria*, is an important disease of sweet peppers. Resistance is the best means to manage the disease. Dominant alleles at three loci, Bs1, Bs2, and Bs3, provide resistance to common BS races, but recently, new races have been isolated that are capable of overcoming these resistance genes.

Utilization of horizontal resistance might contribute to disease control and reduce the problem of new races. The objective of this study was to identify RAPD markers linked to quantitative trait loci (QTLs) conferring BS resistance. A total of 123 F_7 recombinant inbred lines (RILs) were developed from the intraspecific (*C. annuum*) cross NacionalAG-506 (susceptible) × CNPH703 (resistant). The parents and 123 RILs were grown in a climate-controlled greenhouse at AVRDC with four replicates and six plants per replication. Leaves were inoculated with BS race 1, the most common race in Taiwan. Symptoms were rated by the Barrett and Horsfall (BH) scale (0-11, 0 = resistant, 11 = susceptible), and by lesion size (1-7 scale, 1 = small, 7 = large). The resistant and susceptible parents had mean BH ratings of 2.0 and 6.3, respectively, and mean lesion size scores of 1.7 and 5.6, respectively. The 123 RILs had a BH mean of 4.6, and means ranged from 2.1 to 5.9, with an approximately normal distribution. For lesion size, the 123 RILs had a mean of 4.2 and a range of 2.2-6.2, but showed an approximately bimodal distribution. RAPD molecular marker data were collected at the University of Wisconsin, Madison, and National Taiwan University, Taipei. Each lab screened parental DNA samples for polymorphism using 1000 Operon RAPD primers. One hundred eighty-two RAPD markers and one qualitative locus

Table 13. *Linkage group, map position, and LOD scores for QTLs identified for BH rating and lesion size in a F_7 mapping population*

Linkage group	Map position	BH rating LOD	Lesion size LOD
1	160	3.0[1]	
2	0	7.0[1]	
2	278	3.1	
4	216	20.6	19.1
5	40	3.3	
7	110	3.9	4.7
12	156	3.8	

[1] QTL for resistance came from the susceptible parent.

QTL = quantitative trait loci; BH = Barrett and Horsfall scale; and LOD = log of odds

Table 14. *Yield, plant and fruit traits of the top 10 inbred lines in a spring preliminary yield trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Maturity (DAT)	Total yield (g/plant)	Biomass[2] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Harvest index (%)
9852- 56	79	113	1183	284	11.9	3.8	39.0	30	81
9852- 90	83	115	893	231	10.7	2.0	14.8	61	79
9852-173	76	111	853	301	9.7	1.7	10.5	81	74
9852-327	76	111	824	336	11.5	1.8	11.8	70	71
9852- 27	82	115	775	458	7.6	2.1	9.5	82	63
9852- 91	85	117	721	236	10.3	1.8	11.8	61	75
9852-121	84	113	716	346	11.3	1.9	12.8	56	67
9852-149	79	113	689	390	10.1	1.5	7.3	95	64
9852-253	81	113	678	379	11.7	1.3	6.8	100	64
97-7644	81	115	670	196	11.0	1.9	12.5	54	77
F_1 HyHot 3	82	117	844	349	14.9	1.4	12.8	66	71
F_1 Golden Heat	77	113	811	370	13.0	1.3	9.5	85	69
Mean	83	114	455	299	9.5	1.6	8.2	67	60
Range	65-106	101-123	83-1183	89-526	3.7-19.1	0.9-3.8	2.0-39.0	14-167	16-86
$LSD_{0.05}$	9	7	274	130	1.8	0.3	2.8	43	15
CV (%)	6	3	30	22	9.5	8.8	17.4	32	13

[1] DAT = days after transplanting.

[2] Plant weight after all fruits removed.

(L locus) were scored in the 123 RILs. A linkage map was constructed with 12 linkage groups and six unlinked (>50 cM) markers, which covers an estimated 1824 cM of the pepper genome. Approximately 75 of the 182 RAPD markers were co-segregating or tightly linked (≤2 cM). Segregation at each marker locus was checked for deviation from the expected 1:1 ratio, and 75 out of 183 markers (including the L locus) revealed skewed distributions (P≤0.01).

RAPD loci significantly (p≤0.01) associated with BH rating and lesion size were detected by composite interval mapping, using the program PLABQTL. A QTL was defined as one or more consecutively linked RAPD loci significantly associated with a trait (LOD score ≥3.0). Seven QTLs on six linkage groups were significantly associated with BH rating (Table 13). Two QTLs on two linkage groups were associated with lesion size, which possibly explains the bimodal distribution observed in lesion size values. The lesion size QTLs were also associated with BH rating. The QTL with the largest LOD scores for lesion size was observed on linkage group 4. For BH rating, the seven QTLs accounted for 64.3% (R^2) of the phenotypic variation, with a combined LOD score of 24.6. Surprisingly, the susceptible parent contributed two resistance QTLs for BH rating. For lesion size, the two QTLs accounted for 52.5% (R^2) of the phenotypic variation, with a combined LOD score of 17.8. Both resistance QTLs came from the resistant parent.

Contact: T G Berke

Multiple disease resistant chili pepper

Chili peppers are widely grown in the sub-tropics and tropics. However, chili pepper yields are unstable due to diseases and insects. AVRDC is developing improved chili pepper inbred lines with multiple disease and insect resistance for the hot and humid tropics in order to improve the yield stability and decrease production costs.

Two preliminary yield trials (same entries) were conducted (RCBD, two replications, 10 plants per plot, 30,000 plants per hectare) to evaluate 121 breeding lines and accessions during the cool, dry season (planted 4 February), ideal for chili pepper growth, and the hot, rainy season (planted 1 April), less conducive to chili production. Data for the top 10 lines in each season are shown in Tables 14 and 15. Five entries were among the top ten yielders in both trials. The mean yield of the summer trial was 30% less than the mean yield of the spring. This was due to a decrease in fruit size, not fruit number. Entry-by-environment interactions were significant for all traits except fruit number.

Table 15. *Yield, plant and fruit traits of the top ten inbred lines in a summer preliminary yield trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Maturity (DAT)	Total yield (g/plant)	Biomass[2] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Harvest index (%)
9852- 78	63	110	600	540	10.4	1.6	7.0	86	53
9852- 91	63	111	585	700	9.5	1.5	7.0	84	46
9852-121	66	111	565	600	11.4	1.5	9.0	63	48
9852- 93	66	112	560	910	10.9	1.1	4.5	124	38
9852-173	62	108	555	600	8.9	1.6	7.8	72	48
9852-115	65	112	550	530	14.9	1.5	11.0	50	51
9852-171	65	110	525	500	9.2	1.6	7.5	70	51
9852- 90	65	115	520	670	9.0	1.6	7.5	69	44
9852-149	63	107	495	1050	9.5	1.4	5.8	86	32
F_1 HyHot 3	63	107	510	1040	11.3	1.1	6.0	85	33
F_1 Golden Heat	62	111	330	920	13.7	1.1	6.8	48	26
Mean	66	110	320	726	8.7	1.3	5.5	67	32
Range	60-74	103-116	90-600	100-1630	3.1-18.3	0.8-2.7	1.5-20.3	16-194	6-59
$LSD_{0.05}$	5	5	219	358	2.0	0.3	2.2	48	14
CV (%)	4	2	34	24	11.4	10.1	19.4	36	23

[1] DAT = days after transplanting.
[2] Plant weight after all fruits removed.

AVRDC started its International Chili Pepper Nursery (ICPN) in 1990. The trial includes 20 entries, all inbred lines, plus 1-2 local checks, inbreds or hybrids. During the hot, rainy season (sowing 1 April), the 9th ICPN was evaluated at the AVRDC. The experimental design was RCBD with four replications. Two commercial F_1 hybrids were used as checks. Data for the entries are shown in Table 16. Plants were harvested weekly, during a period of almost continuous rain. Flooding killed most plants so the trial was suspended after five harvests. Anthracnose incidence was high and caused a high cull percentage. Two lines, 9852-19 and 9852-173, showed excellent field tolerance to anthracnose, with cull percentages of 11% and 14%, respectively. The two lines also yielded significantly higher than the other lines, including the checks. Two lines, 9852-61 and 9852-110, had very high capsaicin content (100,533 and 130,632 Scoville Heat Units, respectively) and would be suitable for oleoresin production. Entries in the 9th ICPN were screened for six common diseases as seedlings in the greenhouse or screenhouse at AVRDC (Table 17).

Contact: Terry Berke

Multilocation testing of the International Chili Pepper Nursery

It would be impractical to develop varieties for each environment in which chili might be grown, so breeders define a target population of environments (TPE) and then test their lines in a representative sample of these. Preliminary yield trials are conducted in one or two environments in hopes of identifying lines with broad adaptation (high and stable yield) in the TPE. Ideally, preliminary yield trial environments are chosen for their similarity to the TPE.

Table 16. *Yield, plant and fruit traits of the 9th International Chili Pepper Nursery summer field trial, AVRDC, 1999*

Code #	Anthesis (DAT)[1]	Market yield (g/plant)	Total yield (g/plant)	Cull (%)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit no. /plant	Capsaicin (SHU)[2]
9852- 15	28	211	339	38	8.2	1.3	5.4	39	9,645
9852- 17	23	104	280	62	9.9	1.1	5.3	20	24,811
9852- 18	29	230	309	25	8.2	1.4	4.9	47	3,108
9852- 19	25	335	375	11	9.1	1.3	5.4	62	4,799
9852- 51	29	73	128	43	4.4	1.0	1.8	42	29,940
9852- 54	25	59	220	74	7.0	0.9	2.3	26	43,655
9852- 61	30	13	125	90	6.3	0.9	2.2	6	100,533
9852- 77	25	90	228	62	9.4	1.4	6.3	14	11,034
9852- 78	19	92	319	73	9.3	1.5	5.1	18	12,097
9852- 79	28	126	276	55	9.0	1.4	6.6	19	6,310
9852-100	29	74	189	62	6.9	1.3	3.4	22	9,171
9852-110	29	57	155	63	5.3	0.9	1.8	32	130,632
9852-170	26	65	235	73	7.8	1.1	3.8	17	82,807
9852-173	25	391	454	14	8.7	1.5	6.9	57	7,959
PBC 142	31	33	118	71	5.3	0.8	1.4	24	64,292
PBC 308	26	84	338	76	10.5	1.8	10.5	8	17,773
97-7114	27	57	278	79	8.4	1.4	6.5	9	8,048
97-7127	28	89	202	56	10.2	1.7	7.5	12	48,046
97-7195-1	29	136	283	53	8.7	1.3	4.9	28	34,237
97-7644	27	127	335	62	10.2	1.0	3.9	33	16,067
F_1 HyHot 3	26	4	251	98	14.0	1.2	6.8	1	NA
F_1 Golden Heat	25	51	336	85	11.4	1.3	6.1	8	47,537
Mean	27	122	259	57	8.1	1.2	4.8	27	33,248
$LSD_{0.05}$	3	51	61	15	1.0	0.2	1.2	12	11,034
CV(%)	9	32	16	17	8.0	10.9	17.0	34	25

[1] DAT = days after transplanting.

[2] Scoville Heat Units

AVRDC's International Chili Pepper Nursery (ICPN) has been distributed for testing all over the world for nine years. On average, 10 cooperators per year return yield data and information on other traits (Table 18). The number of entries distributed to each cooperator has varied, from 13 to 30, but since the 6th ICPN, the number has been standardized at 20. A long-term check, PBC 142, has been included since the 2nd ICPN so that comparisons can be made between environments within trials and among environments across trials.

Several stability parameters have been used, including the coefficient of variation (CV), the regression coefficient (b) on the environmental index, the deviations from regression (s^2_d) of a genotype on the environmental index, the rank correlation index, and the additive main effects multiplicative interaction (AMMI) model.

We performed two types of data analyses, rank summation, and standardization of values against the long-term check (PBC 142) in order to conduct combined data analysis. Rank summation uses the relative rank of each entry in each environment and has no units. Genotypes with high and stable yield will have a relatively high rank ($u \leq 6$) and low variance ($ó^2 \leq 30$). Using these criteria, 19 genotypes tested in the past nine years had high and stable yield (Table 19). Standardization of values against the long-term check allows comparisons among trials within nurseries and among nurseries across years. By setting the long-term check arbitrarily to 100% in

Table 18. *ICPN feedback received from cooperators over the past nine nurseries*

Trial	Cooperators no.	Entries no.	Mean rank of PBC 142	Mean rank of best line
1	17	30	NA	5.7
2	12	15	7.3	4.8
3	8	16	7.4	3.2
4	7	16	9.1	3.3
5	10	13	6.0	3.6
6	13	20	9.3	4.5
7	14	20	11.5	5.2
8	16	20	14.5	5.5
9[1]	6	20	14.4	6.9

[1] Data reported as of November 1999.

Table 17. *Disease reactions of entries in the 9th International Chili Pepper Nursery*

Code	ChiVMV	PB	PVY	ToMV	CMV	BW
9852- 15	0	87	42	100	100	50
9852- 17	100	100	100	100	100	72
9852- 18	92	87	0	100	50	89
9852- 19	0	96	0	100	100	92
9852- 51	0	37	0	100	0	64
9852- 54	25	92	0	100	66	3
9852- 61	0	92	100	100	66	78
9852- 77	0	100	0	100	33	78
9852- 78	17	8	0	100	33	17
9852- 79	17	96	0	100	0	88
9852-100	0	0	100	100	33	11
9852-110	0	100	0	100	0	60
9852-170	0	96	100	100	0	58
9852-173	50	100	0	100	83	17
PBC 142	33	87	100	100	33	78
PBC 308	100	56	100	100	100	25
97-7114	83	100	33	100	66	61
97-7127	66	83	0	100	100	31
97-7195-1	50	8	0	100	50	3
97-7644	83	100	0	100	100	39
F_1 HyHot 3	NT	NT	NT	NT	NT	NT
F_1 Golden Heat	NT	NT	NT	NT	NT	NT

ChiVMV = chili veinal mottle virus; PB = phytophthora blight; PVY = potato virus Y; ToMV = tomato mosaic virus; CMV = cucumber mosaic virus; BW = bacterial wilt. Numbers are percent diseased plants after inoculation. NT = not tested. Number of inoculated plants: 24 for PB, 36 for BW, and 12 for each of the others.

each environment, the yield of each entry relative to the long-term check can be computed on a percentage basis by dividing its yield by the yield of the check. The relative yield of each environment can be computed by averaging the relative yields of all entries in a given environment. The relative yield of the best lines in each trial, the number of lines yielding >200% relative to the check, and the relative mean yield and range of each nursery is shown in Table 20. For the first seven trials, the relative mean of the trial fluctuated around a mean of 137%, never rising higher than 158%. The 8th ICPN showed a significant increase in the relative mean at 384%, and the 9th ICPN (which had received responses from six cooperators by press time) also had a relative mean >300%. Over all nine trials, a total of nine varieties showed a relative mean yield >400% of the long-term check (Table 21).

Cluster analysis of both rank summation and standardized mean data of the entries in each ICPN trial was performed to try to group environments into mega-environments. The resulting clusters were analyzed to see if there was any geographical effect (area of the world, altitude, etc.) on performance. When rank summation data were used, each trial clustered into 2-4 distinct clusters, such as the 2nd ICPN trial, for example (Table 22). Three distinct clusters were formed, but there was no geographical effect on performance. Information about the season in which the crop was grown (hot-wet, hot-dry, cool-wet, or cool-dry) and/or the soil fertility might help explain this clustering. Similar clustering was found in the other ICPN trials. When standardized yield data were used for cluster analysis, the high-yielding

Table 19. *ICPN entries with high and stable yield (u<6 and ó^2<30)*

Trial l	Entry	Mean rank	ó^2	Disease resistance[a]
1	F_1 Hot Beauty	5.7	23.2	NT[b]
2	PBC 598	4.8	9.2	
	PBC 384	4.8	11.2	BW, PVY
	PBC1347	4.8	9.8	BW, PVY
3	PBC 535	3.2	17.4	BW, PVY
	PBC 473	4.2	9.4	BW
	PBC 485	5.4	7.3	
4	PBC 581	3.3	6.3	BS, BW, PVY
	PBC 600	4.4	20.0	BS
5	PBC 374	3.3	12.9	
	92-1203	5.3	16.5	PVY
	PBC 142	6.0	9.3	BS
6	PBC 973	4.5	12.1	BW, BS
	PBC 972	5.3	19.9	BW, BS, PVY
	PBC 586	5.4	15.4	CMV, PVY
	PBC 601	5.9	11.0	BW, CMV, PVY
	PBC 585	5.9	17.3	BW, CMV, PVY
7	PBC1474	5.2	6.8	BS, BW, PVY
8	PBC 308	5.6	28.1	

[a] Each ICPN trial is tested for resistance to anthracnose, bacterial spot (BS), bacterial wilt (BW), chili veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), phytophthora blight (PB), potato virus Y (PVY), and tomato mosaic virus (ToMV).

[b] Not tested.

Table 20. *Relative yield of the best line in each trial, number of lines yielding >200% relative to the check, and the relative mean yield and range of each of the nine ICPN trials*

Trial	PBC 142 rank (ck)	Top (%)	No. of lines >200% of ck	Trial mean	Trial range (%)
1	NA	NA	NA	NA	NA
2	10/15	262	1	120	54-262
3	13/16	404	3	158	39-404
4	12/16	171	0	114	73-171
5	10/13	301	3	148	54-301
6	12/20	279	5	138	59-279
7	18/20	243	3	144	90-243
8	20/20	729	18	384	192-729
9[1]	20/20	589	14	307	113-589

[1] Data received as of November 1999.

Table 21. *ICPN entries from the first 9 trials that yielded >400% of long-term check PBC 142*

Trial	Line	Yield (%)	Disease resistance[1]
8	97-7195-1	729	BW, PVY
8	PBC 308	615	
8	97-7623	554	BW
8	97-7126	544	ChiVMV
9	9852-173	507	BW, PVY
8	97-7644	479	PVY
8	PBC 161	477	BW, CMV, PVY
8	97-7127	433	BW, PVY
9	97-7644	419	PVY
3	PBC 535	404	BW, PVY, PB
9	97-7127	403	BW, PVY
9	97-7195-1	401	BW, PVY

[1] Each ICPN trial is tested for resistance to anthracnose, bacterial spot (BS), bacterial wilt (BW), chili veinal mottle virus (ChiVMV), cucumber mosaic virus (CMV), phytophthora blight (PB), potato virus Y (PVY), and tomato mosaic virus (ToMV).

environments tended to cluster together, as did the low-yielding environments. Maha Illupalama (MI), Sri Lanka, had a very wide range of yields, and formed a distinct cluster. The mean and range of each environment is shown in Table 23. The clustering pattern was very different from that observed using the rank summation data, and again did not show any geographic effect on performance. Similar clustering patterns were found in the other ICPN trials. Grouping environments into similar patterns of cultivar performance might allow reduction in the number of testing sites and thus conserve resources.

Contact: Terry Berke

Generation and RAPD verification of *Capsicum* interspecific hybrids for developing anthracnose resistant peppers

Anthracnose, incited by *Colletotrichum* spp, causes substantial pre- and post-harvest fruit decay of pepper, especially during the hot-wet season in the tropics and subtropics. No commercial varieties are highly resistant to anthracnose. However, AVRDC's mycology unit has identified accessions of *C. chinense* and *C. baccatum* resistant to anthracnose (see *AVRDC Report 1997*). A varietal improvement program was initiated to introgress resistance from the wild *Capsicum* species to cultivated peppers. Since direct crosses between *C. annuum* and *C. baccatum* rarely produce viable seeds, this activity was initiated to rescue interspecific progenies via *in vitro* culture technique. Hybrids derived through embryo-rescue were later verified with RAPD molecular markers.

Four *C. annuum* lines, PBC950, PBC534, PBC972, and PBC66, were crossed as female parents to anthracnose resistant donor parents PBC81 (*C. baccatum*) and PBC932 (*C. chinense*). Flowers of female parents were emasculated one day before opening and hand-pollinated by the donor parents the following day, either before 1000 hours or after 1600 hours. Developing seeds were excised from fruits, beginning at 10 days after pollination (DAP) until 90 DAP, and cultured on Murashige and Skoog (MS) basal medium under light/dark period of 16/8 hours and at 25±0.5°C. DNA was extracted from the young leaves of plants derived from embryo rescue to confirm they were interspecific hybrids.

Primer kits AE and AN from Operon Technology were used for RAPD analysis. RAPD reactions were performed in 25 ml volume containing 2.5 ml 10× buffer (0.5M Tris-HCl, 1M KCl), 3 mM MgCl2, 2.5 mM dNTPs, 0.2 mM primer, 0.5 unit *Taq* DNA polymerase and 0.1 ng pepper genomic DNA. Amplification was executed with a Thermolyne thermal cycler (Amplitron II). The thermal cycle program was 1 min at 94°C, 1 min at 40°C, and 2 min at 72°C for 3 cycles, followed by 30 sec at 94°C, 30 sec at 40°C, and 1 min at 72°C for 40 cycles, and

Table 22. *Cluster analysis of the 2nd ICPN trial based on rank summation data*

Cluster	Locations
1	Davis, CA, USA; Bouake, Cote d'Ivoire; Reduit, Mauritius; Ludhiana, India; TARI, Taiwan
2	MI, Sri Lanka; Keluang, Malaysia; AVRDC, Taiwan; Nanjing, China; Kasetsart, Thailand
3	Suwon, Korea; Nazareth, Ethiopia

Table 23. *Standardized mean and range of yields observed in 12 environments in the 2nd ICPN trial*

Trial location	Mean	Range	Cluster
Davis, CA, USA	105	65-150	1
Bouake, Cote d'Ivoire	91	20-165	1
Reduit, Mauritius	176	0-375	3
Ludhiana, India	93	9-251	2
TARI, Taiwan	126	36-261	1
MI, Sri Lanka	191	0-1294	4
Keluang, Malaysia	155	46-365	2
AVRDC, Taiwan	25	0-73	2
Nanjing, China	89	28-238	1
Kasetsart, Thailand	62	0-119	2
Suwon, Korea	190	83-287	3

Table 24. *Fruit setting rate of interspecific* Capsicum *hybridization*

Cross	No. of flowers pollintaed	No. of fruit set	Fruit set (%)
C. annuum x *C. baccatum*			
PBC950 × PBC81	4062	502	12.4
PBC534 × PBC81	3168	443	14.0
PBC972 × PBC81	4888	1344	27.5
PBC66 × PBC81	3867	500	12.9
C. annuum × *C. chinense*			
PBC950 × PBC932	144	2	1.4
PBC534 × PBC932	115	28	2.4
PBC972 × PBC932	80	17	21.3
PBC66 × PBC932	321	29	9.0

then further extended at 72°C for 10 min. The RAPD products were then fractionated in 2.0% agarose gels by electrophoresis at 50V for 4 hours.

The fruit setting rates of *C. annuum* × *C. baccatum* were higher than those of *C. annuum* x *C. chinense* (Table 24). PBC972 showed the highest fruit-set rate among the four *C. annuum* parents, but *in vitro* germination of developing seeds from PBC972 × PBC81 was poor. In general, embryos harvested 30 DAP or later showed better germination compared to those harvested before 30 DAP. However, parental genotype was also an important factor affecting *in vitro* germination, and seeds harvested from *C. annuum* × *C. chinense* crosses had higher germination percentages compared to the *C. annuum* × *C. baccatum* crosses. Some seedlings from the *C. annuum* × *C. baccatum* crosses did not develop normally due to lack of shoot tip and/or root development after germination; however, all seedlings from *C. annuum* x *C. chinense* developed normally. All seedlings from *C. annuum* × *C. chinense* crosses were confirmed, through RAPD analysis, to be interspecific hybrids (Table 25). The percentage of confirmed interspecific hybrid plants in *C. annuum* × *C. baccatum* crosses ranged from 77 to 100. RAPD analysis proved to be effective in the verification of pepper interspecific hybrids and most hybrids were verified with one or few primers.

Contact: C A Liu and C G Kuo

Table 25. *Number of seedlings confirmed to be interspecific hybrids through RAPD analysis*

Cross	No. of seedlings tested	No. of hybrids (interspecific hybrid %)	Polymorphic primer used for verification
C. annuum x *C. baccatum*			
PBC950 × PBC81	56	43	AN3
PBC534 × PBC81	60	58	AN3
PBC972 × PBC81	22	19	AN6, AN9, AE3
PBC66 × PBC81	27	27	AN3
C. annuum × *C. chinense*			
PBC534 × PBC932	21	21	AE7, AE10
PBC972 × PBC932	22	22	AN6, AN10, AN11, AN12
PBC66 × PBC932	40	40	AN6

Table 26. *Reaction of Taiwan ChiVMV isolates on selected* Capsicum *spp entries*

Line	ChiVMV isolate[1]			
	P1037, P3380	P3389	P714	P3215, P3384, P3488, P3525
VC16, 58, 160, 241, 255; C00265; PBC371, 521	I[2]	I	I	I
VC41	I	I	I	S
PBC522, PBC524, C01664	I	I	S	S
VC232, PBC365	I	S	S	S

[1] Origin of isolates: P1037 Taichung/Da Nan (common strain); P3380; P3389, virology field from ChiVMV-resistant plants; P714 Yunlin/Hsilo; P3215, P3384, Pingtung/Likung;P3488, P3525, Hualien/Chian.

[2] I = immune, no symptoms, negative ELISA; S = susceptible (80-100% infection)

CMV/ChiVMV resistance identified and characterized

Chili veinal mottle potyvirus (ChiVMV) and cucumber mosaic virus (CMV) are major chili production constraints and causes of yield instability. However, few sources of resistance to these viruses have been identified. Research in 1999 focused on screening *Capsicum* germplasm for resistance to these two viruses, detection of strains, multilocation screening, and characterization of resistance genes.

Initial screening for CMV resistance was carried out by mechanical inoculation of 24 seedlings per entry at the three-leaf stage with the common CMV strain P-522, followed by enzyme-linked immunosorbent assay (ELISA) at 14 days after inoculation. ELISA-negative plants were re-inoculated and a second ELISA was conducted 30 days after the second inoculation. Thirteen entries, VC16, VC40, VC185, VC211, VC223, VC228, VC231, VC232, VC237, PBC521, PBC549, PBC569, and PBC370 were resistant to the common P-522 and their resistance held up in a second, confirmation screening. Plants of all 13 entries were, however, susceptible to a highly aggressive CMV strain, P-3613, which was isolated and purified from peppers grown in an AVRDC field.

The protocol for ChiVMV resistance screening was the same as described for that of CMV. Resistance (no symptoms, negative ELISA tests) to the common local ChiVMV P-1037 was found in 20 entries: CO1664, CO0265, VC16a, VC58a, VC160, VC211, VC236, VC237, VC240, VC241, VC255, PBC122, PBC148A, PBC370, PBC371, PBC521, PBC522, PBC523, PBC524, and PBC693. A confirmation screening of the resistant entries with P-1037 was carried out and all lines were confirmed resistant.

Additional ChiVMV isolates were collected and purified (by four single local lesion transfers to *Nicotiana tabacum* ‘White Burley’) from infected pepper plants grown in farmers’ fields in different locations throughout Taiwan. Based on their reactions in lines resistant to the common ChiVMV strain (Table 26), seven ChiVMV isolates (P3380, P714, P3215, P3384, P3488, P3525, and P3389) seemed to constitute three new strains.

Reactions of selected chili entries to Thai and Malaysian ChiVMV isolates indicated that they could be grouped into distinct strains, seven in Malaysia, and five in Thailand (Table 27). None of the *Capsicum* spp. entries tested was resistant to all seven ChiVMV strains in Malaysia. However, entry VC58 was resistant to four of the seven strains. Entries VC58, VC160, VC185, and PBC569 were resistant to all five of the Thai ChiVMV strains. These results suggest that more than one resistance gene exists in *Capsicum*, offering resistance to one or several strains of ChiVMV. The existence of a number of distinct strains of ChiVMV in Asia must be considered in AVRDC’s resistance breeding program. Several resistance genes from different sources of resistance need to be combined to produce improved lines with stable resistance to all the ChiVMV strains that might exist in a particular region.

Selected *Capsicum* spp accessions were screened for resistance to other potyviruses, such as pepper veinal mottle potyvirus (PVMV), the most important virus on pepper in Africa, and the related Ethiopian pepper mottle virus (EPMV), to determine whether resistance gene(s) for ChiVMV are also effective against these two potyviruses. At least five genes for potyvirus resistance are reported in *Capsicum* spp Some genes confer resistance to more than one potyvirus, such as *pvr1* and *pvr3* to TEV, PepMoV, and potato virus Y (PVY). Previous screening results at AVRDC showed that some ChiVMV resistant germplasm was also resistant to PVY. Testing of selected ChiVMV-resistant lines for resistance to other potyviruses, such as PVMV and its strains and related viruses, indicated that some ChiVMV-resistant lines were also resistant to some of the African potyviruses (Table 28). Two entries, VC58 and VC39, were resistant to both strains of PVMV and to EPMV. This could mean that the same gene(s) that confers resistance to ChiVMV also offers resistance to the above mentioned African potyviruses, or that two sets of genes exist in those lines, one that provides resistance to ChiVMV and another that provides resistance to PVMV. This will be further investigated. Some of the AVRDC *Capsicum* germplasm identified with resistance to the major African potyviruses might be of direct use in East Africa, provided that agronomic evaluation shows farmer acceptance.

Contact: S K Green

Table 27. *Reactions of selected pepper entries to ChiVMV isolates from Taiwan, Malaysia, and Thailand*

Line	Taiwan				Malaysia[1]							Thailand [2]				
	1037	3389	714	3488	1	2	3	4	5	6	7	1	2	3	4	5
VC41	I*	I	I	S	R	R	R	S	S	S	S	R	I	S	I	I
VC58	I	I	I	I	R	R	R	R	S	S	S	I	I	I	I	I
VC160	I	I	R	I	R	S	S	S	S	S	R	I	I	I	I	I
VC185	I			S	S	S	R	S	R	R	S	R	R	R	I	R
VC237	R	R	MS	S	S	S	R	S	S	R	S	MR	I	MR	MR	I
VC238	R	MR	MS	S	S	S	R	S	S	S	S	S	MR	S	I	MS
PBC370	I	I		I								R	MS	S	I	S
PBC521	I	I	R	I								I	MR	S	MR	MR
PBC569	I			S								I	I	I	I	I

[1] isolates 1 to 7 correspond to type, Pelbagai, Szechuan, K. Brang-5, Gambang-7, Liuggi-51, Sarawak-6 respectively.

[2] isolates 1 to 5 correspond to CM-1, BP, UB 32, PJ83, SKh-5 respectively.

* I = Immune (0% infection); R = resistant (1-20% infection); MR = moderately resistant (21-40% infection), moderately susceptible (41-75% infection); S = susceptible (>75% infection).

CMS chili lines

Hybrid seed production is labor-intensive, particularly emasculation of flowers on female plants. Male sterility can be used to eliminate hand emasculation and reduce labor costs. Male sterility also increases the purity of the F_1 seed since no self-pollination takes place. Cytoplasmic-genic male sterility (cgms) was first reported in 1958 in an introduction of *C. annuum*, PI 164835, from India. Most authors have reported that a single nuclear gene, designated *rf1*, interacts with S cytoplasm to produce sterility, and the allele, *Rf1*, restores fertility. Plants with N cytoplasm are fertile regardless of whether they have the *Rf1* or *rf1* allele. Some authors have reported that certain genotypes apparently carry a second nuclear gene, designated *rf2*, which is needed in addition to *rf1* in order to produce sterility in S cytoplasm.

Many authors have reported that cgms can be unstable under different environments, depending on the genotype. Korean seed companies have been using cgms for several years for hybrid seed production, and their A lines are stable under diverse environmental conditions. The largest study of cgms, utilizing 270 lines, found 152 to be stable maintainers, 66 to be stable restorers, and 52 to be unstable, with large deviations in sterility in different environments. Of 39 large-fruited sweet peppers, 20 were stable maintainers, and 18 were unstable. Assuming a single-gene system, of the six possible cytoplasmic-nuclear genotype combinations, only the nuclear genotype *rf1 rf1* in S cytoplasm is sterile.

AVRDC's work on cytoplasmic male sterility (cgms) in chili started in 1996 in response to numerous requests from National Agricultural Research Systems (NARS), university researchers, and small seed companies in Asia. Hybrid chili peppers are gaining popularity in Asia, particularly among major chili producers in India, where in 1999 hybrids accounted for about 10% of the market, and in Indonesia, where hybrids account for about 20% of the market.

There are at least five possible outcomes when a pepper line is testcrossed to a source of cgms (A line):

1 The testcross hybrid is 100% sterile and stable under diverse conditions, indicating that the line is a maintainer (B line).
2 The testcross hybrid is unstable during the growing season. Initially all flowers are sterile or fertile, but later in the season the pattern is reversed, due to temperature and/or humidity.
3 The testcross hybrid is a mixture of sterile and fertile plants. This indicates that the line is heterogeneous at the *rf1* locus, and purification via single plant selection should be conducted. This outcome is common among heterogeneous Asian landraces.
4 The testcross hybrid is 100% sterile in some environments and fertile in other environments, again, probably related to temperature and/or humidity.
5 The testcross hybrid is 100% fertile under all conditions, indicating that the line is a restorer line (R line).

AVRDC testcrosses 10-15 tropically adapted chili pepper lines each year to a Korean cgms A line (kindly donated by Choong Ang Seed Co. under a restricted-use agreement) to determine if they are B or R lines. Based on the testcross results, putative B lines are backcrossed to the F_1 to begin the process of converting them into A lines. After three years, only 10–15% of the testcrossed lines have been classified as putative maintainers, and some of these are unstable. In 1999, 10 new testcrosses were made utilizing small-fruited chili peppers with various combinations of disease/insect resistance, as shown in Table 29.

Table 28. *Screening of selected chili veinal mottle virus (ChiVMV-1037)-resistant* Capsicum *entries for resistance to two strains of pepper veinal mottle virus (PVMV-Gh, PVMV-Eth) and another potyvirus from Ethiopia (EPMV)*

Accession # [1]	PVMV [2]		EPMV [3]	
	Gh	Eth	430/94	PN-1
VC16 *	R [4]	R	S	S
VC33, VC37	S	S	S	S
VC35, VC36*	R	S	S	R
VC39, VC58	R	R	R	R
VC160*	R	S	R	R
VC208, VC240*, VC243*, VC256*, VC257*	R	NT	NT	NT

[1] These lines were also found resistant to the PVMV strain from Nigeria (J. Hughes)
[2] PVMV-Gh = (PVMV) isolate from Ghana (A.T. Brunt); PVMV-Eth = PVMV isolate (374/94) from Ethiopia (Y. Hiskias) and only distantly to
[3] EPMV = Ethiopian pepper mottle virus; by sequence and serological comparisons, EPMV is weakly related to PVMV, and only distantly to ChiVMV. EPMV is therefore either a strain of PVMV, or a distinct virus.
[4] R = resistant (1-20% infection); S = susceptible (> 75% infection)

In 1999, 7 F_1 testcrosses were evaluated for sterility, with the following results: two were fertile, two were sterile, and three were unstable/mixed. The sterile lines and one mixed line were chosen for further backcrossing (the recurrent parent of the mixed cross will simultaneously be purified). Two lines at the BC_1F_1 stage (HyHot3selex, tolerant to CMV, with large fruits, and PBC 717, resistant to PVY and BW) were advanced two generations. Two lines at the BC_2F_1 stage (PBC 362, resistant to TMV, and PBC 292, tolerant to mites) were advanced two generations. Three lines at the BC_3F_1 stage (PBC 483, tolerant to CMV and anthracnose, PBC 380, with large fruit and high and stable yield, and CCA2341-2, resistant to CVMV and BW) were advanced two generations. One line at the BC_4F_1 stage (PBC 716, with high dry matter and tolerant to thrips) was advanced two generations. One line at the BC_4F_1 stage (PBC 534, resistant to BW, PVY, and CMV) was determined to be homogeneous, and multiplication of the A line for distribution was carried out. Twenty-five seeds each of PBC 534, CCA 4261 (the PBC 534 A line), and PBC 473 (an R line) are available upon request.

Contact: T G Berke

Confirmation of resistance in EG058 to eggplant fruit and shoot borer

Eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis* Guénee, is a very destructive pest of eggplant throughout South Asia, where eggplant is one of the most important vegetables grown throughout the year. Soon after hatching (eggs are laid on leaves) insect larvae bore into the shoot or fruit. Once inside, the larvae are out of reach of pesticide sprays and most natural enemies, such as predators and parasitoids. Farmers respond by spraying frequently so that pesticide residues will be present whenever the EFSB larvae hatch and make their way to the shoot or fruit. Breeding a resistant cultivar would be a safer, more economical approach to combat the pest. In preliminary tests in 1998, we found a landrace of cultivated eggplant that suffered less damage in both fruits and shoots. So, in autumn of 1998, we set up a replicated test to confirm the findings.

Seedlings of EG058, EG075, and local cultivar “Pingtung Long” were raised in a greenhouse and transplanted as five-week-old plants in field plots measuring 1.5 m wide and 15 m long. Each entry was transplanted in randomly selected plots in each of four replicates. The crop was irrigated, weeded, fertilized, and pruned, but no insecticide was used. At irregular intervals, we released laboratory-reared EFSB pupae to increase the ambient pest population in the field to ensure uniform infestation. When EFSB damage started appearing in the shoots, we observed each plant for damage in shoots and fruit. At each observation, the damaged shoots and fruit were discarded (and the EFSB larvae were reared for eventual rerelease of pupae in the field). A total of 13 weekly observations were made. The mean damage data were analyzed for test of Least Significant Difference.

The results are summarized in Table 30. Accession EG058 was the least damaged entry, both in shoot

Table 29. *Parental lines used in cgms testcrosses and their useful traits*

Code No.	Resistances and notable trait(s)
9852- 51	CMV,CVMV, PVY
9852- 61	CVMV
9852-100	BW, CMV(P522 strain),CVMV,PC
9852-110	CMV(P522 strain), CVMV, PVY
9852-154	PVY, flood tolerance
98-5608	CMV, CVMV, PVY
98-5765	heavy fruit set
PBC 142	nematode
PBC 156	flood tolerant
PBC 521-2	CVMV,PVY

Table 30. *Eggplant fruit and shoot borer damage to selected eggplant accessions, AVRDC, Autumn 1998*

Acc. #	Shoot damage (% plants)		Fruit damage (%)	
	19 Nov	26 Nov	19 Nov	26 Nov
EG058	0	2.42 ± 3.09	2.50 ± 5.00	4.04 ± 1.61
EG075	14.15 ± 7.38	10.48 ± 4.84	31.65 ± 9.98	28.41 ± 3.71
Pingtung Long	3.33 ± 0.00	5.65 ± 3.09	27.50 ± 11.34	22.09 ± 5.37
LSD (5%)	11.17	11.62	16.04	11.95

Data shown are for only two out of 13 weekly observations when pest population density was as its peak.

and fruit. At the height of damage in mid November, when 31.67% and 27.50% of EG075 and Pingtung Long fruits was damaged, respectively, only 2.5% of EG058 fruit were damaged (and no insects were in the shoots). It must be pointed out that the peak post-flowering period for all of the entries was later than the peak period of EFSB occurrence. So the pest damage in general is relatively low. Accession EG058 is a green, round-fruited landrace from Thailand. It is not a high yielding, commercially viable cultivar. Its resistance in both shoot and fruit needs to be transferred to a locally adapted commercial cultivar.

EG058 is being tested for EFSB resistance in all countries of South Asia and we are encouraging plant breeders to utilize the line to breed pest resistance into locally preferred eggplant cultivars. We tested to see if EG058's resistance was linked to various morphological characters, including trichome morphology and density, leaf area, leaf thickness, moisture content, shoot thickness, pubescens on shoot, moisture content, and dry weight. No strong association was found. This points to the possible existence of some antibiotic factor.

In conclusion, a land-race of eggplant, EG058, shows moderate to high levels of resistance to EFSB. The resistance appears to be genetic and worthwhile transferring into commercial cultivars.

Contact: N S Talekar

Project 2. Off-season onion and garlic

Project 2 focuses on AVRDC's research on bulb alliums. Its key objectives are to:

- improve the productivity and storability of onion in the cool-dry season
- develop technologies to eliminate diseases and viruses in garlic and increase yield

Fluctuations in the supply of onions result in unstable prices. Drastic increases in prices of onion and garlic cause great hardship in many countries. In order to reduce fluctuations in onion and garlic supply, and stabilize prices, onion and garlic lines adapted to the cool-dry season, and with improved yield potential, good storability and resistance to important diseases, must be developed. But onion is a biennial crop—it needs two years to complete its life cycle—and garlic is propagated vegetatively and shows limited genetic variability. So varietal improvement of onion and garlic will be slow compared to achievements with other crops.

In cool-dry environments, stemphylium leaf blight (SLB) and purple blotch (PB) are the major diseases limiting onion production. Extensive testing of onion germplasm has revealed few opportunities for progress in developing multiple-disease-resistant lines. However, durable resistance to SLB and PB has been identified in an allied species, *Allium fistulosum*, giving hope that it could be transferred to *A. cepa*. Interspecific hybrids have shown varying degrees of sterility, but AVRDC plans to incorporate resistance to SLB and PB in onion, and to improve the yield and stabilize the onion supply.

Elimination of yield-limiting viruses in garlic through meristem culture is possible. AVRDC plans to examine the economic viability of virus-free planting materials for garlic.

Early maturing, high- and stable-yielding onion lines

The maturity duration of onions in the tropics is about 120 to 150 days. The average yield of onions in the tropics is about 12 to 15 t/ha. Early maturing (100 to 110 days) and high yielding onion varieties will be valuable to fit in a cereal-based cropping system. This study was undertaken to identify early maturing and high yielding onions.

Eighty-two promising onion accessions were evaluated against check varieties Red Creole, Superex, CAL606, and G429. They were sown on 18 September 1998 and transplanted on 17 November 1998, in three rows in 1-m wide beds, with spacing between and within the row of 15 cm and 10 cm, respectively. The trial was conducted using a RCBD with two replications, each with 30 to 60 plants per plot. Marketable bulb yield, bulb size, and days to maturity were recorded.

Among the 86 entries evaluated, 69 were yellow, 8 red, and 9 white. The average marketable yields of yellow and white onions in this trial were higher, compared to the red varieties (Table 31). Of the 69 yellow onions, 8 (11.6%) matured in 100 days or less, whereas 3 white varieties out of 9 matured in

100 days or less. The mean bulb size of both red and white onions was smaller than the yellow onions (Table 31). The red onions took the longest to mature, while the white ones were the earliest (Table 31). Based on days to maturity, yield, and other horticultural characteristics, three varieties of each bulb color onion were selected for further evaluation and use in the breeding program (Table 32).

Contact: S Shanmugasundaram

Measuring total soluble solids in onions

Onion supply in the tropics is low and unstable due to poor productivity and short storability. The major problem in storage in the tropics is rotting. High total soluble solids (TSS) has been proved to be associated with long storage life; however, TSS distribution within bulb tissue and the relationship between bulb color and TSS are not clear. This study was undertaken to 1) determine the differences in TSS in different parts and scales of onion within a bulb, 2) determine the differences in TSS among varieties with different bulb color, and 3) ascertain a good sampling method to measure the TSS of onions.

Eight onion varieties, three yellow, three white, and two red bulbs, were used (Table 33). Seeds of all the varieties were sown on 8 October 1998. The seedlings were transplanted in the field on 18 November 1998. At maturity the varieties were

Table 31. *Days to maturity, bulb size, and yield of red, white, and yellow onions*

Color of varieties	No. of entries	Days to[1] maturity	Bulb size (g)	Marketable yield (t/ha)
Red	8	124 (4.2)	191 (74.6)	30.6 (21.63)
White	9	103 (6.5)	193 (36.9)	51.1 (13.42)
Yellow	69	108 (8.2)	233 (55.5)	53.5 (19.72)

[1] Values in parenthesis are standard deviation.

Table 32. *Promising entries selected based on early maturity and high yield in three bulb-color categories*

Acc. #	Variety name	Marketable bulb yield (t/ha)	Days to maturity	Bulb size (g)
Red				
AC 724	Franciscana	42.8	120	206
TA 492	Red Bandana	63.8	125	297
TA 471	Redbone	58.5	130	306
	Red Creole (ck)	17.8	125	133
White				
AC 687	Rio Redondo	58.2	95	224
AC 692	RCS9211	59.8	98	207
AC 546	Primero	33.7	105	141
Yellow				
AC 691	RCS 1927	96.1	105	326
TA 468	Linda Vista (PSX 8589)	90.6	103	302
TA 491	Bronco	77.0	105	326
	CAL 606 (ck)	69.2	111	270

Table 33. *Sources and bulb characteristics of onion bulbs used in this experiment*

Entry	Variety name	Seed co.	Color
TA1002	Excalibur (H)	Rio Colorado, USA	Yellow
TA1026	RCS 1103 (H)	Rio Colorado, USA	Yellow
AC855	E 515 (H)	Yates, Austarlia	Yellow
TA271	Samaru Composite	Nigeria	Red
TA383	Regal PVP	Sunseed, USA	Red
TA363	PSR 11390 (H)	PetoSeed, USA	White
TA375	Contessa	Asgrow, USA	White
AC843	White Hawk	Bejo, Holland	White

Note: H refers to hybrid.

Table 34. *Coefficient of variation for TSS in different method*

Method	CV %
Middle core portion	13.1
Random mixture	10.9
Top or bottom portion	33.3
Different scales	11.3

Table 35. *TSS content of composite juice from middle and random of eight varieties*

Variety	Middle	Random
Yellow		
AC855	9.78 bc[1]	7.63 c
TA1002	7.98 d	4.98 d
TA1026	11.17 b	9.83 b
Red		
TA271	10.25 bc	8.83 b
TA383	7.17 d	5.95 d
White		
TA363	20.07 a	17.60 a
TA375	8.62 cd	7.20 c
AC843	10.40 b	9.13 b

[1] Means with columns followed by same letter are not significantly different at P<0.05 by Duncan's Multiple Range Test.

harvested and cured for 10 days in the field. Six bulbs of each variety were taken at random. Each bulb from each variety was cut horizontally in the middle, top and basal portion, and each portion was individually analyzed. After removing the dry skin of the bulb, the individual scales, beginning from the outermost one, was numbered centripetally and seven scales were individually tested for TSS. From each scale portion (top and basal) a 2×3-cm piece was crushed and TSS was determined using a refractometer (digital refractometer PR-1, Atago Co., Japan). For each bulb, a random sampling of tissue from the whole bulb was crushed and the squeezed juice was measured for TSS. Six replications were used for each measurement.

Three sampling methods were compared: juice from the middle core section of the bulb, juice from a random collection of scales from the whole bulb, and juice from either the top or bottom half of the bulb and different individual scales. Each set of data was analyzed by ANOVA (analysis of variance).

Differences in TSS between varieties, between bulb color, between top and basal portion of the bulb, and between different scales were all highly significant.

Among the three different methods to measure TSS, the random mixture showed the lowest coefficient of variation (CV), which indicates that it is the best sampling method.

The other two methods, collected from the middle core portion and different scales, were similar to the best method (Table 34). (Only the method that used the top or bottom portion of the bulb had a very large CV.) Therefore, any one of the three methods can be used to determine TSS; however, the middle-core and random sample methods seemed preferable due to their ease. These two methods showed clear differences in TSS among the varieties tested (Table 35).

Contact: S Shanmugasundaram

Effect of bulb size and storage conditions on storability of onions

The relationship between bulb size and the storage life of onion and the affect of accumulated temperature and relative humidity on the storage of onion of various bulb sizes were studied.

The variety California 606 was sown on 1 October 1998 and transplanted on 6 November 1998. The spacing between and within the row on a 1-m wide bed was 15 cm and 10 cm, respectively. The bulbs were harvested on 16 March 1999 and cured for 10 days in the field. They were classified into small (<6.5 cm), medium (>6.5–8 cm), large (8–10 cm), and extra large (>10 cm). Thirty bulbs of each size were put in nylon mesh bags and placed on a rack in a well-ventilated storage room. The experiment was conducted from 2 April 1999 to 27 August 1999, in RCBD with three replications. At three-week intervals, the bulbs were checked and counted for sprouting and rotting. The total soluble solids and dry matter content of the bulbs were also analyzed prior

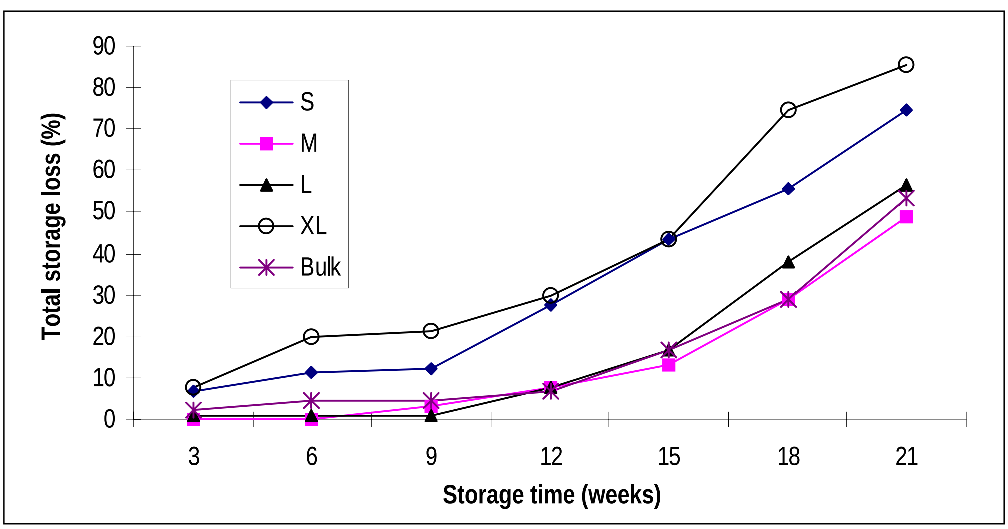

Figure 3. *Effect of bulb size on total storage loss of onion cv "CAL 606" under ambient conditions.*

to storage. The accumulated maximum, minimum, and mean temperatures, and RH for the storage room were also recorded. Pearson correlation coefficient for total storage loss and temperature as well as RH were determined.

Increase in storage loss fit both linear and quadratic response curves to storage time. The R^2 values and the equations to estimate the storage loss at specific accumulated temperature or RH for different bulb sizes are given in Table 37. Neither dry matter content nor total soluble solids differed among bulb sizes. Significant difference in storage loss was observed in relation to bulb sizes. The medium, large, and bulked bulbs stored longer than the small and extra large bulbs.

Increase in total storage loss seemed related to accumulation of temperature or humidity (Tables 36 and 37) (Figure 3); however, further experiments under different conditions are needed to develop equations that can be applied generally.

The accumulated temperature as well as RH may be used as an indicator to estimate the total loss in storage.

Contact: S Shanmugasundaram

Table 36. *The ambient conditions of storage room during 2 April to 27 August 1999*

Source	Temperature			RH %		
	Max.	Min.	Mean	Max.	Min.	Mean
Mean	31.31	24.02	27.67	89.33	58.33	73.83
SD	2.91	2.6	2.56	3.07	11.88	6.75

Table 37. *Equations of total storage loss vs. accumulated temperature and relative humidity in various bulb sizes of onion cultivar CAL 606 under ambient conditions*

Bulb size	Equation	R^2
	Temperature	
Small	$Y = 3E\text{-}06X^2+0.0008X+4.241$	0.9914
Medium	$Y = 6E\text{-}06X^2–0.0127X+6.8222$	0.9889
Large	$Y = 7E\text{-}06X^2\text{-}0.0166X+9.4035$	0.9953
Extra large	$Y = 5E\text{-}06X^2\text{-}0.005X+9.9362$	0.9735
Bulk	$Y = 6E\text{-}06X^2\text{-}0.0168X+12.354$	0.9827
	RH%	
Small	$Y = 6E\text{-}07X^2\text{-}0.002X+4.6702$	0.9894
Medium	$Y = 8E\text{-}07X^2\text{-}0.005X+7.102$	0.9910
Large	$Y = 1E\text{-}06X^2\text{-}0.0065X+9.843$	0.9948
Extra large	$Y = 7E\text{-}07X^2\text{-}0.0008X+9.8284$	0.9720
Bulk	$Y = 9E\text{-}07X^2\text{-}0.0065X+12.609$	0.9836

Effect of temperature on storage loss in onion

One of the main factors affecting storage life of onion is temperature. This experiment examined two condition: 1) ambient storage (28.5±1.7°C, 79.2±6.5%RH), and 2) low temperature cold room (10°C, 95% RH).

The seeds of eight onion varieties (Table 38) were sown on 20 October 1998 and transplanted on 8 December 1998. They were harvested on 30 March 1999, and the bulbs were cured for 10 days in the field. Forty bulbs, with uniform size, representing each variety were put in nylon mesh bags and placed in the two storage rooms, with two replications for each variety and storage room. The experiment was conducted in an RCBD design. Sprouting and rotting counts were made every three weeks. The rotten ones were examined for causal diseases.

Among the eight varieties, the marketable weight of AC 540 and TA 377 exceeded 80% (Table 39) after 15 weeks storage in the 10°C cold room. Sprouting was the major cause of loss under low temperature. There was very high correlation between sprouting and total loss (r = 0.989 at P = 0.0001). Under the ambient conditions, the marketable weight of TA 1025, TA 1026, and TA 377 remained 67 to 70% after 15 weeks of storage. Loss under ambient conditions was due to rotting (Table 40). The infection of black mold and fusarium rot accounted for most of the loss due to rotting. Highly significant correlation between rotting and total loss (r = 0.909 at P = 0.0001) was observed. Similarly, bacterial rot and black mold were highly correlated to total loss (r = 0.939 and 0.959 both at P= 0.0001, respectively).

Based on the above results, TA 377, TA 1025, and

Table 38. *Source of onion varieties used in storage trials*

Acc. #	Variety	Seed co.
AC 540	Gladiator	Yates, Australia
AC 571	PS 13489	Peto Seed, USA
AC 572	Lida VST	Peto Seed, USA
CAL 606	California 606 (H)	California, USA
TA 1025	RCS 1102 (H)	Rio Colorado, USA
TA 1026	RCS 1103 (H)	Rio Colorado, USA
TA 377	Serrana	Asgrow, USA
TG 502	Texas Early Grano 502	Starke Ayres, RSA

TA 1026 have good storability under ambient conditions. TA 377 also has good storability under low temperature.

Contact: S Shanmugasundaram

Evaluation of virus free shallots

One of the major factors limiting yield in shallot is infection due to virus. AVRDC has produced virus free shallot through meristem culture. The objective of this trial was to evaluate and compare the yield potential of virus free-shallots against two check cultivars infected with viruses.

The trial was conducted in an AVRDC field. A total of 22 virus free germplasm and two check varieties (S 25 and S 28) were evaluated using RCBD with two replications. The seed bulblets were planted on 25 September 1998. The spacing between rows and plants was 20 cm and 15 cm, respectively. In each 0.75-m wide bed there were two rows per plot, with 30 plants per plot. Bulb yield per hectare and average bulblet number per plant from five plant samples were recorded. The bolting behavior of the bulbs in the field was rated as 0 = no bolting and 4 = more than 50% bolting. The bulb color was recorded. All the harvested bulbs from each entry were stored under ambient conditions for four months from February to June 1999. At the end of four months, storage loss due to sprouting and rotting was determined and expressed as a percentage. The data were analyzed statistically and the means were compared using Duncan's Multiple Range Test.

The results are shown in Table 41. Two virus-free germplasm entries, VFS97m3 and VFS41m9, had significantly higher yield, about 30 t/ha, almost double that of check S28. The yield potential of four virus-free germplasm entries was on par with S28.

Table 39. *Varietal differences for loss after 15 weeks of storage at 10°C*

	Percentage of				Disease infection (%)		
Variety	MKT wt	Total loss	Rotting	Sprouting	BR	BM	FR
AC540	85.55 a	14.15 d	8.35	8.75 c	0.00	0.00	8.35
AC571	4.50 c	96.30 ab	3.75	93.80 a	0.00	1.25	2.50
AC572	0.00 c	100 a	9.30	89.50 a	1.20	0.00	9.30
CAL606	1.55 c	98.75 ab	0.00	96.25 a	0.00	0.00	0.00
TA1025	26.05 b	75.25 c	8.05	68.45 b	0.00	1.30	6.80
TA1026	7.75 c	92.10 b	1.00	91.10 a	0.00	0.00	1.00
TA377	80.85 a	13.75 d	9.90	6.25 c	0.00	0.00	9.90
TG502	24.90 b	76.25 c	15.00	63.75 b	0.00	2.50	12.50
Mean of eight varieties	28.89	70.82	6.92	64.73A	0.15	0.63	6.29
CV (%)	17.98	13.13	64.62	16.88	400.00	261.00	64.40

MKT wt = marketable weight. Means followed by the same letter within column does not differ significantly at P<0.05 by Duncan's Multiple Range Test.

Table 40. *Varietal differences for loss after 15 weeks of storage under ambient conditions*

	Percentage of				Disease infection (%)		
Variety	MKT wt	Total loss	Rotting	Sprouting	BR	BM	FR
AC540	33.24 b	63.75 bc	63.75 b-d	0.00	10.00 bc	37.50 a-c	40.00 a
AC571	26.94 b	66.25 b	66.25 bc	1.25	22.50 ab	47.50 ab	16.25 de
AC572	3.80 b	95.00 a	95.00 a	11.25	33.75 a	60.00 a	31.25 a-c
CAL606	24.59 b	71.67 ab	71.67 ab	3.33	20.00 ab	41.67 a-c	38.34 ab
TA1025	69.88 a	22.50 c	22.50 de	1.25	0.00 c	15.00 cd	17.50 c-e
TA1026	67.33 a	22.75 c	21.75 e	3.25	2.25 c	19.50 b-d	8.00 e
TA377	70.32 a	23.09 c	24.41 c-e	0.00	0.00 c	5.10 d	24.04 b-d
TG502	38.65 ab	55.58 bc	56.83 b-e	4.91	9.91 bc	39.51 a-c	25.86 a-d
Mean of eight varieties	41.84	52.57	52.77	3.16	12.30	32.22	25.15
CV (%)	35.64	32.41	32.46	104.00	52.34	35.17	23.69

MKT wt = marketable weight. Means followed by the same letter within column does not differ significantly at P<0.05 by Duncan's Multiple Range Test.

Bulblet number varied by variety. The lowest storage loss was observed in S28. The pink or red varieties bolted, but the orange-bulbed varieties did not (Table 41).

Contact: S Shanmugasundaram

Evaluation of *A. cepa* x *A. fistulosum* lines to develop Stemphylium leaf blight and purple blotch resistant onion

Stemphylium leaf blight (SLB), caused by *Stemphylium vesicarium*, and purple blotch (PB), caused by *Alternaria porri*, are the two major diseases of onion in the tropics. In the past, screening germplasm for resistance to these diseases found material with some level of tolerance, but results were inconsistent. However, screening *Allium fistulosum* accessions identified durable resistance to the two diseases. Crosses were made between *A. cepa* and *A. fistulosum*. The F_1s were selfed and advanced by inbreeding. The F_1s were also backcrossed and selfed to recover *A. cepa* traits. The inbred and backcrossed progenies were invariably sterile and had poor seed set. The ultimate objective has been to combine the good quality bulbing from *A. cepa* and durable resistance to the two diseases from *A. fistulosum*, retaining maximum pollen and ovule fertility to ensure good seed set.

A batch of 111 interspecific hybrid lines from 22 crosses, along with four checks, AC47 and Granex 429 (both *A. cepa*), and TA198-P and AF468-P (both *A. fistulosum*) were sown on 25 August 1998 and artificially inoculated with pathogens on 29 October 1998 in a growth room. Disease reactions were recorded on 4 November 1998 using a rating scale of 1 (no symptom) to 5 (more than 50% infection). The number of plants in each rating category was expressed as percent, both in the growth room and, subsequently, in the field. The seedlings that survived in the greenhouse were transplanted to the field on 26 November 1998. The spacing between rows and between plants was 20cm. Each 1.5-m wide bed had three rows. Plastic mulch was used to control weeds. Susceptible check varieties were planted all around the field and on one side of each row. Just before harvest, disease incidence was rated. Bulbing and seed setting behavior was also recorded (Table 42).

In another trial, 63 BC_1F_1, and 51 BC_1F_2 lines were sown on 7 September 1998 and transplanted in the field on 30 November. Spacing between and within rows was 20 cm and 15 cm, respectively. There were three rows in each 1.5-m-wide bed. Plastic mulch was used to minimize weeds. No fungicides were used. SLB reaction, flowering, pollen fertility, bulb size, and seed set were observed.

The results of four promising crosses (CF5, CF19, CF61, and (CF8 × AC53)-1-0) out of 22 evaluated are shown in Table 1. The susceptible *A. cepa* and resistant *A. fistulosum* checks in the growth room and

Table 41. *Yield and other horticultural traits of virus free shallot germplasm in the field*

Variety	Yield (t/ha)	Average bulblet number/plant	Storage loss (%)	Bulb color[a]	Bolting behavior[b]
VFS97m3	29.9 a	27 c	41.2	O	0
VFS41m9	28.6 a	31 bc	48.2	O	0
VFS71	23.3 b	33 bc	44.1	O	0
VFS70	22.9 b	35 b	64.0	O	0
VFS97m5	22.4 b	31 bc	63.7	O	0
S25 (check)	22.1 b	16 d	89.5	R	2
VFS99m1	20.6 bc	9 de	95.4	R	2
VFTA169m2-2	19.9 bcd	8 e	83.3	R	3
VFTA297m5	18.0 cd	32 bc	78.7	P	2
VFS97m5	17.6 cd	27 c	75.7	R	2
VFS101m4	17.4 cd	8 e	83.2	R	3
S28 (check)	15.9 d	57 a	27.0	O	0
Mean (24 lines)	17.5	18	73.6		
CV %	10	16	21		

Within columns means followed by the same letter do not differ significantly at P = <0.05 DMRT.

[a] Color: O = orange; R = red; P = purple.

[b] Measured as percentage of plants bolting: 0 = no bolting; 1 = <5%, 2 = 5-30%, 3 = 30-50%, 4 = >50%

in the field were clear-cut and distinct for SLB reaction. Of four crosses, CF5 and CF19-15-5-9-0 appeared to have resistance governed by a dominant gene(s). However, crosses CF19-22-0, CF61, and CF8 × AC53 showed resistance governed by incompletely dominant genes. All the seedlings of interspecific hybrids were resistant as seedlings to SLB, but in the field they showed less resistance to SLB, while *A. fistulosum* was resistant in the greenhouse and in the field. Except for CF5(9)-0, the other hybrids had fairly good bulb size. Three hybrids had fairly good seed set (Table 42). The cross (CF8 × AC53)-1-0 had no flowers.

As shown in Table 43, out of 63 BC_1F_1 lines, seven entries had reasonable bulb size and four among them had very good pollen fertility. Three out of nine BC_1F_1 lines had good levels of SLB resistance. Two had some seed set (Table 43). The desirable traits of the BC_1F_2 are also shown in Table 43. In spite of very high pollen fertility the seed set was poor. The reasons for poor seed set will be further investigated. No lines with good bulb size coupled with SLB resistance and good fertility have been obtained.

Contact: S Shanmugasundaram

Multilocation evaluation of promising garlic lines

The yields of garlic have varied markedly with location. Differences in yield among locations have been likely due to infection by virus diseases and due to environmental differences. The objective of this study is to evaluate selected virus-free and other high yielding garlic clones to determine their yield at different locations.

Seven promising garlic lines and a check variety, Hsilo, were evaluated at AVRDC, Yi-Chu Research Station in Chia-Yi, and in a farmer's field in Mai-Liao in Central Taiwan. The trials were planted on 14 October, 9 October, and 1 November 1998, respectively. Plots at AVRDC were 3 m long and 1.2-m wide, with four rows per bed and 30 plants per row, for a total of 120 plants per replication. In Yi-Chu and Mai-Liao, the beds were 0.7-m wide and each bed had two 6-m-long rows, with 60 plants per row, for 120 plants per replication. RCBD was used with three replications.

Yield, average bulb weight, bulb equatorial diameter, and clove number per bulb were recorded and statistically analyzed. The means were compared by Duncan's Multiple Range Test.

The mean squares from the general linear model (GLM) showed that the yield and other characters varied significantly with location (Table 44). Highly significant differences were observed between genotypes for all the variables. Genotype by location interaction was highly significant for yield.

As shown in Table 2, VFG 180(3-8) was the highest yielder with 14.4 to 15.5 t/ha in all three locations. Average bulb weight and equatorial diameter varied between varieties only in Yi-Chu and

Table 42. *Promising progenies of* A. fistulosum *and* A. cepa *for SLB resistance, bulb development and seed set*

Cepa × *Fistulosum*	SLB reaction (% plants)[1]					Ave. rating		Bulbing[3]	Seed set[4]
	1	2	3	4	5	GH[1]	field[2]		
CF5(9)-0	71	27	2	0	0	1.3	3	1-2	2-3
CF5(8)-0	43	53	3	0	0	1.6	4-5	3-4	3
CF19-15-5-9-0	38	63	0	0	0	1.6	5	5	2-3
CF19-22-0	5	18	49	23	5	3.1	5	4-5	3
CF61-1-1-0	6	0	63	31	0	3.2	5	4	3
(CF8 × AC53)-1-0	0	0	77	18	5	3.3	5	4-5	No FL
AC47 (*A. cepa*)	0	0	5	31	13	3.6	5	5	5
Granex429 (*A. cepa*)	0	0	6	45	48	4.4	5	5	No FL
TA198-P (*A. fistulosum*)	72	28	0	0	0	1.3	1-2	0	5
AF468-P (*A. fistulosum*)	78	22	0	0	0	1.2	1-2	0	5

[1] 1 = no bulbing similar to *A. fistulosum*; 2 = slight bulbing tendency but thick neck like *A. fistulosum*; 3 = small bulb with thick neck; 4 = medium sized split bulb (similar to a shallot); 5 = single bulb.
[2] % of pollen stained in acetocarmine observed under microscope.
[3] 1 = no symptoms, 2 = <5% infection; 3 = 6-25% infection; 4 = 26-50% infection; 5 = 50% infection.
[4] 1 = <5%, 2 = 6-25%, 3 = 26-50%, 4 = 50-75%, 5 = >75%.

Mai-Liao. Clove number and average clove weight between varieties varied only at AVRDC and Mai-Liao (Table 45).

Although the genotype by location interaction was significant, one of the two virus-free clones, VFG 180(3-8), was consistent in giving highest yield in all three locations. Sample bulbs of this clone are available for evaluation.

Contact: S Shanmugasundaram

Clonal selection for high bulb yield and multiple disease resistance in garlic

Garlic is a vegetatively propagated crop. Clonal selection and mutation selection are two ways garlic is improved for high yield, good horticultural traits, and resistance/tolerance to diseases.

Two sets, consisting of 69 and 31 lines were planted on 1 and 13 October 1998, respectively, by RCBD with two replications. The entries were planted on a bed, 1 m wide and 4 m long to give a population of 120 plants per replication. Yield and severity of virus symptoms were rated. Virus rating was visually done on a scale of 1 (very mild) to 4 (severe symptoms) for the 69 lines. For the 31 entries, ELISA was used to detect viruses (40 plants per entry).

Out of 69 lines, two lines, GL98-6-1-1 and GL123-32, gave 40 to 60% (significantly) higher yield than the check variety, Hsilo (Table 46). Three varieties, GL98-6-1-1, GL98-6, and GL77-6, had lower disease rating than the check variety, Hsilo (Table 46).

Table 43. *Interspecific progenies of elite back crosses and their performance*

Pedigree	Bulb color	No. of plants	Bulb size[1]	Flowering %	Flowering fertility[2]	SLB rating[3]	Seed set[4]
BC_1F_1							
CF16-7 × AC325	LR	1	1	1	84.5	1	2
CF19-34 × AC325	R	1	2	1	56	2	2
CF16-2 × AC727	R	5	3	3	73.8	3	1
CF16-2 × AC444HT-C	R	4	3	5	79.1	3	1
CF16-7-7 × CAL606	R	7	3-4	3	74.5	2	1
CF16-7-8 × AC385-5-N	LR	1	3	1	76.4	4	1
CF16-7-2 × AC131ST-2-0	R	7	3	5		4	1
AC446P(3)ST-3-0 × CF16-7-6	R	3	4	0		4	
AC4ST-4-0 × CF16-7-6	R	2	4	0		4	
BC_1F_2							
(CF52 × AC431)-P	Y	29	2-3	1	97.2	3	1-2
(CF16-7 × AC325)P2-P	LR	6	1	1	84.8	4	2

[1] 1 = no bulbing similar to *A. fistulosum*; 2 = slight bulbing tendency but thick neck like *A. fistulosum*; 3 = small bulb with thick neck; 4 = medium sized split bulb (similar to a shallot); 5 = single bulb.
[2] % of pollen stained in acetocarmine that observed under microscope.
[3] 1 = no symptoms, 2 = <5% infection; 3 = 6-25% infection; 4 = 26-50% infection; 5 = 50% infection.
[4] 1 = <5%, 2 = 6-25%, 3 = 26-50%, 4 = 50-75%, 5 = >75%.

Table 44. *Mean squares from GLM for multilocation trial of garlic for yield and other horticultural traits, 1998-1999*

Source of variance	Df	Mean squares of: Yield	Df[1]	Ave bulb wt.	Clove no.	Diameter
Location (L)	2	26.06 **	2	315.63 **	1,026.65 **	56.50 **
Rep (Location)	6	2.42 ns	6	12.50 ns	24.80 ns	1.97 ns
Genotype (G)	7	64.77 **	7	236.34 **	111.55 **	43.86 **
G × L	14	9.79 **	14	43.86 ns	36.46 *	11.42 *
Error	42	2.73	33	23.96	17.97	5.33

Note: ns, *, and ** mean no significant difference, significant at 5%, and 1% level, respectively.
[1] missing data in some genotypes.

Among the 31 lines from virus resistant selections, GL50-4-1, at 13.2 t/ha, yieled significantly higher than the check, Hsilo (9.3 t/ha), and was similar in yield to virus-free clones, VFG180(3-8) and VFG176m9, both checks (Table 47). Shallot yellow stripe virus (SYSV) was not observed. Lines with low or high shallot latent virus (SLV) had similar yields. With 100% SLV, GL50-4-1 had as high yield (13.4 t/ha) as VFG180(3-8) (15.4 t/ha). With 0% garlic common latent virus (GCLV), FG1 gave 7.1 t/ha, while GL98-5(11)(30), with 100% GCLV, gave 11.7 t/ha. GL98-6-1 was reported in *AVRDC Report 1998* as resistant to to six viruses (including SYSV). In 1999, it was found ELISA-positive for five of those viruses (Table 47). In 1998, the sample size was 5 plants, whereas in 1999, it was 40 plants. Out of 31 entries, five were ELISA-negative for GCLV. The virus-free lines, as reported in 1997 and 1998, became reinfected with onion yellow dwarf virus (OYDV), SLV, and (leek yellow stripe virus) LYSV at high incidence (Table 47). Pearson's correlation coefficient between yield and individual virus infection was not significant.

Contact: S Shanmugasundaram

Table 45. *Yield and other horticultural traits of garlic lines in different locations, 1998-99*

Entry	Yield (t/ha)	Average bulb weight (g)	Equatorial diameter (mm)	Clove number	Average clove weight (g)
AVRDC					
VFG180(3-8)	14.4 a[1]	58.0 a	56.8 a	10.9 c	5.6 a
G98-9	11.8 ab	56.5 a	56.3 a	18.7 ab	3.1 a
G77-6	11.6 ab	58.4 a	57.3 a	11.9 c	5.0 a
G50-3	10.8 b	50.9 a	54.8 a	20.3 a	2.6 b
G98-10	10.5 b	56.4 a	56.4 a	14.9 bc	3.9 ab
Hsilo0.75m12	9.3 bc	53.8 a	55.5 a	9.6 c	5.6 a
Hsilo (check)	6.9 c	51.1 a	56.1 a	9.8 c	5.4 a
VFG176m6	6.3 c	51.3 a	52.5 a	12.5 c	4.1 ab
Mean	10.2	54.5	55.6	13.8	4.3
CV	17.6	10.7	4.9	18.4	20.5
Yi-Chu					
VFG180(3-8)	18.3 a	59.3 a	57.2 a	8.5 a	7.0 a
G98-9	11.7 bc	40.2 b	50.1 cd	8.8 a	4.6 a
G77-6	10.4 c	46.9 b	51.7 b-d	10.8 a	4.4 a
G50-3	11.3 c	43.1 b	50.6 cd	11.8 a	3.7 a
G98-10	11.0 c	49.7 ab	55.6 ab	16.9 a	4.3 a
Hsilo0.75m12	15.0 b	47.8 ab	53.4 a-c	8.2 a	6.0 a
Hsilo (ck)	9.2 c	39.5 b	50.5 cd	11.8 a	3.4 a
VFG176m6	9.9 c	43.8 b	48.2 d	10.8 a	4.0 a
Mean	12.1	46.5	52.4	11.3	4.6
CV	15.4	10.7	3.9	62.1	31.1
Mai-Liao					
VFG180(3-8)	18.5 a	65.4 a	60.3 a	21.6 cd	3.1 ab
G98-9	11.8 bc	55.5 b	58.2 ab	21.8 cd	2.6 bc
G77-6	11.3 c	56.7 b	57.9 ab	33.3 a	1.7 de
G50-3	8.9 d	41.6 c	50.8 d	32.4 ab	1.3 e
G98-10	11.5 c	50.7 b	54.7 bc	25.3 c	2.1 cd
Hsilo0.75m12	12.5 bc	51.0 b	55.3 bc	17.7 d	2.9 ab
Hsilo (ck)	6.9 d	39.0 c	50.1 d	26.5 bc	1.5 e
VFG176m6	13.86	54.06	53.1 cd	15.9 d	3.4 a
Mean	11.9	51.8	55.0	24.3	2.3
CV	10.4	7.5	3.7	14.3	14.0
Mean of all entries	11.4	51.3	54.5	17.1	3.7
CV	14.5	9.5	4.2	24.7	24.4

[1] Means followed by the same letter within the column are not significantly different at P = 0.05 level by Duncan's Multiple Range Test.

Table 46. *Promising clonal selections in garlic, 1998-1999*

Entry	Yield (t/ha)	Virus[1]
GL98-6-1-1	16.6 A[2]	1
GL123-32	14.6 AB	3
GL98-6	14.1 A-C	1
GL98-5(2)(30)	13.3 B-D	3
GL49-30	12.9 B-E	3
GL50-3	12.8 B-E	3
GL73-34	12.5 B-F	3
GL120-33	12.1 B-G	3
GL68-2	11.9 B-H	3
GL229-1	11.8 B-I	3
GL77-6	11.8 B-I	1
F50-36	11.7 B-I	3
FG1 (ck)	5.5 T-V	3
Hsilo (ck)	10.4 C-N	4
Mean of 69 entries	9.2	3
CV (%)	16.9	

[1] Virus ratings by visual scoring, on a scale of 0-5, where 0 = no symptoms, 1 = mild symptoms and higher rating indicates greater severity of symptoms.
[2] Means within columns followed by same letter are not significantly different at 5% by Duncan's Multiple Range Test.

Virus elimination and virus indexing of garlic

AVRDC conducts routine virus elimination and virus indexing to prevent introduction of viruses in exotic garlic germplasm. Improvement in the efficiency of the virus indexing is important, as is the follow up of virus reinfection of germplasm after planting in the field.

Seventy-one percent of garlic lines received in 1998 were found to contain virus—allexivirus (50% of lines received), onion yellow dwarf virus (OYDV) (42%), shallot latent virus (SLV) (17%), leek yellow stripe virus (LYSV) (16%), and garlic common latent virus (GCLV) (1.4%). To eliminate viruses, meristem tips are cultured (20 meristems per line) and the developing plantlets are ELISA tested for six viruses, namely, GCLV, LYSV, OYDV, SLV, shallot yellow stripe virus (SYSV), and allexivirus (actually a complex of viruses). Plantlets are finally examined under an electron microscope to detect viruses (strains) for which antisera or monoclonal antisera are unavailable.

The first ELISA test, conducted on meristem-derived plantlets, just before transplanting to soil,

Table 47. *Yield performance and virus infection rate of virus resistant garlic clones, 1999*

Entry	Yield (t/ha)	Percentage of virus infection[1] SLV	GCLV	OYDV	LYSV	MbFV
GL50-4-1	13.2 ab[2]	100	3	48	10	100
GL49-1-1	13.1 ab	98	8	43	33	20
GL98-6-1	12.7 a-c	85	5	25	3	25
GL98-6-2	12.5 a-d	83	40	45	3	35
GL98-21	12.4 a-d	58	0	80	15	58
GL98-5(14)-2	12.0 a-e	58	100	55	5	20
GL98-23	11.9 a-e	80	3	98	20	68
GL98-5(11)(30)	11.7 a-f	58	100	20	10	45
GL49R2S3-1	11.5 b-g	100	0	50	3	83
Hsilo 0.5L8	11.0 b-h	100	0	95	3	30
Hsilo (ck-)	9.3 b-h	88	10	45	33	58
FG1 (ck-)	7.1 h	100	0	90	45	33
VFG180(3-8) (ck+)	15.4 a	35	0	30	10	18
VFG176m9 (ck+)	13.2 ab	45	3	58	45	10
Mean of 31 entries	10.3					
CV (%)	15.9					

Note: ck- is negative check without virus elimination; ck+ is positive check that is virus-free.
[1] Percentage of virus infection is based on ELISA detection for 40 plants per entry.
[2] Means within columns followed by same letter are not significantly different at 5% level according to DMRT.
SLV = shallot latent virus, GCLV = garlic common latent virus, OYDV = onion yellow dwarf virus, LYSV = leek yellow stripe virus, MbFV = mite-borne filamentous virus

detected 8% virus infection, while the second ELISA, conducted at the end of the first growth cycle in soil, detected 4% infected plants. The third ELISA test found only 2% infection. All ELISA-positive plants were discarded.

Interestingly, the electron microscope revealed that 35% of plants harbored virus at the end of the second growth cycle. The virus particles were flexuous filaments with a length of >600 nm, typical of allexivirus. These might constitute a new allexivirus (strain), which was not eliminated by meristem-tip culture and which our antisera and monoclonal antibodies failed to detect. It is, therefore, important to develop diagnostic probes, such as virus-group-specific primers or monoclonal antibodies, that would allow earlier detection of all allexiviruses and their strains.

Up to November 1999, 307 virus-free garlic and 34 virus-free shallot lines had been produced, with another 213 garlic lines in the pipeline.

Virus reinfection and yields were investigated on two meristem-derived clones of the cultivar Black Leaf, planted in an AVRDC field for six consecutive growth periods. In the sixth growth cycle, there were two treatments: planting virus-free plants and planting randomly chosen plants from the previous growth cycle. Each treatment consisted of 20 plants. The experiment (RCBD, three replications) was planted under a net cage. Before harvesting, all plants were tested by indirect ELISA for the six viruses mentioned above.

Although yields of the two meristem-derived garlic clones in the sixth growth period were 63–73% lower than yields in the fifth growth period, they were still significantly higher than those of continuously field-grown garlic (Table 48).

The percentage of virus-free plants increased significantly when planting material originated from virus-free plants rather than from randomly chosen plants of the previous season. However, the use of virus-free planting material had no significant effect on yield. Virus infection was generally low, which is to be expected since a net protected all plants. The virus infection that was observed most likely came from the plants originating from randomly chosen planting material. These viruses were then transmitted to other plants by aphids (vectors of LYSV and OYDV) and mites (vectors of allexivirus) that might have entered the cage when it was opened briefly for management of the planting.

Contact: S K Green

Screening of Allium species germplasm for resistance to onion thrips

Onion thrips, *Thrips tabaci* Lindemann, feeds on a wide variety of crop plants. Larvae and adults feed

Table 48. *Yields and virus-reinfection of meristem-derived virus-indexed plants of the cultivar "Black Leaf" grown for the sixth season in the field (protected by a net)*

Origin of planting material[1]		Yield/plant (g)	Increase[2] (%)	% virus reinfection						% virus-free plants
				LYSV	OYDV	Allexi virus	SLV	SYSV	GCLV	
M_1 (cage)	VF	60.1 a	(46.6)	8.3	2.0	2.0	0	0	0	91.7 a
	R	61.7 a	(50.0)	15.0	18.3	15.0	0	0	0	65.0 bc
M_2 (cage)	VF	49.0 b	(19.5)	2.0	0	0	0	0	0	98.3 a
	R	45.3 bc	(10.5)	16.7	16.7	3.3	0	0	0	73.3 b
M_2 (no cage)	VF	49.9 b	(21.7)	0	0	2.0	0	0	0	96.7 a
	R	49.3 b	(20.2)	35.0	13.3	5.0	0	0	0	53.3 c
F (cage)		41.0 c		90.0	100	90.0	0	0	0	0 d
	CV	6.6								9.6
	LSD	5.96								11.67

[1] VF = cloves for planting were chosen from plants found to be virus-free by ELISA in the previous growing season.
R = cloves for planting originated from randomly chosen plants of the previous growing season.
Cage = cloves used for planting were chosen from bulbs grown in the field under a net cage/ in the previous season.
No cage = cloves used for planting were chosen from bulbs grown in the field and not protected by a net in the previous season.
[2] with respect to corresponding yield of non-meristemed, continuously field-propagated plants (F).

on onion foliage by scraping the leaf surface and sucking the plant sap. This destroys the integrity of the plant's chlorophyll, adversely affecting photosynthesis. The insect can multiply rapidly in the dry season, and damage can become significant in a matter of days, resulting in heavy yield loss. AVRDC's past research on host-plant resistance involved subjecting young plants to high thrips population pressure in a greenhouse.

We have found, however, only minor or no thrips damage to young plants in the field, but considerable damage during the bulb enlargement stage. This is corroborated by observations that non-bulb-forming species *A. fistulosum* and *A. porrum* remain green even when the onion thrips population is high enough to destroy neighboring bulb-forming *A. cepa*, in the bulb enlargement stage.

Therefore, in 1999 we screened our Allium germplasm for resistance to onion thrips in the field, during the bulb enlargement stage.

Seeds of each of 310 accessions were sown in seedling flats filled with special seedling raising medium. Six-week-old seedlings were transplanted in the field in 0.75-m wide raised beds divided into 4.5-m-long single bed plots. Seedlings of each accession were transplanted on 18 November 1998 in single rows on the top of each bed. Each bed had 30 seedlings. The plots were top-dressed with fertilizer, weeded, and irrigated. No insecticide was used. When the thrips population was high, we rated the plants on a scale of 0 to 5; where 0 = no insect damage, 1 = 20% leaf area affected, 2 = 40% leaf area affected, 3 = 60% leaf area damaged, 4 = 80% leaf area damaged and 5 = 100% leaf area damaged.

Thrips damage increased dramatically during the last few days of February and first two weeks of March, peaking in early March. Most *A. sepa* entries turned brown, however, *A. fistulosum* and *A. porrum*, both of which do not form bulbs, remained distinctly green. Some *A.cepa* entries, such as AC550, AC730, TA235, TA367, TA1017, TA243, TA385, and TA584, remained green. These entries, however, were either late maturing or have a growth habit similar to *A. fistulosum,* i.e., long neck and very small bulb.

We have yet to find an *A. cepa* accession that is consistently resistant to onion thrips during bulb enlargement. Other researchers have also failed to find a useful level of resistance in *A. cepa*. Therefore, it is necessary to develop other control methods to combat thrips on onions.

Contact: N S Talekar

Project 3. Legumes for crop diversification

Project 3 focuses on expanding the production of legumes in cereal-based cropping systems. Its major objective is to evaluate and promote the use of improved short-duration mungbean and soybean lines (including vegetable soybeans) in these systems.

In many developing countries in the tropics and subtropics, cereals, such as rice, wheat, and maize, are the staple food crops, and are cultivated continuously. Monocropping with cereals depletes the soil of its nutrients, increasing the risk to farmers and limiting their income. Moreover, as a food source, cereals are deficient in proteins, vitamins, minerals and dietary fiber.

Appropriate, short-duration, multiple-disease-resistant mungbeans and soybeans (including vegetable soybeans) can effectively diversify the cropping system, enhance soil productivity, improve farmers' income and provide additional protein, vitamins and minerals to the diet. AVRDC, in collaboration with its national partners in Asia, has developed improved mungbeans and soybeans; almost all the mungbean varieties cultivated in Southeast Asia and China are derived from AVRDC lines.

In South Asia, the major constraint for mungbean production is mungbean yellow mosaic virus (MYMV). Through AVRDC's shuttle breeding program with Pakistan, new lines have been developed with good levels of resistance/tolerance to MYMV. To evaluate these improved MYMV-resistant/tolerant lines, and the best MYMV-resistant varieties available from different national partners in South Asia, a mungbean network was organized by the six South Asian countries, and AVRDC was asked to be the executive agency of the network.

SAVERNET

High yielding, stable MYMV resistant mungbean lines

South Asia accounts for almost 58% of world mungbean production and 75% of world mungbean production area. Mungbean yellow mosaic virus (MYMV), spread by whiteflies, is a major factor limiting production—a severe epidemic can destroy a crop. Pesticides are ineffective. The main way to control the disease is with resistant varieties.

A mungbean research subnetwork was established in March 1997, under the umbrella of the South Asia Vegetable Research Network (SAVERNET), to collect improved MYMV resistant cultivars, organize multilocation trials in different seasons, and select the best MYMV-resistant, high-yielding cultivars for each member country.

In total, 32 improved cultivars have been collected from Bangladesh, India, Pakistan, Sri Lanka, Thailand, and AVRDC. The seeds were multiplied at AVRDC and distributed for trials in 16 locations in six SAVERNET countries: Bangladesh (4), Bhutan (1), India (7), Nepal (1), Pakistan (2), and Sri Lanka (1). Kharif (wet season) trials were planted in June or July and summer (dry season) trials were planted in March or April. The trials were RCBD with four replications. Plots were 4.0 × 1.8 m (harvest plot size 3.8 × 1.2 m) with six rows per plot. Spacing between plants within the row was 10 cm. Recommended cultural practices were used. The selection of entries was based on yield, earlier maturity, and resistance/tolerance to MYMV compared to the local check variety.

Results from nine trials in five countries in 1998 and 16 trials in five countries in 1999 were received. Highlights are presented below.

Bangladesh – Seven trials were conducted in 1998 and 1999. Some of the MYMV susceptible varieties, such as KPS #1 and KPS #2, had no yield in some trials where MYMV was severe. VC 6372(45-8-1), NM-54, NM-94, NM-92 produced yields of more than 1.2 t/ha (up to 1.7 t/ha) in about 60 to 70 days, and all had a low MYMV rating. Bangladesh has already released NM-92 as BARI Mung 5. Bangladesh Agricultural Research Institute, Bangabhandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Development Cooperation, and NGOs have produced 2.2 t of seed of the variety. They plan to produce almost 8.0 t of seed in year 2000. BSMRAU has also produced 500 kg of seed of VC 6372(45-8-1) for release as a new variety.

Bhutan – Out of 17 varieties evaluated in 1998, KPS #2 and BARI Mung 2 gave more than 2000 kg/ha. In 1999, there were three planting dates: May 5, June 6, and August 6. The first two crops were affected by monsoon rain at flowering and pod and seed development stage, and, therefore, seed quality and yield were low. The August crop had good quality seed and KPS #2 was again the highest yielder with 729 kg/ha.

India – Results from eight trials have been received. A 25 May 1999 planting of NM-92 produced 900 kg/ha and was 12 to 26 days earlier maturing than the check variety in Tamil Nadu, south India. In Lam, Guntur VC 6372(45-8-1) and NM-92 produced 475 and 443 kg/ha in 55 and 58 days, respectively. The new varieties yielded significantly higher and matured about 10 days earlier than the check. VC 3960-88, VC 6372-(45-8-1), VC 6173-8-6, and NM-92 significantly outyielded the local check, Kopergaon, in Akola. At the Indian Agricultural Research Institute, Delhi, in spite of drought, high temperature, and harsh conditions, VC 6370(30-65) and NM-94 produced 562 and 461 kg/ha respectively in 60 days.

At Punjab Agricultural University (PAU) in Ludhiana, the April-sown crops of NM-94 and NM-92 produced 2051 and 1333 kg/ha in 56 and 58 days, respectively, compared to the check variety, 1319 kg/ha in 63 days. After the wheat harvest in April, farmers have about 60 days before they plant rice. Entries with high yield and early maturity can fit this slot.

A June planting of VC 3960-88 at PAU gave 1431 kg/ha in 67 days, compared to 1236 kg/ha in 81 days for the check. New improved mungbean might replace rice in some locations where the water table is getting deeper and deeper due to excessive pumping of water for rice.

Nepal – Out of 18 varieties evaluated, ML-613 and ML-267 produced 330 and 311 kg/ha compared to local check variety Saptari's 138 kg/ha.

Pakistan – Four out of 18 varieties produced 2.1 t/ha in a trial planted on 4 July 1998 at Faisalabad. Of the four varieties (VC 3960-88, VC 6153B-20P, VC 6372(45-8-1), and VC 6153B-20G) VC 3960-88 and VC 6372(45-8-1) had low MYMV ratings.

In the trial planted on 22 July 1998 at National Agricultural Research Center, Islamabad, Basanti produced significantly higher yield (1.55 t/ha) than NM-92 (1.21 t/ha). Basanti's MYMV resistance was as good as that of NM-92.

Sri Lanka – Out of 18 varieties planted in the wet season (November) 1998, KPS #2, VC 6173B-6, and VC 6153B-20G produced significantly higher yield (1.72, 1.52 and 1.39 t/ha, respectively) than the local check, MI-5 (1.16 t/ha). MYMV incidence was very low.

In the 1999 dry season, eight promising entries from the 1998 wet season trial were evaluated along with the local checks MI-5 and Harsha. VC 6173B-6 produced 1.80 t/ha, 8% higher than MI-5.

Out of 17 varieties evaluated in dry season (*yala*) (May) 1999, VC 6173B-10, PDM-54, SML-134, BARI Mung-4, BARI Mung-2, NM 94, and VC 6368(46-10-4) produced significantly higher yield than the local check. The yield of selected lines ranged from 2.43 to 2.20 t/ha, compared to 2.20 t/ha for MI-5. MYMV was not a serious problem.

Contact: S Shanmugasundaram

Diversity of MYMV and interaction of environment and MYMV

Preliminary research has suggested that the genetic diversity of mungbean yellow mosaic virus (MYMV) might be responsible for the different reactions observed when MYMV-resistant mungbean lines, developed in Pakistan, are grown in different locations in South Asia. Furthermore, knowledge of the epidemiology of MYMV, particularly in the different leguminous and weed hosts that it infects, will help to develop strategies to control the virus.

A survey was, therefore, conducted to determine the occurrence of geminiviruses in mungbean, other leguminous crops, and weeds, and to determine whether these are the same virus, strains of one virus, or distinct geminiviruses. Leaf samples were collected from various countries (Table 49) from plants showing yellow mosaic, yellow mottle, and/or leaf curling symptoms, which are typical of geminivirus infection. They were squashed on nylon membranes and tested by nucleic acid hybridization (NAH), using two different 1.4 kb DIG-labeled probes: MYMV-BD3, made against an MYMV from mungbean in Bangladesh, and MYMV-IN/Ban, previously made against an MYMV from mungbean in the Bangalore area, South India. The latter was shown to have 98% nucleic acid homology with MYMV from Thailand. Some fresh samples were also tested by PCR, following total nucleic acid extraction and using the degenerate primer pair PAL1v 1978/PAR1c 715, which amplifies the top part of the DNA-A of whitefly-transmitted geminiviruses. Some of the PCR samples were cloned and sequenced as described previously. Table 49 shows the reactions of different legumes collected from various countries in South and Southeast Asia. Blackgram seems to be another host of MYMV-IN/Ban in India. The yellow mosaic of mungbean in Sri Lanka gave a positive reaction with the MYMV-IN/Ban probe, suggesting that MYMV-IN/Ban is also present in Sri Lanka. Other samples were negative, suggesting that the yellow mosaic symptoms were either not caused by a geminivirus, or were caused by geminivirus(es) not detectable by the two probes/primers used in our tests.

Two legume geminiviruses were cloned, one from soybean (SYMV-IN/Mah) collected from western India (Maharashtra) and one from mungbean, collected from Bangladesh (MYMV-BD3).

Sequence comparisons of SYMV-IN/Mah with other known legume geminiviruses (Table 50) showed very high sequence similarities of >96% with blackgram yellow mosaic virus of South India and the MYMV from Thailand, indicating that these three viruses are the same virus, or very closely related strains of the same virus.

The geminivirus from Bangladesh (MYMV-BD3) had high sequence similarity (>90%) only with MYMV from northern India (Table 51), suggesting that these two viruses are related strains of the same virus.

From the sequence data so far available, it appears that two distinct yellow mosaic viruses occur in legumes in South and Southeast Asia, namely the MYMV from Thailand (MYMV-Th) and the MYMV from northern India (MYMV-IN). The latter

Table 49. *Survey for mungbean yellow mosaic virus (MYMV) in legume crops, 1999*

Country	Crop	No. samples tested	postive/ negative	Positive (%)	Type of test [2] (Probe used)
Nepal					
	Mungbean	6	0[1]		PCR
	Mungbean	45	0		NAH (MYMV IN/Ban)
India					
South	Mungbean	6	0		PCR
West	Blackgram	55	30*	54	NAH (MYMV IN/Ban)
	Soybean	4	3	75	PCR
	Mungbean	5	0		PCR
North	Mungbean	2	0		PCR
Bangladesh	Mungbean	22	1*		PCR
	Blackgram	1	0		PCR
	Soybean	1	0		PCR
	Mungbean	63	13	21	NAH (MYMV-BD3)
	Cowpea	5	0		NAH (MYMV-BD3)
	String bean	1	0		NAH (MYMV-BD3)
	Weed	1	0		NAH (MYMV-BD3)
Sri Lanka	Mungbean	48	14	29	NAH (MYMV IN/Ban)
	Mungbean	1	0		PCR
	Soybean	1	0		PCR
	Cowpea	1	0		PCR
Vietnam	Mungbean	4	0		PCR
Thailand	Mungbean	16	0		PCR
Tanzania	Mungbean	10	0		NAH (MYMV IN/Ban)

[1] Samples marked with * were cloned and sequenced

[2] NAH = nucleic acid hybridization test; PCR = polymerase chain reaction

comprises only MYMV BD3 from Bangladesh, whereas MYMV-Th seems to comprise three strains: BGYMV-IN, blackgram yellow mosaic virus from South India; SYMV-IN/Mah, the soybean yellow mosaic virus from West India; the MYMV from mungbean in Bangalore; and possibly the MYMV from Sri Lanka and BGYMV from West India.

These initial results suggest that there is much less genetic diversity in legume-infecting geminiviruses in South and Southeast Asia than in the geminiviruses infecting tomato in the same region. To confirm this, more legume viruses need to be cloned and sequenced.

Contact: S K Green

Genetic diversity among promising mungbean lines

Many countries and AVRDC have developed improved mungbean varieties resistant/tolerant to mungbean yellow mosaic virus (MYMV), a serious disease limiting the crop's production in South Asia. This study was undertaken to determine the degree of genetic diversity among these varieties, with the help of random amplified polymorphic DNA analysis (RAPD).

The 38 cultivars analyzed are listed in Table 52. The CTAB (Doyle & Doyle, 1987) method was followed to extract genomic DNA from young leaves of mungbean plants grown in an AVRDC experimental field. A total of 600 UBC (University of British Columbia) 10-mer primers were screened for the RAPD analysis. RAPD reactions were carried out in 25 ml volume containing 2.5 ml 10 × buffer (0.1 M Tris-HCl, 0.5 M KCl), 3 mM MgCl2, 2.5 mM dNTPs, 0.2 mM primer, 0.625 unit *Taq* DNA polymerase, and 0.1 ng plant genomic DNA. Amplifications were performed in a Thermolyne Thermal Cycler (Amplitron II). The thermal cycle program was 1 min at 94°C, 1 min at 40°C, and 2 min at 72°C for 3 cycles, followed by 30 sec at 94°C, 30 sec at 40°C, and 1 min at 72°C for 40 cycles, and then further extended at 72°C for 10 min RAPD products were fractionated in 2.0% agarose gel by electrophoresis at 50V for 4 hours.

One hundred RAPD bands (with 0/1 scoring method) were scored. By employing the NTSYS-pc system, the scored RAPD bands were used for the multidimensional scaling (MDS) analysis to determine the dissimilarity in a multidimensional space and for the unweighted pair-grouped (UPGMA) cluster analysis to measure the genetic similarity among the tested materials. Only the results of the latter are reported and discussed here.

Similarity levels among the 38 accessions ranged from 0.54 to 0.89, but were concentrated between 0.6 and 0.8. Basanti, BINA Mung 2, and VC6173 B-10

Table 50. *DNA similarities of the soybean geminiviruses (SYMV-IN/Mah)* from Maharashtra, West India with other legume infecting geminiviruses*

Virus[1]	Genebank	Hosts	Location	% DNA similarity[2]				
				Whole genome	Precoat	CP	C_1	C_4
BGYMV-IN[3]	AJ 132575	Blackgram	India (South)	98	99	99	99	99
MYMV-Thai	AB 017341	Mungbean	Thailand (North)	97	98	97	97	97
MYMV-IN	AF 126406	Blackgram Mungbean Soybean	India (North)	82	83	71	83	86
MYMV-BD3*		Mungbean	Bangladesh	79	80	76	82	NT
CGMV[4]	AF 029217	Cowpea	Nigeria	60	58	62	62	66
Croton gv*		*Croton* sp.	Nepal	61	57	64	60	60

[1] Viruses marked with * are those that have been cloned and sequenced at AVRDC; the other viruses have been characterized by other researchers.
[2] Precoat, CP, C_1, C_4 = precoat protein, coat protein, replicase, C_4 (= unknown) open reading frames respectively.
[3] BGYMV = blackgram yellow mosaic virus;
[4] CGMV = cowpea golden mosaic virus.

were found to be distinct varieties. Low similarity was found (<0.6) between BINA Mung-2 and CO3, ML267, BARI Mung 2 or NIMB101; Basanti and VC6173 B-10 or VC6368 (46-40-4); and VC6173 B-10 and CO3, BASANTI or VC1973A.

The tested materials could be separated into four main clusters. The phenogram (Figure 4) shows that all “VC” lines were concentrated in cluster II, except VC 1973A, VC 6153 B-20P, and VC 6173 B-10. The “VC” lines, developed at AVRDC, tended to be much closer than the materials obtained from South Asia. It could be due to the fact that “VC” lines have parents or ancestors with similar genetic background. The materials from Sri Lanka, Pakistan, Thailand, and most material of Indian origin were grouped in cluster III. BARI Mung 2, BARI Mung 4, BINA Mung 1 and BINA Mung 2 were separated into clusters I and IV. These two groups showed lower similarity with the other clusters, 0.70 and 0.64 respectively. The results imply that the BARI Mungs and BINA Mungs have different genetic background, even through they are from Bangladesh.

The above results constitute baseline information about the relationship between these promising materials. It is of paramount importance, however, to obtain further information on their pedigrees as well as their tolerance/resistance levels in different locations. The integration of this information would facilitate the selection of the best MYMV resistant/ tolerant, high yielding varieties for South Asia. Moreover, in-depth information about the phylogenetic relationships between these materials, as well as their pedigrees, could expedite varietal improvement.

Contact: C G Kuo

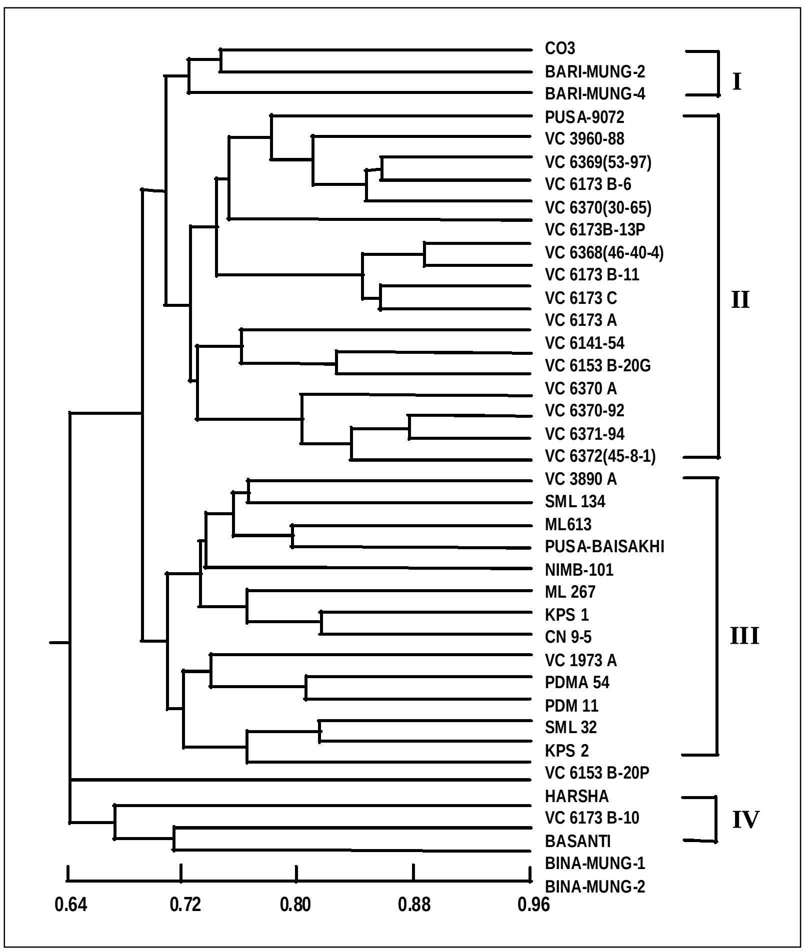

Figure 4. *Cluster analysis of 38 mungbean cultivars. The scale on the bottom of the phenogram is the genetic similarity coefficient, based on 100 RAPD bands. The Roman numerals on the right indicate mungbean main clusters.*

High yielding tropically adapted vegetable soybeans

In most developing countries, farmers have small land holdings and usually grow cereals as subsistence staple food. The time between or after cereal crops is usually short. Therefore, any legume to be included in a cereal-based cropping system must be early maturing. And it should provide reasonable return on

Table 51. *DNA similarities of the mungbean yellow mosaic virus from Bangladesh (MYMV-BD-3) with other legume infecting geminiviruses*

Virus[1]	Genebank	Hosts	Location	% DNA similarity[2]				
				Whole genome	Precoat	CP	C_1	C_4
MYMV-IN	AF 126406	Mungbean Soybean Blackgram	India (North)	94	95	93	92	
BGYMV [3]	AJ 132575	Blackgram	India (South)	81	80	75	82	
MYMV-Thai	AB 017341	Mungbean	Thailand (North)	82	80	74	82	
SYMV-IN/Mah*****		Soybean	India (West) (Maharashtra)	79	80	76	82	
CGMV[4]	AF 029217	Cowpea	Africa (Nigeria)	61	61	63	63	
Croton gv*****		*Croton* sp.	Nepal	61	63	64	61	

[1] Viruses marked with * are those that have been cloned and sequenced at AVRDC; the other viruses have been characterized by other researchers.
[2] Precoat, CP, C_1, C_4 = precoat protein, coat protein, replicase, C_4 (= unknown) open reading frames, respectively.
[3] BGYMV = blackgram yellow mosaic virus.
[4] CGMV = cowpea golden mosaic virus.

Table 52. *Accessions included in the analysis of RAPD marker and their origins*

No.	Accession	Original source	No.	Accession	Original source
1	CO3	India	20	VC 1973 A	AVRDC
2	SML 134	India	21	VC 3960-88	AVRDC
3	PDMA 54	India	22	VC 6141-54	AVRDC
4	PDM 11	India	23	VC 6153B-20G	AVRDC
5	SML 32	India	24	VC 6153B-20P	AVRDC
6	ML 267	India	25	VC 6369(53-97)	Pakistan/AVRDC
7	KPS 1	Thailand	26	VC 6370 A	Pakistan/AVRDC
8	ML 613	India	27	VC 6173 B-6	AVRDC
9	CN 9-5	Pakistan	28	VC 6173 B-10	AVRDC
10	BASANTI	India	29	VC 6173 B-13P	AVRDC
11	KPS 2	Thailand	30	VC 6370(30-65)	Pakistan/AVRDC
12	BINA MUNG-1	Bangladesh	31	VC 6370-92	Pakistan/AVRDC
13	BINA MUNG-2	Bangladesh	32	VC 6371-94	Pakistan/AVRDC
14	HARSHA	Sri Lanka	33	VC 6372(45-8-1)	Pakistan/AVRDC
15	BARI-MUNG-2	Bangladesh	34	VC 3890 A	AVRDC
16	BARI-MUNG-4	Bangladesh	35	VC 6368(46-40-4)	Pakistan/AVRDC
17	PUSA-BAISAKHI	India	36	VC 6173 C	AVRDC
18	PUSA-9072	India	37	VC 6173 A	AVRDC
19	NIMB-101	Sri Lanka	38	VC 6173 B-11	AVRDC

investment, sustain soil productivity, and complement the cereal-based diet to enhance protein and micronutrient nutrition.

Advanced yield trials 1998 and 1999

Breeding lines found promising in intermediate trials are further tested in advanced yield trials (AYTs). AYTs are conducted in the spring, summer, and autumn in the same year. In 1998, two sets of AYTs were conducted, each with 11 breeding lines and 3 check varieties. Spring, summer, and autumn trials were planted on 12 February, 22 July, and 29 September, respectively, in plots 5 × 2 m, with four rows per plot, with plants spaced 10 cm apart within the row. The trial used RCBD with four replications. Green pod yield, total pod yield, total biomass, and other horticultural characters were recorded.

In spring 1999, two trials were planted on 9 February, one set with six breeding lines and two check varieties, and the other set with eight breeding lines and two checks. Methods were similar to the 1998 trials.

None of the selections from the AYTs conducted in spring 1998 (reported in *AVRDC Report 1998*) had significantly higher yield than the check varieties, KS #1 and KS #5, when tested in the summer season. In autumn, 2 of 11 selections in AYT1, and 5 of 11 in AYT2 had significantly higher yield than both check varieties (Table 53). One-hundred-seed weight and the number of graded pods per 500 g were significantly higher in the selected entries (Table 53).

In spring1999, three selections were 25-46% higher yielding than checks KS #1 and KS #5. The seed size of GC 93010-1-1-1-1 was substantially larger and had fewer pods per 500 g, which is highly desirable in the Japanese market (Table 54).

Table 53. *Promising selections from advanced yield trial (AYT) 1 and 2, AVRDC, autumn season*

Entry	Graded pod yield (t/ha)	100-seed wt. (g)	Days to maturity	Graded pods per 500 g	Sugar (%)
AYT-1					
G 92001-P-25-1	6.46	72.4	71	180	13.7
G 92017-12	6.40	70.3	76	190	12.6
KS #1 (ck)	5.63	64.6	67	209	13.1
KS #5 (ck)	5.45	77.0	67	199	12.2
Mean (11 entries)	5.94	70.0	71	195	12.6
CV	6.5	2.4	1.0	3.8	2.2
AYT-2					
G 92014-P-12-1	6.84	75.6	75	175	11.4
G 93010-2-2-2	6.22	73.2	76	196	11.8
G 93033-9-1-1-2	6.00	71.4	75	185	11.7
G 91023-23-1	5.63	75.8	76	185	11.3
G 93023-24-2-1-1	5.59	69.6	71	196	12.9
KS #1	4.49	61.8	67	218	13.2
KS #5	4.68	72.8	67	203	12.2
Mean	5.35	69.7	73	196	12.1
CV	8.9	3.0	0	3.0	2.4

Within each trial, the difference between yield of selections shown and the checks is significant at P<0.05 according to least significant difference.

Intermediate Yield Trials

Four intermediate yield trials (IYT) were conducted in each season (spring, summer and autumn) 1998. Each trial had 20 entries plus two checks, KS #1 and

Table 54. *Promising selection from AYT 2, AVRDC spring season, 1999*

Entry	Graded pod yield (t/ha)	100-seed wt. (g)	Days to maturity	Graded pods per 500 g	Sugar (%)
GC 93010-1-1-2-2-6	12.0	78.9	80	134	11.2
GC 93010-1-1-2-5	11.8	88.1	83	126	10.0
GC 93010-1-1-1-1	10.78	83.1	83	136	10.2
KS #1 (ck)	9.58	68.7	69	166	12.9
KS #5 (ck)	8.20	85.0	76	151	10.5
Mean	10.33	75.8	79.5	146	10.9
CV	6.8	5.8	0	7.1	4.2
LSD	1.03	6.3	0	15.1	0.7

Within each trial, the difference between yield of selections shown and the checks is significant at P<0.05 according to least significant difference.

KS #5. The spring, summer, and autumn season trials were planted on 16 February, 21 July, and 24 September. Each trial was RCBD with two replications, plots were 5 × 2 m (harvest plot size 5 × 1 m) with four rows per plot, 350,000 plants per ha in spring and summer, and 400,000 plants per hectare in autumn.

In 1999, three IYTs were conducted. IYT1 and IYT2 had 18 entries plus two checks, while IYT/T (Taiwan, Council of Agriculture project) had 22 entries plus two checks. All trials were planted on 9 February. All other details are as for the 1998 IYTs.

In summer 1998, none of the IYT entries outyielded the checks. In autumn, eight entries had significantly higher yield than one or both of the checks (Table 55).

Some of the promising selections from spring 1999 are described in Table 55; among these, GC 94018-46-1 has the highest sugar content, 14.1%.

In 1998 and 1999, all of the high yielding entries were slightly later maturing than the check cultivars, with the exception of GC 92016-69-2-1.

The market prefers fewer graded pods per 500 g and higher 100-seed weight. GC 92005-120-1-3-1 and GC 93010-1-1-2-2-2 were best based on these criteria.

AVRDC Vegetable Soybean Evaluation Trial

There is sustained interest in AVRDC-developed vegetable soybeans. In 1999, 33 cooperators from 20 countries received one AVRDC Vegetable Soybean Evaluation Trial (AVSET), including 125 AGS (AVRDC *glycine max* selection) lines, 104 pedigree lines, and 30 other accessions for evaluation.

In Oregon, AGS 292 has been released as Buker's Favourite by Nichol's Nursery. In Mauritius, AGS292 and AGS339 were released as VSS1 and VSS2 respectively, in April 1999. Their yield potential is 8-10 t/ha of green pods. Farmers produce their own seed and market their soybean by themselves. Whole pod vegetable soybean is popular among consumers in Mauritius, where it sells for US$2/kg, making it a highly profitable crop for farmers. In Vietnam, AGS 346 was released in February 1999 as VRQ 46. It matures in 65–85 days and gives a marketable yield of 11–14 t/ha green pods. Three crops can be grown in a year. In Hawaii, eight vegetable soybean entries were planted on 10 July 1999 at Hoolehua (21°N latitude, about 140

Table 55. *Promising selections from intermediate yield trial (IYT) AVRDC, autumn 1998 and spring 1999*

Entry	Graded pod yield (t/ha)	100-seed wt. (g)	Days to maturity	Graded pods per 500 g	Sugar (%)
IYT-1998					
GC 93021-24-3	7.1	74	68	196	13.6
GC 93054-1-2-4	6.5	74	68	185	13.6
GC 93010-1-1-2-5	6.2	76	75	170	11.3
GC 93010-1-1-1-1	6.2	76	75	178	11.5
GC 94029-10-1	6.0	76	68	179	11.7
GC 93054-1-2-2	6.0	74	69	183	13.5
KS #1 (ck)	4.7	68	60	216	13.1
KS #5 (ck)	4.5	68	74	203	12.7
Mean[1]	5.1	74	68	201	12.6
LSD 0.05	0.9	0	5.2	12.7	0.7
IYT/T-1998					
GC 92005-120-1-3-1	8.4	76	87	156	12.9
GC 93012-1-1-2-2-4	7.3	76	72	185	11.4
KS #1 (ck)	5.9	68	60	218	12.7
KS #5 (ck)	4.6	68	67	212	11.4
IYT-1 1999					
GC 95017-12-2-2-1	12.6	84	70	160	10.4
GC 92016-69-2-1	12.4	76	81	157	11.2
KS #1	9.9	69	61	173	13.3
KS #5 (ck)	9.3	76	85	166	10.9
Mean	9.3	80	70	167	10.3
LSD 0.05	1.6	0.8	7.5	9.7	1.0
IYT-2 1999					
GC 93010-1-1-2-2-2	13.6	80	82	139	10.9
GC 95020-18-1-1-2	11.9	84	72	164	10.2
GC 95020-21-2-2-1	11.8	80	80	141	10.4
KS #1	9.0	69	61	169	13.4
KS #5	8.6	76	82	157	10.5
Mean	10.3	79	71	163	10.7
LSD 0.05	1.3	0	5.5	9.0	1.0
IYT/T 1999					
GC 94027-24-1	12.4	80	72	152	10.5
GC 94018-46-1	10.6	77	79	149	14.1
KS #1	8.8	69	58	177	13.1
KS #5	10.0	77	71	167	10.2
Mean	9.1	79	71	167	10.9
LSD 0.05	2.1	0	5.5	9.5	1.0

Within each trial, the difference between yield of selections shown and the checks is significant at P<0.05 according to LSD.

[1] IYT-1998, mean of 22 entries; IYT/T-1998, mean of 20 entries; IYT-2 1999, mean of 20 entries; IYT/T 1999, mean of 24entries.

meters above sea level). The yield of two- and three-seeded pods ranged from 7 to 18.6 t/ha. The results are given in Table 56.

Preliminary results from the unreplicated trial suggest that the AVRDC entries hold potential compared to the locally grown varieties, and consumers prefer them.

In a trial in Swaziland in 1998–99, AGS 346, AGS 344, AGS 345, and AGS 335 produced 16.8, 11.5, 10.5, and 9.75 t/ha, respectively.

In the dry season 1999 trial in the Philippines, AVRDC lines yielded 8.9–11.8 t/ha in 68–75 days, while the check varieties gave 8.6–8.8 t/ha in 78 days.

In a 1998/99 trial in Khumaltar, Nepal, AGS 352 and AGS 355 gave a graded pod yield of 8.4 and 6.5 t/ha in 109 and 87 days, respectively.

In Tuaran, Sabah, Malaysia, AGS 292, AGS 329, AGS 333, AGS 336, and AGS 338 produced graded pod yield of 5.5–7.0 t/ha compared to 3.1 t/ha for check variety AGS 190 (MARDI recommended variety). All entries, including the check, matured in 62–77 days.

Table 56. *Yield and other traits of vegetable soybean evaluated in Hawaii, 1999*

Entry	Total pod yield (t/ha)	Graded pod yield (t/ha)	Days to maturity	Length of pod* (cm)	Width of pod* (cm)
AGS 292	15.6	14.3	56	6.9	1.6
AGS 334	14.6	12.5	66	5.6	1.4
AGS 335	13.9	11.7	66	5.9	1.6
AGS 337	13.7	12.8	65	6.1	1.5
AGS 346	21.1	18.6	67	6.1	1.4
AGS 001	8.0	7.0	57	5.8	1.5
Kahala	12.7	10.6	67	4.3	1.0
Prize	15.4	14.7	65	4.0	1.2

* Length and width of 2- and 3-seed pods.

AVRDC Soybean Evaluation Trial

In 1999, 17 cooperators from 14 countries received 37 AGS lines and 296 other pedigrees and accessions for evaluation.

In a trial conducted in Cambodia by the Agrisud-Battambang project from June to September 1999, GC 87032-9-1 and AGS 129 yielded 2.3 and 2.2 t/ha in 83 and 77 days, respectively, while the local variety (no name) yielded 1.9 t/ha in 119 days.

In Vietnam, AGS 314 yielded significantly higher (2 t/ha in 99 days) than the check, DH 4 (1.1 t/ha in 102 days). The trial was planted on 5 March 1999.

Twelve countries have released 28 grain soybean varieties using AVRDC breeding lines.

Contact: S Shanmugasundaram

Program II

Year-round vegetable production systems

The goal of Program II is to develop and transfer technologies for improvement of year-round peri-urban and homestead vegetable production systems. Peri-urban vegetable production is being promoted as a response to some of the many problems associated with rapid urbanization, especially in developing countries. Most of the technologies being developed for peri-urban vegetable production will also be appropriate for homestead applications.

Vegetables are being evaluated and promoted as a practical and sustainable source of micronutrients for health improvement of urban and rural people in developing countries. Biological and socioeconomic constraints to vegetable production and consumption are being identified, and ways are being developed to overcome them. Technologies for year-round production of leafy vegetables and for off-season (hot-wet) production of high-value fruit vegetables, such as solanums and cucurbits, are being emphasized as means to overcome seasonal fluctuations in vegetable supply. The production technologies are being developed not only to enhance production, but also to minimize health and environmental risks through promotion of judicious use of pesticides and fertilizers. Spin-off benefits from concentrated areas of intensive year-round vegetable production (peri-urban) include income generation, employment opportunities (especially for women), and development of service sector enterprises.

The objectives of Program II are to:

- collect and improve technologies—including crops and production practices—for peri-urban and homestead production systems
- develop cost-effective and safe means of controlling vegetable pests, with reduced reliance on pesticides
- develop a better understanding of socioeconomic and nutritional aspects of vegetables
- develop improved decision-making tools for national agricultural research and extension systems to increase the effectiveness and efficiency of vegetable research and development efforts

Project 4. Improvement and stabilization of year-round vegetable supplies

One of the current major thrusts of AVRDC is development and transfer of technologies for year-round production of vegetables destined for consumption in urban areas. Emphasis is being placed on technologies for tomato production during the off (hot-wet) season and on enhanced year-round leafy vegetable production through improved cultural practices and selection of superior varieties. Considerable effort is being devoted to use of organic fertilizers as a source of nutrients for vegetables and at the same time provide a means of recycling organic municipal and farm wastes.

Off-season tomato production technologies, such as tomatoes grafted onto disease resistant and flood tolerant rootstocks, use of rain shelters, and other management practices, were evaluated in 1999. Various types of composted materials were compared in different proportions with inorganic fertilizers for their effects on vegetable yields and soil properties. Leafy vegetable varieties collected from Southeast Asia were evaluated for yield under different cultural practices and in different seasons.

Many of the activities were carried out both at AVRDC headquarters and in the Philippines. Headquarters activities are reported below and those in the Philippines under the heading of 'Manila peri-urban vegetable project' at the end of the section on Program II.

Effects of rain shelters and grafting on yields of tomatoes transplanted in late August

Production of tomatoes under rain shelters has been shown in numerous experiments at AVRDC and elsewhere to increase tomato production in comparison with open field production during the hot-wet season in the lowlands of Taiwan and other subtropical or tropical locations. Grafting of tomato scions onto bacterial wilt (BW) resistant eggplant rootstocks has been shown at AVRDC to protect the plants from damage caused by waterlogged soils and BW incited by *Ralstonia solanacearum*. Grafting of tomato scions onto BW resistant tomato rootstocks also provides protection against the disease, but not against summer flooding. The purpose of this study was to evaluate three levels of rain shelters and three levels of grafting in all combinations for their effects on tomato yields during the hot-wet season. Transplanting was planned for late June 1999, but due to unusually heavy and continuous rainfall during this period, transplanting could not be done until 20 August; therefore, most of the fruit development in this experiment occurred after the hot-wet season. Although the hot-wet season production period was missed, we were able to learn about the performance of tomatoes using these

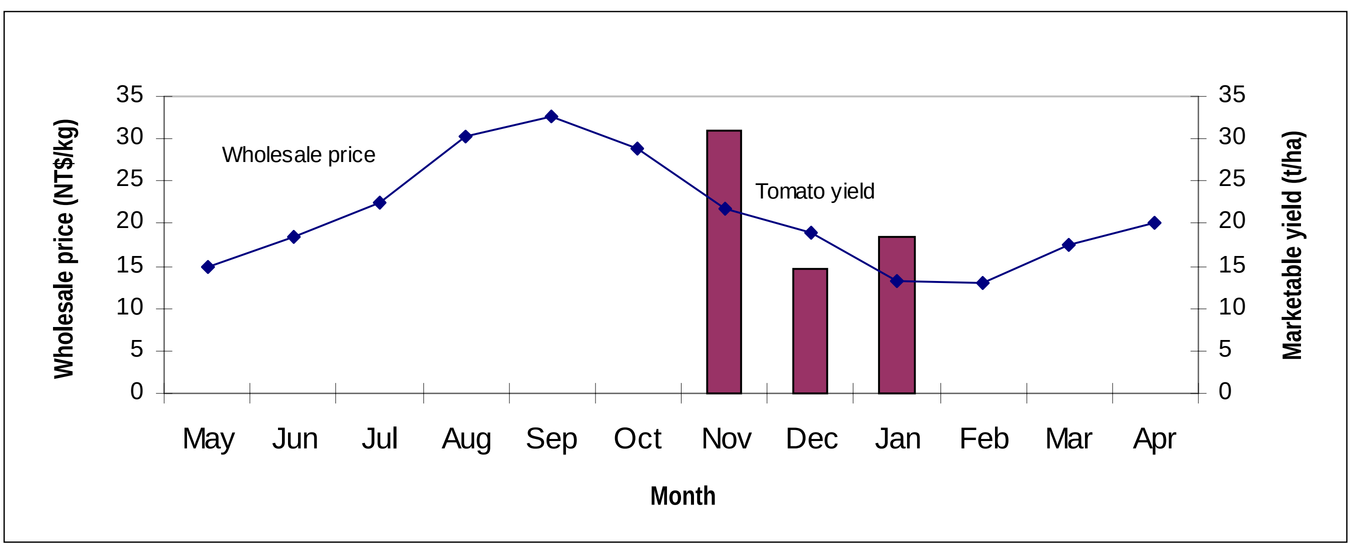

Figure 5. *Average (1994-1998) monthly wholesale tomato prices in Taiwan and yields from tomato line CL5915-206D4-2-2-0 transplanted 20 August 1999.*

technologies when grown under less stressful conditions. This information is very useful because we need to know the limitations and advantages of the technologies when used under environmental conditions other than those for which they were designed.

Rain shelter treatments included no shelter, open-side rain shelter, and enclosed-side rain shelter. Plants of tomato line CL5915-206D4-2-2-0 (CL5915) grafted onto EG203 eggplant rootstock, onto Hawaii 7996 (H7996) tomato rootstock, and nongrafted were tested in combination with all three shelter treatments in a randomized complete factorial block design using 26 plants per plot and three replications. The rain shelter covers and the sides of the enclosed shelters were 32 mesh nylon netting. All plants were pruned to two stems and staked. Harvests were made once or twice per week as the fruit reached the color breaking stage, and marketable yields were determined. Harvesting began on 1 November 1999 and continued through 24 January 2000. There were no heavy rains to cause flooding after the plants were transplanted into the field. To stress the plants, the entire research field was flooded by furrow irrigation for a 9-day period in October, a 22-day period in November, and again for a 20-day period in December. The level of floodwater was maintained at least 1 cm over the surface of the plant beds.

No plants died as a result of the intentional long periods of flooding and no plants died from BW. Only a few scattered plants were killed by southern blight incited by *Sclerotium rolfsii*. Although it is well known that damage to tomato by flooding is much greater when temperatures are high, the lack of plant mortality among nongrafted tomatoes and those grafted onto tomato rootstock came as a surprise. Tomato plants often die soon after flooding during the hot season, e.g., in a flooding experiment during September 1997, tomato plants were permanently wilted within 2 days after a 70-hour flood treatment and all plants died over the next few days. Tomato plant damage in flooded soils is generally attributed to root damage caused by anoxia. The sudden death during the hot season and the lack of plant death in cooler seasons following flooding causes us to suspect that in addition to damage from anoxia, some other factor(s), such as a biological agent, might be contributing to mortality of tomato plants following flooding in the summer.

There were no differences in yields based on shelter treatment (Table 57), which came as no surprise, because rainfall was not heavy during the time the experiment was in the field. It was thought that there might be a negative effect from the shelters due to shading, but this was not observed. Light measurements showed a light reduction inside the rain shelters of about 25% compared to the nonsheltered treatment.

There was no difference in marketable yield from nongrafted CL5915 tomatoes and those grafted onto eggplant rootstock, however the yield of CL5915 tomato grafted onto H7996 was significantly higher than nongrafted CL5915 and those grafted onto eggplant (Table 57). Previous studies have shown a yield reduction with tomato plants grafted onto eggplant when they are grown during the main season (fall and winter) in Taiwan. Failure to observe a yield reduction due to grafting onto eggplant in this study might be due to the long periods of flooding, which did not kill any plants but most likely caused more damage to the nongrafted plants than those on eggplant rootstock. The increased yield from tomatoes grafted onto H7996 tomato rootstock shows that this rootstock imparts some advantageous characteristic to grafted plants in addition to its BW resistance, because BW did not occur in any of the experimental plots.

Table 57. *Effects of rain shelters and grafting on yield of tomatoes transplanted in late summer 1999, AVRDC headquarters*

	Marketable yield (t/ha)			
	Rain shelter (S)			
Grafting (G)	No shelter	Open-side	Enclosed-side	G-mean
Non-grafted	61.8	66.6	63.8	64.1 b
Grafted onto tomato, H7996	79.6	71.5	75.1	75.4 a
Grafted onto eggplant, EG203	59.0	57.3	61.5	59.2 b
S-Mean	66.8 a	65.1 a	66.8 a	

In a row or column, means followed by the same letter are not significantly different at P<0.05 by least significant difference.

Average marketable tomato yields amounted to about 65 t/ha (Table 57). Yields would have been lower if the field had been established in June with production occurring August through October as planned. Production from the experimental plots caught only the tail end of the traditional period of low supply and high prices, with most of the production occurring during a period of low prices, illustrating the need for proper timing to capture the higher prices (Figure 5). Furthermore, no benefit was seen in this study from the use of rain shelters or from grafting onto eggplant, reemphasizing that these technologies should be employed only for hot-wet season tomato production. On the other hand, utilizing H7996 as a tomato rootstock should be looked at further for the possibility of enhancing yields in the main season, in addition to its known benefit of providing BW resistance.

Contact: Y C Roan and L L Black

Development of recommendations for tomato production on grafted plants

Tomato yields are very low in tropical lowlands during the hot-wet season. Two of the major limiting factors are waterlogged soils and bacterial wilt (BW). Grafting tomato scions onto eggplant rootstocks has been shown to greatly increase yields xof tomatoes grown in soils that often become waterlogged or where BW is likely to occur. Grafting onto BW resistant tomato rootstocks also provides protection against this disease, but it does not give any protection against soil flooding. Most previous research conducted on grafted tomatoes has been done with indeterminate tomato lines or varieties. The purpose of this study was 1) to compare yields from determinate and indeterminate tomato varieties grafted onto eggplant, 2) to evaluate the effect of growth regulators (Tomatotone) on yield, and 3) to compare the production period with seasonal prices of tomatoes in Taiwan.

During summer 1999, tomato yield trials were conducted to test the effectiveness of various cultural practices employed in conjunction with tomatoes grafted onto eggplant rootstocks. Determinate (CLN2026D) and indeterminate (CL5915-206D4-2-2-0) tomato lines were grafted onto an eggplant rootstock, EG203. The determinate plants had side branches pruned at the first two to three nodes and were then allowed to branch freely producing five or more stems that were supported on a horizontal net. The indeterminate plants were individually staked and their growth habit managed in two ways: 1) plants kept pruned to a single stem and 2) plants pruned to a double stem. In addition, the yield effects of applying a commercial fruit-set hormone, Tomatotone, to flower clusters were evaluated on each plant type. All experiments were conducted under open-side rain shelters on 30-cm-high beds. Plants were transplanted to the field on 15 June.

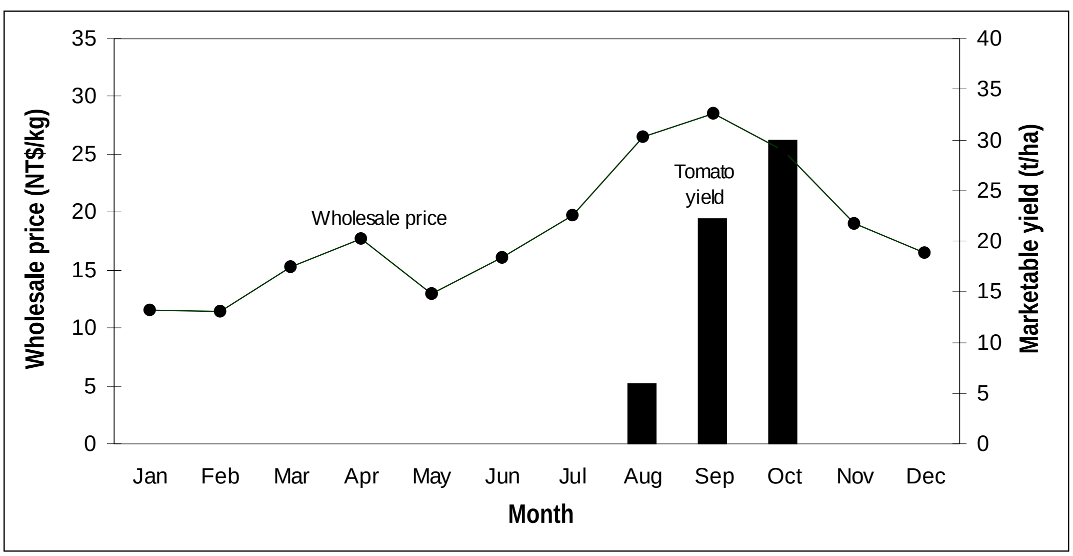

Figure 6. *Average (1994–1998) year-round wholesale tomato prices in Taiwan and yields from tomato line CL5915-206D4-2-2-0 grafted onto EG203 eggplant rootstock and grown in an AVRDC field under rainshelters; transplanted on 15 June.*

Very heavy rainfall occurred during July and August, which caused extensive flooding, but no plants were lost to BW or flooding. There was no yield response to the Tomatotone treatment; therefore, mean yields from the with- and without-Tomatotone treatments were used to compare the three pruning treatments. The indeterminate plants grown with a double stem produced 45.8 t/ha, which was significantly higher than the 34.6 t/ha yielded from plants grown with a single stem (Table 58). Yield from the determinate plants, at 38.2 t/ha, was intermediate to the two indeterminate treatments, but not significantly different from either. These data were obtained from plants grafted onto eggplant rootstocks and grown under rain shelters. An unrelated adjacent experiment conducted without rain shelters during the same time period using tomato hybrid FMTT 586, nongrafted and grafted onto EG203, yielded only 3.4 and 9.1 t/ha, respectively. These are typical yields for tomatoes grown without protection during the hot-wet season in Taiwan and are shown here to emphasize the importance of rain shelters for summer tomato production.

Yield comparisons between determinate and indeterminate tomatoes show they have similar yield potentials when grown under these conditions and that determinate varieties should be further evaluated for off-season tomato production involving grafting and rain shelter technologies. Pruning indeterminate tomatoes to two stems for summer production, a practice already recommended for nongrafted tomatoes, appears to be the best practice for grafted plants as well. The failure to obtain a response from Tomatotone applications was unexpected based on results from previous studies, and this must be reevaluated. One of the goals of this research is to develop economical production technologies to overcome environmental stresses and enhance tomato production during the hot-wet season. The tomato plants in this study were transplanted on 15 June; the harvest period was 17 August through 31 October, which coincides with the period when tomato supplies are lowest and prices are highest in Taiwan (Figure 6).

Contact: D L Wu and L L Black

Table 58. *Yields of indeterminate and determinate tomatoes grafted onto eggplant rootstock (EG 203) and grown under rainshelter from 15 June to 31 October 1999*

	Marketable yield, t/ha		
	Indeterminate		Determinate
Fruit-set	CL 5915-206D4-2-2-0		CLN 2026D
Hormone	one stem	two stems	five stems
Tomatotone	37.5 ab	47.2 a	32.4 b
No Tomatotone	31.6 a	44.4 a	43.9 a
Difference	5.9[ns]	2.8[ns]	-11.5[ns]
Mean	34.6 b	45.8 a	38.2 ab

Mean separation within row at P<0.05 by LSD; values are means of four replications.

Use of inorganic starters to enhance efficacy of organic fertilizers

As reported in *AVRDC Report 1998*, application of organic fertilizer combined with starter solution increased cherry tomato yields significantly compared to yields obtained using standard inorganic fertilizer. Three studies were carried out at AVRDC in 1999 to compare the effects of starter solutions, in

Table 59. *Treatments in first common cabbage experiment, autumn 1998*

	Fertilizer applied (kg/ha)								
	Organic sources			Chemical sources			Starter solution		
Fertilizer treatment	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Pig manure	150	427	62	0	0	0	0	0	0
Pig manure+starter*	150	427	62	0	0	0	3.6	7.2	3.6
SI applied all as top dressing +starter	0	0	0	150	90	120	3.6	7.2	3.6
Standard inorganic+starter	0	0	0	150	90	120	3.6	7.2	3.6
Standard inorganic fertilizer (SI)	0	0	0	150	90	120	0	0	0

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 75-75-75 kg/ha, and top dressing of 25 kg N/ha at 15 and 45 days after transplanting, and N-P_2O_5-K_2O, 25-45-15 kg/ha, at 27 days after transplanting.

*Starter fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O=6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).

combination with inorganic and organic fertilizers, on the yield of mid-duration common cabbage. In the second experiment, times of solution application and form of starter solution were evaluated.

There were 5, 6, and 12 treatments in the first, second, and third experiments, respectively. All experiments were arranged in randomized complete block design with two (first experiment) and three (second and third experiment) replications (Tables 59, 61, and 63). Beds were 1.5 m wide with two rows of plants per bed; within-row spacing was 45 cm. Seedlings of a local early-autumn variety were transplanted on 22 October, and a local summer-autumn variety was transplanted on 17 March and 1 September 1999. Initial growth response was measured by total (leaf and root) dry weight at 12 days after transplanting. Cabbage heads were harvested on 29 December 1998 and 15 June and 1 November 1999, respectively. Total N, P, and K uptakes of whole plants were analyzed at harvest.

The first autumn trial showed that adding starter solution to the standard inorganic fertilizer check resulted in 36% more dry weight after 12 days of growth (Table 60). The use of pig manure (PM) alone retarded early growth by 24%, as compared with the inorganic check; but when the starter solution was applied together with PM, there was a dramatic increase (46%) in growth. This was significantly higher than the inorganic fertilizer check. When starter with PM was applied, initial N, P, and K uptakes were 57, 68, and 68% higher, respectively, than application of PM alone.

Table 60. *The effects of organic fertilizer and starter on initial growth, nutrient uptakes and head yields of common cabbage, autumn, 1998*

Fertilizer treatment	Total dry weight at 12 DAT (g/plant)	Index	Nitrogen uptake at 12 DAT (mg/plant)	Index	Head yield (t/ha)	Index
Pig manure	1.32 c	76	29.5 c	41	33.4 c	59
Pig manure+starter*	2.13 a	123	71.5 b	98	47.3 b	83
SI applied all as top dressing +starter	2.03 ab	117	81.8 b	112	50.1 b	88
Standard inorganic+starter	2.36 a	136	110.3 a	151	60.5 a	106
Standard inorganic fertilizer (SI)	1.73 b	100	72.8 b	100	57.1 a	100

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 75-75-75 kg/ha, and top dressing of 25 kg N/ha at 15 and 45 days after transplanting (DAT), and N-P_2O_5-K_2O, 25-45-15 kg/ha, at 27 DAT.
*Starter fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O = 6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).

Table 61. *Treatments in second common cabbage experiment, spring 1999*

Fertilizer treatment	Fertilizer applied (kg/ha): Organic sources: Solid fertilizer N	P_2O_5	K_2O	Organic sources: Starter& liquid fertilizer N	P_2O_5	K_2O	Chemical sources: Solid fertilizer N	P_2O_5	K_2O	Chemical sources: Starter& liquid fertilizer N	P_2O_5	K_2O
Chicken manure+starter-I[1]	210	178	224	0	0	0	0	0	0	3.6	7.2	3.6
Chicken manure+starter-O[2]+2 OLF[3]	210	178	224	10.8	5.4	5.4	0	0	0	0	0	0
Pig manure+starter-I	210	236	58	0	0	0	0	0	0	3.6	7.2	3.6
Pig manure+starter-O +2 OLF	210	236	58	10.8	5.4	5.4	0	0	0	0	0	0
Standard inorganic+starter-I	0	0	0	0	0	0	210	90	120	3.6	7.2	3.6
Standard inorganic fertilizer	0	0	0	0	0	0	210	90	120	0	0	0

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 70-90-45 kg/ha, and top dressing of N-K_2O, 45-25 kg/ha, at 13 and 20 days after transplanting (DAT), and N-K_2O, 50-25 kg/ha, at 35 DAT.
[1] Starter-I fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O = 6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).
[2] Starter-O fertilizer was organic liquid fertilizer (N-P_2O_5-K_2O = 12%-6%-6%), diluted and applied at a rate of 120-60-60 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-1.8-1.8 kg/ha).
[3] OLF was same fertilizer solution as starter-O, but applied at 1st and 2nd top dressing time as organic liquid fertilizer.

The effects of starter on both inorganic and organic fertilizer treatments were more obvious in the early growth than in the head yield. Application of PM alone reduced head yield by 41%, as compared with the standard inorganic fertilizer check (Table 60), but when starter was applied with PM, the yield improved significantly, by 24%. Adding starter to standard inorganic fertilizer increased yield by only 6%, while replacing the basal fertilizer with small amounts of starter solution reduced yield by 12% (both not significant). Total N, P, and K uptakes at harvest were significantly lower in the PM alone treatment compared to the inorganic check. For starter application with PM, total N, P, and K uptakes improved by 12, 15, and 15%, respectively.

The spring trial aimed to test the effects of two kinds of starters, organic and inorganic, added to two kinds of manure, chicken and pig, along with their

Table 62. *The effects of organic fertilizer and starter on initial growth and head yield of common cabbage, spring 1999*

Fertilizer treatment	Leaf dry weight at 12 DAT (g/plant)	Leaf dry weight at 12 DAT Index	Root dry weight at 12 DAT (g/plant)	Root dry weight at 12 DAT Index	Head yield (t/ha)	Head yield Index
Chicken manure+starter-I[1]	8.30 a	92	0.59 ab	93	34.8 bc	77
Chicken manure+starter-O[2]+2 OLF[3]	6.59 a	73	0.53 ab	84	36.1 bc	79
Pig manure+starter-I	6.55 a	73	0.53 ab	83	29.7 c	65
Pig manure+starter-O+2 OLF	6.64 a	74	0.47 b	74	32.4 c	71
Standard inorganic+starter-I	9.05 a	100	0.61 ab	96	46.0 ab	101
Standard inorganic fertilizer	9.01 a	100	0.63 a	100	45.4 ab	100

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 70-90-45 kg/ha, and top dressing of N-K_2O, 45-25 kg/ha, at 13 and 20 days after transplanting (DAT), and N-K_2O, 50-25 kg/ha, at 35 DAT.

[1] Starter-I fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O = 6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).

[2] Starter-O fertilizer was organic liquid fertilizer (N-P_2O_5-K_2O = 12%-6%-6%), diluted and applied at a rate of 120-60-60 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-1.8-1.8 kg/ha).

[3] OLF was same fertilizer solution as starter-O, but applied at 1st and 2nd top dressing time as organic liquid fertilizer.

Table 63. *Treatments in third common cabbage experiment, autumn 1999*

Fertilizer treatment	Total fertilizer applied (kg/ha): Organic sources, Solid fertilizer N	P_2O_5	K_2O	Chemical sources, Solid fertilizer N	P_2O_5	K_2O	Chemical sources, Starter& liquid fertilizer N	P_2O_5	K_2O
Chicken manure 3[1]	630	1949	1614	0	0	0	0	0	0
Chicken manure 2[1]	420	1300	1076	0	0	0	0	0	0
Chicken manure 1[1]	210	650	538	0	0	0	0	0	0
Chicken manure 2+ starter[2]	420	1300	1076	0	0	0	3.6	7.2	3.6
Chicken manure 1+ starter	210	650	538	0	0	0	3.6	7.2	3.6
Chicken manure 1+ starter + 1 ILF[3]	210	650	538	0	0	0	7.2	14.4	7.2
Chicken manure 1+ starter + 3 ILF[3]	210	650	538	0	0	0	14.4	28.8	14.4
Pig manure 1	210	533	91	0	0	0	0	0	0
Pig manure 1 + starter	210	533	91	0	0	0	3.6	7.2	3.6
Standard inorganic + starter	0	0	0	210	90	120	3.6	7.2	3.6
Standard inorganic + starter + 3 ILF	0	0	0	210	90	120	14.4	28.8	14.4
Standard inorganic fertilizer	0	0	0	210	90	120	0	0	0

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 70-90-45 kg/ha, and top dressing of N-K_2O, 45-25 kg/ha at 13 and 20 days after transplanting (DAT), and N-K_2O, 50-25 kg/ha, at 35 DAT.

[1] Amounts of chichen manure applied equivalent to 3 times, 2, and 1 times of N applied as inorganic solid fertilizer, respectively

[2] Starter-I fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O = 6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).

[3] ILF was same fertilizer solution as starter, but applied at 1st and 2nd top dressing time as inorganic liquid fertilizer.

application methods. However, due to continuous rain before transplanting, soil moisture was very high, and the effects of starter were not as obvious as in the autumn trial. Addition of starter solution to the standard inorganic check did not improve the initial growth at 12 days after transplanting (Table 62). This might be because the starter was diluted and because the solid fertilizer dissolved rapidly. Chicken manure (CM) with inorganic starter achieved early growth equivalent to 92% of that achieved by the standard inorganic fertilizer treatment, while PM with starter achieved 73%. Head yields achieved by CM combined with either inorganic or organic starters were not significantly different from yields produced by inorganic fertilizer treatments, which indicates the effects of starter solutions. The effects of inorganic or organic starters were not significantly different in combination with CM or PM.

The 1999 autumn trial showed similar results as that in 1998. When applications of CM were increased two to three times, supplying equivalent amounts of N as applied as inorganic fertilizer, the initial growth was not improved greatly (Table 64). However, wherever the starter solutions were applied with CM, the initial growth was significantly accelerated in terms of both leaf and root dry weight (Table 64). With application of PM alone, initial growth was only 65% of that grown with inorganic fertilizer, but when starter solution was applied with PM, there were dramatic increases in early growth (by 36 and 33% in leaf and root dry weight, respectively). The starter solution enhanced the efficiency of both CM and PM.

Inorganic fertilizer treatment produced yields significantly greater than those obtained from organic fertilizer treatments alone (both CM and PM). Head yield from treatments combining PM and starter was 13% higher than using PM alone, and was not significantly different from yields obtained with the standard inorganic fertilizer check. Combining starter with CM had less effect on yields of common cabbage compared to the PM treatment. This might be due to the differences in N releasing rates. Applying liquid fertilizer solution in the later stage was not effective in increasing the efficiency of organic fertilizers.

Starter solutions can also be very useful in boosting the effect of organic fertilizer on the early growth and yield of common cabbage. When starter solution is combined with organic fertilizer, the effect in improving organic fertilizer efficiency seems more applicable to long-duration crops that can fully utilize the nutrients from organic sources. But because common cabbage is a mid-duration crop,

Table 64. *The effects of organic fertilizer and starter on initial growth and head yields of common cabbage, autumn 1999*

Fertilizer treatment	Leaf dry weight at 12 DAT (g/plant)	Leaf dry weight at 12 DAT Index	Root dry weight at 12 DAT (g/plant)	Root dry weight at 12 DAT Index	Head yield (t/ha)	Head yield Index
Chicken manure 3[1]	4.97 d	75	0.42 bc	86	37.7 cd	76
Chicken manure 2[1]	4.65 d	71	0.39 c	79	29.6 d	60
Chicken manure 1[1]	4.59 d	70	0.41 c	84	30.0 d	61
Chicken manure 2+ starter[2]	6.51 bc	99	0.53 a	108	32.1 cd	65
Chicken manure 1+ starter	6.74 bc	102	0.51 a	105	31.8 cd	64
Chicken manure 1+ starter + 1 ILF[3]	6.45 bc	98	0.51 a	104	28.0 d	57
Chicken manure 1+ starter + 3 ILF[3]	6.16 c	94	0.49 ab	100	36.5 cd	74
Pig manure 1	4.30 d	65	0.36 c	74	34.9 cd	71
Pig manure 1 + starter	6.65 bc	101	0.52 a	107	41.4 bc	84
Standard inorganic + starter	7.76 ab	118	0.53 a	110	49.1 ab	100
Standard inorganic + starter + 3 ILF	8.07 a	123	0.55 a	112	51.6 a	105
Standard inorganic fertilizer	6.58 bc	100	0.49 ab	100	49.3 ab	100

Standard inorganic fertilizer comprised a basal application of N-P_2O_5-K_2O, 70-90-45 kg/ha, and top dressing of N-K_2O, 45-25 kg/ha at 13 and 20 days after transplanting (DAT), and N-K_2O, 50-25 kg/ha, at 35 DAT.

[1] Amounts of chichen manure applied equivalent to 3 times, 2, and 1 times of N applied as inorganic solid fertilizer, respectively.

[2] Starter-I fertilizer was inorganic liquid compound fertilizer # 4(N-P_2O_5-K_2O = 6%-12%-6%), diluted and applied at a rate of 120-240-120 mg of N-P_2O_5-K_2O in 50 ml water per plant (equivalent to N-P_2O_5-K_2O, 3.6-7.2-3.6 kg/ha).

[3] ILF was same fertilizer solution as starter, but applied at 1st and 2nd top dressing time as inorganic liquid fertilizer.

the nutrients in the organic fertilizer are not fully utilized. Therefore, increase in head yields due to starter solution with organic fertilizer can vary depending on season and type of organic fertilizer.

Contact: C H Ma and L L Black

Development of efficient composting methods for municipal and agricultural wastes

Composting is an old technique. About a century ago, composts were a major source of nutrients supplied to crops. Due to mechanization and chemical fertilizer development, however, composts gradually disappeared from farms. Increased concern for the environment has prompted a second look at composting, as a way to recycle waste.

The objective of this study was to establish a method to produce better quality compost using common agricultural wastes, in a small-farm setting.

Among the raw materials used, pig bone meal contains the highest concentration of N, while chicken manure (CM) has the highest Ca content. Pig manure (PM) and CM have higher contents of P. Six recipes were designed (Table 65). Ammonium sulfate was added to the 1st and 2nd composts to adjust the C:N ratio. Raw materials were mixed and shaped into 1 × 1 × 1.2 m piles (l × w × h) under a net house with a plastic shelter. Water was added to adjust the moisture to about 65%. Every two weeks, the piles were turned to ensure good aeration. Temperature, moisture, nitrogen, and carbon changes were monitored during composting. When the composts were mature, field studies were conducted to compare the effects of compost and standard inorganic fertilizer on the growth and yield of common cabbage. There were seven treatments in a randomized complete block design with two replications. Standard inorganic fertilizers were applied at a rate equal to 150-90-120 kg/ha N-P_2O_5-K_2O. All composts were applied at rates equivalent to 150 kg N/ha. Beds were 1.5 m wide with two rows of plants per bed; within-row spacing was 45 cm. Seedlings were transplanted on 22 October 1998. Initial growth response was measured by measuring total dry weight at 12 days after transplanting. Cabbage heads were harvested from the check and compost plots on 29 December 1998 and 6 January 1999, respectively. Total N, P, and K uptakes by the whole plants in each treatment were analyzed.

Table 65. *Recipes of compost mixture of different organic wastes (volume based, %)*

Compost no.	Rice bran	Pig manure	Chicken manure	Bone meal	Saw-dust	Rice hull	Rice straw
1	10	10	-	-	40	40	-
2	10	-	10	-	40	40	-
3	5	-	-	5	45	45	-
4	-	12.5	-	2.5	-	40	45
5	-	-	12.5	2.5	-	40	45
6	-	-	-	2.5	32.5	32.5	32.5

Table 66. *Compositions of processed composts before application to field*

Composts no.	pH	EC	T-C (%)	T-N (%)	C/N	P (%)	K (%)
1	5.51	4.59	46.0	1.59	29	2.18	0.49
2	7.34	2.27	34.1	1.37	25	2.06	0.42
3	7.25	1.55	49.6	0.97	51	1.03	0.23
4	7.73	3.40	32.9	2.00	16	3.45	0.91
5	8.23	3.90	22.0	1.61	14	2.74	1.24
6	7.03	1.37	50.4	1.19	42	0.55	0.37

Table 67. *Effects of compost application on initial growth, head yield, and nutrient uptake of common cabbage*

Fertilizer treatment	Total dry weight at 12 DAT		Head yield		Total nutrients uptake and index: Nitrogen		Phosphorus		Potassium	
	(g/plant)	Index	(t/ha)	Index	(kg/ha)	Index	(kg/ha)	Index	(kg/ha)	Index
Compost 1	1.71 a	99	45.5 b	80	127.0 b	69	16.7 b	82	150.3 a	99
Compost 2	1.60 a	92	30.3 c	53	104.1 bc	57	12.6 cd	62	112.1 bc	74
Compost 3	1.48 a	85	18.7 d	33	71.3 d	39	8.7 e	42	79.8 d	52
Compost 4	1.58 a	91	42.9 b	75	114.7 bc	63	15.4 bc	75	122.0 bc	80
Compost 5	1.63 a	94	41.8 b	73	121.6 b	66	15.1 bc	74	131.5 ab	86
Compost 6	1.50 a	87	26.8 c	47	93.6 cd	51	11.2 de	55	95.9 cd	63
Standard inorganic(ck)	1.73 a	100	57.1 a	100	183.1 a	100	20.4 a	100	152.2 a	100

DAT = days after transplanting.

Composition of composts

Table 66 presents some properties of composts before application to field. Composts 1, 4, and 5 were higher in N than the others, but composts 3 and 6 still were very high in C:N ratio, and might not be suitable composts. These results imply that N in pig bone meal might easily be lost during composting.

Effects of compost on initial growth and yield of common cabbage

Application of composts tended to retard early growth slightly as compared with the standard inorganic fertilizer check, but the difference was not significant (Table 67). Responses of cabbage to compost application in the initial stage were closely correlated with N availability from the composts. All the compost treatments produced significantly lower yield than did the standard inorganic fertilizer. However, composts 1, 4, and 5 achieved head yields equivalent to 73–80% of the head yield produced using the standard inorganic check. The nutrient uptakes (except K) in the compost treatments were all significantly lower than the check. Composts 1, 4, and 5 performed better than did the other composts.

Contact: C M Ma and L L Black

Project 5. Integrated insect and disease management (IPM) for environment-friendly production of safe vegetables

Phytophagous insects, plant diseases, and weeds are major constraints in vegetable production throughout the world. These ‘pests’ are especially important in the tropics and subtropics because environmental conditions are often conducive year-round for growth and development of hosts and pests. In addition to developing resistant vegetable cultivars, AVRDC is developing pest-control technologies that emphasize biological, cultural, and mechanical control to minimize the use of chemical pesticides. Harmonious integration of these approaches is the keystone of AVRDC’s integrated pest management (IPM) research. Besides being sustainable, the IPM approach reduces production costs and makes available to consumers good quality vegetables at affordable prices. At the same time, it reduces the risk that chemical pesticides poison humans and the environment.

AVRDC’s IPM research emphasizes management of several insect pests and two plant diseases. Insect pests include: diamondback moth (*Plutella xylostella* (L.)), cabbage webworm (*Hellula undalis* (F.)) and cabbagehead caterpillar (*Crocidolomia binotalis* (Zeller)); armyworms (*Spodoptera exigua* (Hübner) and *S. litura* (F.)), and onion thrips (*Thrips tabaci* Lindermann) on onions; eggplant fruit, and shoot borer (*Leucinodes orbonalis* Guenée) and cotton leafhopper (*Amrasca biguttula biguttula* (Ishina)) on eggplant; broadmite (*Polyphagotarsonemus latus*) and cotton aphid (*Aphis gossypii*) on chili pepper; and maruca pod borer (*Maruca vitrata*) on mungbean and yardlong bean; and Asiatic tomato fruitworm (*Helicoverpa armigera*) on tomato. Among vegetable diseases, bacterial wilt (*Ralstonia solanacearum*) and fusarium wilt (*Fusarium oxysporum* f sp *lycopersici*) in tomato and eggplant are focuses for IPM research.

Research activities related to management are described in this section. Activities related to host-plant resistance breeding are reported under Program I.

Study of *Solanum viarum* as a possible trap crop to control tomato fruitworm

In spring 1988, while screening eggplant and related wild *Solanum* species for resistance to cotton leafhopper, heavy infestation of *Solanum viarum* foliage by larvae of tomato fruitworm (TFW), *Helicoverpa armigera* (Hübner), was noticed. Various instar larvae were found feeding voraciously only on the four plots of *S. viarum* scattered over a 0.1-ha area, whereas all other plots, planted to various *Solanum* species, were free of TFW damage. In several laboratory studies conducted during summer 1998, TFW larvae consistently preferred to feed on *S. viarum* leaves over its natural host, tomato fruit (TFW devastates tomato crops in Asia, Africa, and the Pacific). This suggested that *S. viarum* is highly preferred by TFW, which opened the possibility of using this wild plant as a trap crop. So, in 1998–99 we performed a laboratory cage study and preliminary field study with the intention of developing *S. viarum* as a trap crop to combat TFW.

A walk-in cage 2.5 × 2.5 × 1.8 m, consisting of 16 mesh nylon net wrapped around a sturdy wooden frame was used. Two 10-week-old, healthy, flowering, potted tomato plants and two *S. viarum* plants, bearing about equal leaf canopy, were placed in the corners of the cage, with the tomatoes and *S. viarum* diagonally opposite. Ten pairs of two-day-old mated TFW adults were released in the cage to lay eggs. Two days after insect introduction, we recorded the number of eggs on *S. viarum* and on the tomato plants. This exercise was repeated five times, using fresh plants and new adults every time. Each of the five tests was considered one replication, and oviposition data were analyzed by paired t test.

The field experiment consisted of two large plots, one planted to only tomato and the other planted to tomato interspersed with rows of *S. viarum*. A parcel of land was ploughed and worked into 1.5-m-wide, raised beds. The area was divided into two large blocks, each measuring 51 × 15 m separated by an empty distance of 45 m. Each block consisted of 34, 15-m-long beds. In the trap-cropped block, six-week-old seedlings of *S. viarum* were transplanted in one row on the top of beds #1, 12, 23, and 34, maintaining a distance of 1 m between two adjacent plants in each row. In the remaining 30 beds, we transplanted 4-week-old tomato seedlings of cultivar TK70 in an identical manner. In the monocropped block, we planted only tomato in all 34 beds.

The crop was grown by standard cultural practices. No insecticide was used on the tomato plants, but *S. viarum* plants received a weekly application of deltamethrin to protect them from TFW damage and to maintain a thick leaf canopy for up to 4 weeks after transplanting. When the tomato plants started flowering, we periodically released an equal number of either pupae or adults from each of three points erected 10 m from each planted block. A total of 72 male and 1138 female pupae and 72 pairs of adults were dispensed during the season to increase pest population pressure for uniformly high infestation.

From the start of tomato flowering, we observed each tomato plant from both blocks and *S. viarum* plants from the trap-crop block and recorded the number of TFW eggs laid. Three such observations were made at an interval of 10 days. When fruit setting began, we observed tomato fruit for TFW larval damage four times at an interval of 2 weeks. In the first two observations, we recorded healthy and damaged fruit. In the last two, we observed only six randomly selected plants in each row and recorded TFW-damaged and healthy fruit. At each observation, we plucked and discarded damaged fruit. We also harvested ripe red fruit and recorded the number and weight of healthy and damaged fruit. For comparison of yield, we recorded fruit yield (weighing healthy and damaged fruit) in three sections: rows 2–11, 13–22, and 24–33 in each block.

The results of the cage study are summarized in Table 68. Each of five observations revealed that TFW adults prefer to lay eggs on *S. viarum*. On

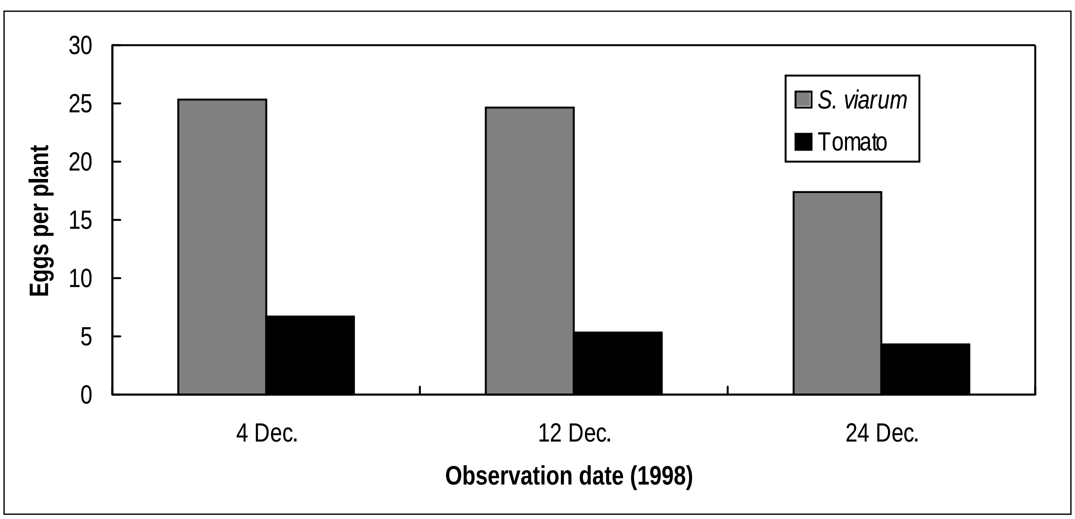

Figure 7. *Extent of oviposition of TFW on* S. viarum *and tomato plants during three observations.* (S. viarum *data represent mean of four rows [16 plants/row]; tomato data represent 30 rows.)*

average, more than nine times as many eggs were laid on *S. viarum* (19.7 eggs) than on tomato (2.0 eggs). The TFW adults' overwhelming preference for *S. viarum* suggests that there are chemicals in the foliage of *S. viarum* that attract TFW for oviposition and larval feeding. It is noteworthy that *S. viarum* has never been reported to be a host of TFW.

The results of the field study are summarized in Figure 7. As in the cage experiment, TFW adults always laid more eggs (four times more) on *S. viarum* than on tomato. On tomato plants, eggs were scattered on leaves, stems, flowers, and fruit, but on *S. viarum*, eggs were confined to leaves.

TFW laid substantially more eggs on monocropped tomato than on trap-cropped tomato (Table 69), except for the first observation when the number of eggs per plant was similar. If we were to use 10-row sections between *S. viarum* rows in the trap-cropped block and identical sections in the monocrop block as three replicates, the number of eggs laid on the monocropped plants would be significantly greater than on the trap-cropped tomato in the last two observations. It is obvious that in the trap-cropped block, many of the TFW adults were attracted to *S. viarum* plants to lay eggs, leaving fewer insects to go to the tomato plants. This is the probable reason for the reduced oviposition on tomato planted in the trap-cropped block.

Oviposition is the first act of insect infestation. In an overwhelming number of cases, TFW larvae hatching from eggs laid on a particular plant remain and feed on that plant only. Therefore, attracting TFW adults, especially ovipositing females, away from tomato to an economically unimportant trap plant species such as *S. viarum* is an attractive approach to control TFW on tomato and other economically important crops.

Results of the TFW damage to tomato fruit observed four times during the season are summarized in Table 70. Within each treatment, pest damage varied from row to row. On average, however, tomatoes planted with *S. viarum* as a trap crop suffered substantially less damage than tomatoes planted as a sole crop.

TFW larvae fed voraciously on the foliage of *S. viarum*. In fact early in the season, these plants had to be protected by insecticide sprays to reduce pest damage so that the canopy could be maintained. Late in the season, many TFW larvae feeding on *S. viarum* were found to be parasitized by a hymenopterous

Table 68. *Oviposition of tomato fruitworm on tomato and* S. viarum *plants confined in a cage*

Plant species	No. eggs per plant
S. viarum	19.70 ± 4.40
Tomato	2.00 ± 2.24
t	8.018

Cage size: 2.5 m x 2.5 m x 1.8 m. Data are mean of five paired observations between 2 Nov and 21 Dec 1998. *t* test significant at P<0.01

Table 69. *Oviposition of TFW on tomatoes planted as monocrop and with* S. viarum *as trap crop*

Observation dates	No. eggs per tomato plant	
	Trap cropped	Monocropped
4 Dec 1998	6.70 ± 2.18	5.68 ± 1.59
14 Dec 1998	5.26 ± 1.62	7.45 ± 1.74
24 Dec 1998	4.14 ± 0.81	5.02 ± 0.99

Data are for 30 rows (16 plants/row) for trap cropped, and 34 rows of monocropped tomato.

Table 70. *Effect of* S. viarum *trap cropping on damage to tomato fruit*

Observation dates	Damaged fruit (%) per tomato plant	
	Trap cropped	Monocropped
29 Dec 1998	9.55 ± 4.79	15.31 ± 4.81
12 Jan 1999	5.98 ± 1.81	8.84 ± 1.84
26 Jan 1999	4.37 ± 1.18	6.43 ± 1.62
10 Feb. 1999	2.46 ± 0.87	3.44 ± 0.75

Data are for 30 rows (16 plants/row) for trap crop, and 34 rows of monocropped tomato.

Table 71. *Tomato fruit yield in trap-cropped and mono-cropped plots*

Tomato plot	Yield (t/ha)		
	Total	Damaged	Marketable
Trap-cropped	43.90 ± 1.53	1.09 ± 0.03	42.81 ± 1.54
Monocropped	41.43 ± 0.31	1.72 ± 0.19	39.71 ± 0.43

Data are for 30 rows of tomato in each block. Yield data are not adjusted for 10% loss of land under *S. viarum.*

parasitoid, *Campoletis chlorideae* Uchida. This is the first record of occurrence of *C. chlorideae* attacking TFW in Taiwan.

Total and marketable yield in the trap-cropped plot were higher and damaged fruit lower than in the monocropped tomato (Table 71). It must be mentioned that during each of the four insect-damage observations, which were done when fruits were still green, pest-damaged fruit from both treatments were discarded promptly. This explains why at harvest, when only mature marketable size fruit were picked, damaged fruit was minimal.

Results of this preliminary field experiment point out the potential for using *S. viarum* as a trap crop to control TFW on tomato. It is, however, necessary to manipulate planting of *S. viarum* to further reduce pest damage and minimize the land needed for *S. viarum*. This work will be pursued in 1999–2000. Leaves of *S. viarum* seem to contain chemicals that attract TFW females to lay eggs. Identification and synthesis of these chemicals could lead to their production and use in continuous trapping of TFW females.

Contact: N S Talekar

Effect of barrier nets in the control of diamondback moth on cabbage

Diamondback moth (DBM), *Plutella xylostella* (L.), is a serious pest of all crucifer vegetables. In cooler highlands, our research emphasizes introduction of the parasitoid *Diadegma semiclausum*. Although a larval parasitoid, *Cotesia plutellae*, is prevalent in the warmer lowlands of most countries, this and other natural predators of DBM are inadvertently killed off by pesticides.

Vegetable production is gradually moving under protective structures, such as large screen cages, plastic tunnels, and greenhouses. Such structures protect vegetables from direct damage by rain and help to reduce damage by most insect pests. Despite this, farmers still use chemical insecticides to combat crucifer insect pests inside these structures. Therefore, we have begun to study the pests likely to become problematic in protected cultivation systems, their seasonality, whether field control methods can be transferred directly to protected cultivation or will require modification, and whether good maintenance of structures alone will be enough to combat DBM. In spring 1999, in the first of a series of planned experiments, we monitored the incidence of DBM inside one such structure.

We ploughed a 20-m-wide, 66-m-long parcel of land, applied basal fertilizer, and formed 1.5-m-wide, 20-m-long raised beds. About 5–6 m from this parcel, parallel to its length, a 3-m strip was worked into two 1.5-m-wide raised beds. One-month-old, greenhouse-raised common cabbage seedlings were transplanted on these beds 4 weeks ahead of transplanting the main cabbage crop in the main experimental area. One month after transplanting the cabbage in the 3-m-wide area, field-collected DBM adults were released on these plants, which were to serve as a source of DBM for the experimental area.

One month after transplanting the DBM source rows, the 66 × 20 m parcel was divided into three 20 × 20 m blocks with an empty distance of 3 m between adjacent blocks. One parcel at one end was enclosed on all four sides with a 2-m-high, 16-mesh nylon net structure. A 40-cm flap of net at the top of the structure was flexed outward and downwards at an angle of 85 degrees vertical to the net wall. The 20 × 20 m plot at the other end of the parcel was enclosed with 2-m-high, 16-mesh nylon net, and the top was closed with 16-mesh net. The middle 20 × 20 m plot was maintained as an open field check.

One-month-old, DBM-free common cabbage seedlings were transplanted in two parallel rows on the top of each 1.5-m-wide bed in all three blocks. The crop was cultivated by traditional cultural practices, such as weeding, irrigation, fertilizer application, disease control practices, etc. However, no insecticide was used. The integrity of the nylon net was maintained with timely repair.

Starting 4 weeks after transplanting of the experimental cabbage crop, and once each week thereafter, we observed 50 plants, selected at random, and recorded the number of DBM larvae feeding on each plant in each of the three plots. We brought 30 big larvae from each plot to the laboratory and raised the insects until pupation, at which time we recorded the number of DBM and parasitoid (*Cotesia plutellae*) pupae developing from these larvae, and calculated the percent larvae parasitized in each of three plots. At harvest we recorded the number of harvestable cabbage heads, weight of each head, and total yield.

The results are summarized in Table 72. In the check plot, as well as the open-top barrier plot, the DBM infestation increased very rapidly soon after transplanting, reaching a peak of more than 80 larvae per plant in the open plot and more than 71 larvae per plant in the open top barrier plot in the seventh week after transplanting. Pest populations declined gradually thereafter, reaching less than 1 larva per plant at harvest. This decline was likely due to high parasitism of DBM larvae by *C. plutellae* and possibly heavy pest damage during the first two-thirds of the season, leaving little new growth for DBM to feed on, thus rendering cabbage unacceptable for fresh DBM infestation.

In all previous tests, whether open field or open-top plots, the damage always started at the side closest to the insect source rows. This indicates that adult pests are flying to the net and some are successful in hopping from the net into the plot and thus initiating infestation. Migration of insects from other locations and landing directly in the middle of the planted area cannot be ruled out, but its contribution to total infestation cannot be substantial, especially early in the season, as was evidenced in the completely enclosed plot (see discussion below).

In the completely enclosed plot, the crop was practically free of insects during most of the season, except just before harvest. We suspect that this late infestation was caused by a few adults that landed on the top of the net and laid eggs, which dropped on the plants. The insect population was scattered randomly on cabbage plants inside the net rather than confined to any side. We will investigate this in future tests.

Braconid parasitism of DBM was similar in the open plot and open-top plot, indicating that the open-top net barrier did not prevent movement of *C. plutellae*. We suspect that, like DBM, *C. plutellae* are landing on the net and hopping inside the plot. This assertion is supported by the absence of parasitism in the totally enclosed plots, which did become infested with DBM, albeit to a minor degree. Parasitoid adults probably landed on the side nets, but could not enter because of the top net. That said, it is important to find out how the DBM adults manage to break into the fully enclosed plots. Once the mode of infestation is understood, we can devise countermeasures. This will be researched in 2000.

DBM reduced cabbage yield by 50% and 27% in the open field plot and open-top barrier plot, respectively, compared to the completely enclosed plot, where infestation just before harvest seemed not to affect yield. Reduction in biomass (head weight) was the major contributing factor to yield reduction, indicating that DBM feeding on cabbage is responsible for yield reduction.

Growing cabbage under complete net enclosures (tunnels) is one way to reduce DBM damage. However, towards the end of the season, DBM infestation becomes detectable. This infestation does not affect the yield or quality of the produce in that

Table 72. *Influence of various protective structures on the infestation of cabbage by DBM and the parasitism of DBM, spring 1999, AVRDC*

Observation dates[1]	Open field check		Open-top net barrier		Enclosed-top net barrier	
	DBM larvae/ plant	Parasitism (%)	DBM larvae/ plant	Parasitism (%)	DBM larvae/ plant	Parasitism (%)
02 Mar. 1999	4.64	-[2]	3.40	-	0.2	-
11 Mar. 1999	17.08	-	13.48	-	0.04	-
18 Mar. 1999	40.50	8.3	19.62	13.5	0.22	0
23 Mar. 1999	80.92	23.8	71.58	33.6	0.26	0
30 Mar. 1999	18.70	56.0	40.40	59.0	0.60	0
6 April 1999	8.48	42.0	9.68	69.0	2.2	0
15 April 1999	0.62	0	0.66	0	3.4	0
Harvest 15 April						
Head weight	1.51 kg		1.72 kg		2.24 kg	
Yield	28.6 t/ha		40.5 t/ha		55.0 t/ha	

[1] Transplanting date: 1 February 1999.

[2] Data not recorded.

season, but yield and quality in subsequent seasons could be seriously affected, because with such investment in construction, farmers are likely to grow crucifer after crucifer. Further work is necessary to understand the mode of entry of DBM inside adult-proof net structures before we can devise a method to prevent such infestation.

Contact: N S Talekar

Control of beet armyworm on onion and chili pepper

The beet armyworm (BAW), *Spodoptera exigua* (Hübner), feeds on a wide range of economically important crops, such as onion, shallot, chili pepper, tomato, soybean, mungbean, cotton, and others. And infestation is increasing rapidly in Asia. This is thought to be due to the widespread and indiscriminate use of insecticides. BAW has developed high levels of resistance to insecticides and further use of chemicals will only exacerbate the problem, add to the cost of production, and contribute to environmental degradation. Insecticides have targeted BAW larvae, but it is as adults that the pest spreads. So, in the past two years AVRDC looked closely at the flying habit of BAW adults, and found that more than 95% of BAW adult females fly no higher than 2 m above the soil. This knowledge was used to devise control measures for onion and chili pepper at AVRDC's Asian Regional Center, Kasetsart University, Khampaengsaen campus, Thailand.

A 66 × 20 m area was ploughed, fertilized (187.5 kg/ha N15-P15-K15 basal fertilizer), and divided into three 20 × 20 m blocks, with 3 m between adjacent blocks. The two end blocks were enclosed in 2.2-m-high, 16-mesh nylon net barriers. The top of the enclosures were ringed by a 30-cm-wide flap of net that hung at a 70–75° angle to the vertical to form an additional physical barrier to insect entry. The center block was maintained as a check. The land inside each block was worked into 22, 8 × 1 m flat beds. In each block, five beds were planted to onion cultivar Granex 429, five were planted to onion cultivar Granex 33, and 12 beds were planted to chili pepper cultivar CA365. One-month-old seedlings of both crops were transplanted on 18 November 1998. The onions were spaced 15 cm between rows and 10 cm between plants in each row. The chili pepper plants were spaced 80 cm between rows and 40 cm between plants in each row. On the net of one block, we sprayed methamidophos, cypermethrin, or abamectin in rotation once a week. The net was checked daily for holes or gaps through which BAW of other insects might enter. The crops were grown using routine cultural practices, such as hand weeding, irrigation, and fertilization.

Table 73. *Effect of net[1] barriers on the infestation of onion by beet armyworm, AVRDC-ARC, 1999*

Observation dates	Barrier net only		Barrier net + insecticide[2]		Open field check	
	Infested plants[3]	No. of larvae	Infested plants	No. of larvae	Infested plants	No. of larvae
4 Dec 1998	0	0	0	0	0	0
14 Dec 1998	0	0	0	0	0	0
21 Dec 1998	0	0	0	0	2	2
28 Dec 1998	0	0	0	0	2	2
4 Jan 1999	1	1	1	1	1	1
9 Jan 1999	3	4	0	0	6	13
18 Jan 1999	0	0	5	6	13	15
25 Jan 1999	1	1	3	3	6	7
1 Feb 1999	3	4	1	1	13	66
8 Feb 1999	5	6	5	10	17	25
Total	13	16	15	21	60	131

[1] Mesh size 16.
[2] Insecticides were sprayed on nylon net, not on plants.
[3] 240 plants observed at each interval. Transplanting date: 18 Nov 1998. Harvest date: 16 Feb 1999.

Starting 15 days after transplanting, we took weekly random samples of 240 onion plants and 100 chili pepper plants from each block. We recorded the number of BAW-damaged plants and the number of pest larvae on each plant (Tables 73 and 74). At harvest, weights of marketable bulbs and pods were recorded. The larval populations and number of damaged plants were low in both nylon net treatments compared to the check.

BAW damage to onion in the open plot began within 5 weeks of transplantation, and in the barrier net plots within 7 weeks. The pest population and damage in the open plot were high until harvest, but in the barrier plots, pest populations remained low. Net alone (no spray) produced the highest yield (56.1 t/ha) of Granex 429, while the sprayed-net plot yielded 43.0 t/ha, lower than the open check (49.1 t/ha). This inconsistency might be due to low pest infestation during the first 8 weeks after transplanting, by which time the bulbs had already started to enlarge.

BAW infestation on chili pepper began within one month after transplanting. Infestation was low in the barrier plots compared to the open check, and the damage would not warrant use of pesticide.

It was observed, however, that the pepper suffered more BAW damage than the onion, especially early in the growing season, which suggests that BAW in Thailand prefers chili pepper over onion. As the chili pepper plants matured, perhaps they became less attractive to the BAW, and the larvae moved to the onions.

Towards the end of the growing season, which coincided with the cool-dry period, cotton aphid (*Aphis gossypii*) infestation of chili pepper became very serious in the open field and barrier plots. Anthracnose and tomato spotted wilt virus also took a heavy toll on the chili pepper, resulting in a high proportion of non-marketable yield. In the sprayed-net plot, aphid damage was low and the pod yield was highest, 10.9 t/ha compared to 2.6 t/ha from the non-sprayed net barrier and 3.4 t/ha from the open check. All of this said, barrier plots were about equal in reducing BAW infestation.

A 2.2-m-high, 16-mesh net barrier around newly planted onion and chili pepper can control BAW infestation. Further research is needed to make the technique economically practical. The net barrier sprayed with insecticide, which appeared to control aphids on chili pepper, will be tested in 1999–2000 to confirm the findings.

Contact: N S Talekar

Studies on host-plant interaction and cultural control of onion thrips

Onion thrips, *Thrips tabaci* Lindemann, is an endemic pest of onions, especially bulb onions, *Allium cepa*, in most of the tropics and subtropics.

Table 74. *Effect of net[1] barriers on the infestation of chili pepper by beet arrmyworm, AVRDC-ARC 1999*

Observation dates	Barrier net only		Barrier net + insecticide[2]		Open field check	
	Infested plants[3]	No. of larvae	Infested plants	No. of larvae	Infested plants	No. of larvae
3 Dec 1998	0	0	0	0	0	0
13 Dec 1998	3	6	2	3	10	19
20 Dec 1998	0	0	1	2	0	18
27 Dec 1998	1	1	1	5	16	29
3 Jan 1999	1	2	4	8	11	14
8 Jan 1999	3	4	3	3	3	3
17 Jan 1999	0	1	2	2	2	2
24 Jan 1999	0	0	0	0	0	9
31 Jan 1999	0	0	2	3	0	0
7 Feb 1999	0	0	0	0	0	0
Total	8	14	15	26	42	94

[1] Mesh size 16.
[2] Insecticides were sprayed on nylon net, not on plants.
[3] 100 plants observed at each weekly interval. Transplanting date: 18 Nov 1998. Harvest date: 20 Feb 1999.

The adults and larvae scrape the onion leaf surface and feed on the plant sap. The damage reduces photosynthesis and, as a result, bulb yield. Not surprisingly, thrips can drastically reduce the market value of onions grown for their leaves. The literature and AVRDC's own experience suggest that the chances are slim of breeding an onion adequately resistant to onion thrips. For this reason, we decided to study the interaction between onion thrips and the onion plant with a view to finding a weakness that can be exploited to develop simple, economical thrips control measures. In a series of experiments in autumn-winter 1998-99, we set out to learn what onion growth stage is most vulnerable to thrips attack.

Influence of plant age on onion thrips infestation

Onions were transplanted once a week from 9 November 1998 to 2 March 1999 and thrips damage was monitored weekly. A parcel of land was rotor-tilled and worked into 0.75-m-wide raised beds, which were divided into 3 × 3.3 m plots spaced 1.5 m apart (four beds per 3-m-wide plot). Six-week-old onion (CL606) (greenhouse-raised) seedlings were transplanted in three randomly selected plots. Seedlings were transplanted in a single row (plant to plant distance of 10 cm) on the top of each bed in each plot. The crop was raised using regular cultural practices, such as hand weeding, irrigation, and fertilization. Starting 2 weeks after transplantation, we observed four, 1-m rows in each plot. Foliage damage was recorded on a scale of 0 to 5, where 0 = no damage, 1 = 20% leaf area affected, 2 = 40% leaf area affected, 3 = 60% leaf area affected, 4 = 80% leaf area affected, and 5 = entire leaf area affected.

Results of the weekly monitoring of onion thrips damage to onions planted every week from 9 November to 2 March are summarized in Figures 8 and 11. The weekly damage observations for the three earliest plantings are summarized in Figure 8. Insect damage was not detectable for up to 7 weeks after transplanting. Pest damage increased gradually thereafter but became exponential from weeks 12 to 16. There was highly significant correlation between plant age and onion thrips damage (Figure 9). The older the plant, especially after 12 weeks, the greater the damage.

Abiotic factors, such as temperature, humidity, rainfall, pest population, rather than plant age alone, could have been contributing factors related to thrips

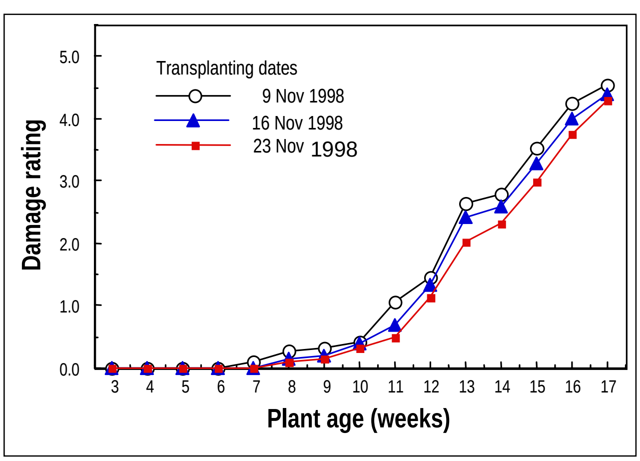

Figure 8. *Influence of plant age on infestation of onion by onion thrips. Weekly observations throughout the season.*

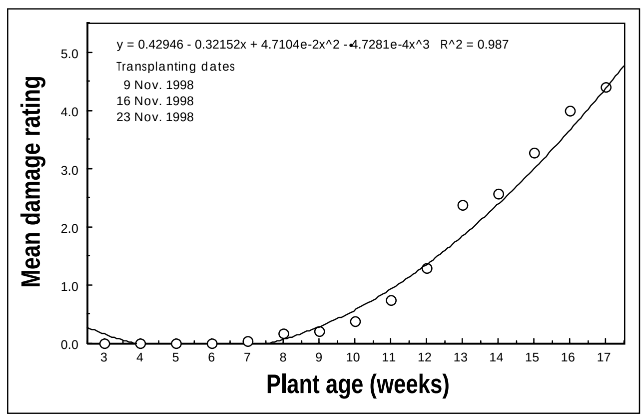

Figure 9. *Correlation between plant age and thrips damage.*

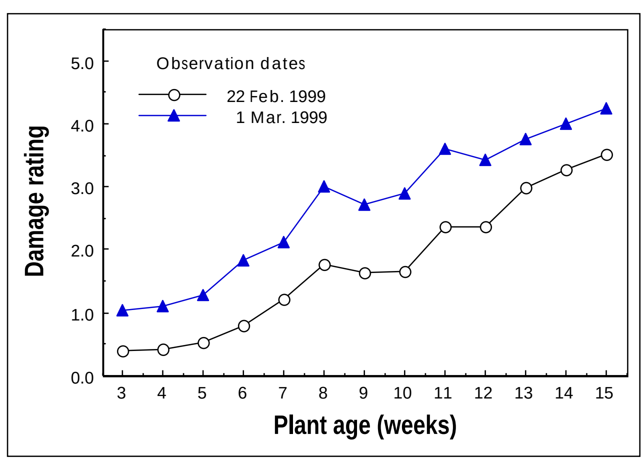

Figure 10. *Thrips damage to onion plants. Observations taken only twice, late in the season when plants of all ages were present.*

damage. Therefore, we analyzed insect damage observations made on fixed dates towards the end of the season, when plants of various ages were standing in the field and were subjected to the same level of ambient pest population, thus negating any environmental effect. Again we found a distinct trend: older plants suffered far more damage than younger plants (Figures 10 and 11). Thrips damage seems to critically increase 10–11 weeks after transplanting. Based on this preliminary observation, insecticides are unnecessary at least up to 10 weeks after onion transplanting (this time span might vary from location to location, depending upon temperature, photoperiod, and crop variety). In general, producers can wait until bulbs begin to enlarge before resorting to control measures, especially chemicals.

Dry matter partitioning in bulb and shoot and its effect on onion thrips infestation

Two 20 × 15 m plots, 1.5 m apart, were prepared and 6-week-old onion (CAL606) seedlings were transplanted on the top of each 0.75-m-wide, 20-m-long bed in both plots. The plots were near the above-mentioned weekly transplanting experiment. Starting 6 weeks after transplanting, and once a week thereafter, we sprayed plants in one plot with profenofos, carbosulfan, or imidacloprid, in rotation. The other plot was maintained as an untreated check. Starting 2 weeks after transplanting and once a week thereafter, we uprooted 4 batches of 10 randomly selected plants each, from each plot. The fibrous roots were discarded and the remaining plant was cut at the root-shoot junction. Ten bulbs and 10 shoots of each batch were weighed and fresh weight was recorded. The plant parts were dried at 100°C for 24 hours. (The enlarged bulbs were cut into 0.5–1-cm slices before drying.) We then recorded the dry weight of both bulb and shoot.

Dry matter accumulation in the bulb takes off from 12 weeks after transplanting onwards and remains high until harvest (Figure 12). This dry matter accumulation coincides with the observed acceleration in onion thrips infestation of the shoot. It is tempting to theorize that during vegetative growth, certain chemicals in the shoot keep the onion plant healthy. As bulb enlargement begins, these chemicals move from the leaves into the bulbs, making the onion shoots vulnerable to onion thrips damage at a critical time when photosynthate is needed in the enlarging bulb. And it is remotely possible that certain chemicals that attract thrips or accelerate thrips reproduction are produced in the foliage during bulb enlargement. We estimate that the variety we used in this study suffered a 30–35% reduction in yield.

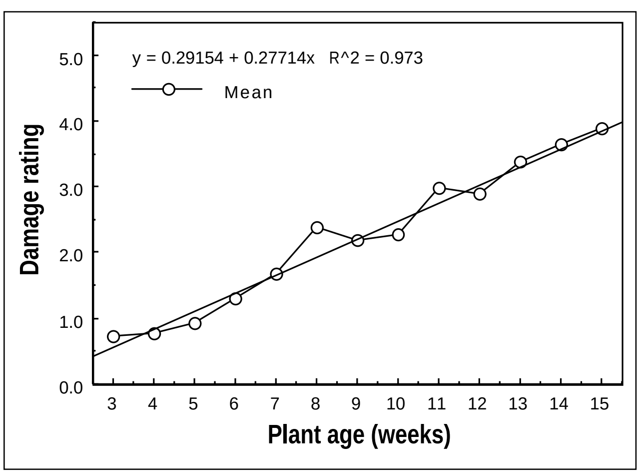

Figure 11. *Correlation between plant age and thrips damage. Observations made only twice, in consecutive weeks, when thrips damage was the highest and plant of various ages were present.*

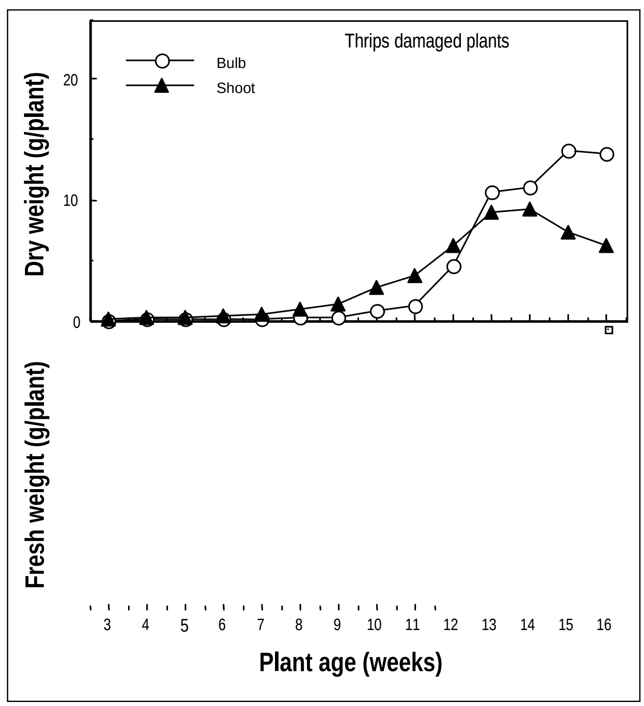

Figure 12. *Accumulation of dry matter in onion shoot and bulb throughout the season in insect-damaged and healthy plants.*

Influence of irrigation methods on infestation by onion thrips

Because rain can reduce pest populations, we tried using sprinkler irrigation to reduce populations of onion thrips. A 50 × 40 m area was rotor-tilled and worked into 0.75-m-wide beds that were further divided into 12, 10 × 10 m plots. The plots were transplanted with 6-week-old onion seedlings. Rotating, perforated pipes were installed 1.5 m above the soil, directly over four randomly selected plots. A drip irrigation system was placed directly on the soil surface in four randomly selected plots. In the remaining four plots, water was dispensed by traditional gravity irrigation. Starting four weeks after transplanting, equal amounts of water were dispensed daily for 10 minutes through the sprinkler and drip irrigation systems. Apart from the irrigation treatments, routine cultural practices were followed, including hand weeding and fertilization. No insecticide was used. When onion thrips damage became evident, we began observing all plants in six, 1-m-long sections in each plot and recorded feeding damage on a 0–5 scale as described previously. At harvest we recorded yield of all bulbs harvested from each plot.

The results of the irrigation study are summarized in Table 75. Our past studies have indicated that keeping soil moist throughout the season, especially during bulb enlargement, reduces severity of onion thrips infestation. In this study we sought to reduce the damage further by using sprinkler irrigation. This was based on the observation that during the rainy season thrips are not a problem, possibly because the insects are washed off or drowned in the leaf cavity where they feed. However, in our study, sprinkler irrigation was no more effective than drip irrigation in controlling thrips. This suggests that siol moisture, rather than physical wash off of the insects, is more important.

Onion thrips prefer older plants and infestation is critical during the bulb enlargement stage. It is in this period, therefore, that it is important to initiate suitable control measures. Keeping soil moist during the bulb enlargement stage helps to reduce onion thrips damage.

Contact: N S Talekar

Grafting cherry tomato on eggplant rootstock to control soil-borne diseases—effect on yield and fruit quality

In order to produce tomatoes year round, growers in the lowland tropics use plastic shelters, net houses, and other simple structures to protect their crops from heat, heavy rain, and insect attack. But farmers tend to cultivate tomato, and other high value horticultural crops, continuously under these structures, which often leads to an increase in disease. Important soil-borne diseases of tomato in the tropics include bacterial wilt (BW) caused by *Ralstonia solanacearum*, fusarium wilt (FW) caused by *Fusarium oxysporum* f sp *lycopersici* (Fol) and root knot nematodes (RN) caused by *Meloidogyne incognita*. In 1998, we demonstrated that grafting tomato on eggplant or tomato rootstocks with stable BW resistance can control BW. Fruit quality of table tomatoes is not affected, but yield potential can vary depending on the scion/rootstock combination used. No work was done on cherry tomatoes (fresh market types with fruit size less than 30 g).

Cherry tomatoes hold good potential for home garden and year-round production systems in lowland tropics, but the popular cultivars lack resistance to soil-borne diseases. So, this study was done to evaluate the FW and RN resistance of cherry tomato grafted on BW resistant eggplant rootstocks, and evaluate the effect on yield and fruit quality. Because of their flood tolerance, eggplant rootstocks have wider application than tomato rootstocks.

Table 75. *Influence of different modes of irrigation on infestation of onion by onion thrips, AVRDC,1998-99*

Irrigation method	Thrips damage rating (1999) 4 March	11 March	18 March	Yield t/ha
Sprinkler	2.79±0.21	3.29±0.05	4.46±0.04	26.48±6.16
Drip	2.76±0.22	3.26±0.21	4.39±0.15	26.43±5.15
Flood	3.73±0.32	4.59±0.11	4.99±0.02	21.33±1.47
LSD (5%)	0.35	0.18	0.14	5.18

Transplanting date: 26 Nov 1998. Harvest date: 23 March 1999. Plot size: 10 × 10 m. Variety: CAL606.

Three BW resistant eggplant lines (EG190, EG203, and EG219) were evaluated in the greenhouse for their reactions to FW and RN. Reaction to FW was determined by trimming roots of 2-week-old seedlings, immersing the roots in a slurry of Fol cultures for 3–5 min, and replanting inoculated seedlings. Strains of race 1 and race 2 of Fol were inoculated, respectively. Reactions were rated 3 weeks after inoculation. For RN evaluation, one-month-old seedlings were inoculated with 500 secondary juveniles of *M. incognita* per seedling. Galling index was scored 45 days after inoculation. To confirm BW resistance on grafted cherry tomato, two field trials were conducted, in autumn 1998 and summer 1999. The cherry tomato cultivars used as scions were Santa (an indeterminant hybrid cultivar from Known-You Seed Co.) and ASVEG #6 (a semi-determinant AVRDC inbred line). EG190, EG203, and EG219 were used as rootstocks. A split-plot, random complete block design (RCBD) was used with 'scion' as the main factor and 'rootstock' as subfactor. There were two replications, with 32 plants per replication. Plots were 3.6 × 4 m, rows were 90 cm apart, and plants were 50 cm apart within the row. The plants received 220-160-200 kg/ha of N-P-K. Incidence of BW was recorded weekly. Yield was based on six harvests. Fruit collected from the first three harvests were used for quality analyses as three measurements. The quality traits measured were fruit weight, brix, pH, acidity, and vitamin C content. Another field trial, transplanted on 4 September 1998, was conducted in an RN disease nursery located at the Tainan District Agricultural Improvement Station, Taiwan. Only ASVEG#6 was used as scion. The experiment design was RCBD with three replications and 40 plants per replication. Plots were 1.5 × 24 m, spacing between rows was 1.5 m, and spacing within rows was 60 cm. Nine t/ha of compost and 200 kg/ha of N-P-K were applied. Yield was calculated based on five harvests. Galling index was rated at the end of the trial based on a scale of 0 to 4 (0 = 0%, 1 = 1–15%, 2 = 16–30%, 3 = 31–50%, 4 = 51–100% of root surface covered by root knot). Fruit quality traits measured were the same as in the BW trials, except for pH and vitamin C content.

Eggplant lines EG190, EG203, and EG219 were found to be resistant to race 1 and race 2 of Fol (no symptoms of FW were observed), while tomato cultivars ASVEG#6 and Santa were resistant to race 1 and susceptible to race 2. The eggplant lines' resistance to Fol was expected, as the pathogen is highly specific to host crops. This resistance should be very stable and it is not necessary to confirm it in the field. The three eggplant lines were also resistant to RN. EG203 and EG219 had galling indexes of 0, while EG190 had a galling index of 1.6 (less than 16% of root surface was covered by root knot). Field evaluations were conducted to confirm resistance to BW and RN. Under high disease pressure in summer, grafting cherry tomato on eggplant significantly reduced wilting incidence and increased yield (Table 76). In autumn, when disease pressure was lower due to the lower temperatures, grafting reduced

Table 76. *Effect of grafting cherry tomato on eggplant rootstock, with regard to incidence of bacterial wilt, yield, and fruit quality in two field trials*[1]

Scion	Rootstock	Summer		Autumn				
		Wilt (%)	Yield[3] (t/ha)	Wilt (%)	Yield (t/ha)	Brix°	Acid (% citrate)	Vitamin C (mg/100 g)
ASVEG #6	EG190	31.8 * [2]	14.2 *	12.5	61.6	7.93 *	0.39 *	37 *
	EG203	29.0 *	19.0 *	6.3	72.2	7.82 *	0.38	37 *
	EG219	23.7 *	17.5 *	2.1	58.7	8.02 *	0.40 *	38 *
	Nongrafted	100.0	0.0	17.2	52.4	7.12	0.37	34
Santa	EG190	55.0 *	3.2	4.7	54.7	8.02 *	0.36	36 *
	EG203	38.8 *	3.4	3.2	66.6	7.63	0.36	34
	EG219	34.7 *	4.4 *	11.0	58.7	7.93 *	0.37	36 *
	Nongrafted	100.0	0.0	15.6	64.0	7.13	0.36	33

[1] Both trials were conducted in a disease nursery of bacterial wilt. The summer trial was transplanted on 2 June 1999 and the winter trial on 12 Oct 1998.
[2] Significant difference between each grafting treatment and nongrafted control of the same scion is indicated by * based on LSD at 0.05 level.
[3] Yield was calculated based on six harvests from 7 Jan to 31 Mar 1999 for the autumn trial and from 4 Aug to 13 Oct 1999 for the summer trial.

wilting, but not significantly, and produced similar yield. The fruit produced from grafted plants had similar fruit weight and pH, but higher brix, acidity, and vitamin C content compared with fruit from non-grafted plants. Grafting reduced the RN severity significantly. Galling was rated on 18 January 1999. Tomatoes grafted on EG190, EG203, and EG219 had galling indexes of 0.7, 0.8, and 1.2, respectively, while non-grafted ASVEG#6 rated 4.0. Plants grafted with EG203 (10.8 t/ha) and EG219 (10.4 t/ha) produced significantly higher yield than the control (7.2 t/ha). Among the quality traits evaluated, significant difference was only observed in the value of brix. The grafted plants produced higher-brix fruits, 6.9–7.1 compared to 6.5 for the control.

In conclusion, EG190, EG203, and EG219 are resistant to BW, FW, and RN. Grafting cherry tomato onto these rootstocks could control BW and RN in the field and result in yield increase, particularly under high disease pressure. Grafted plants produced similar or better quality fruit compared to the nongrafted control.

Contact: J F Wang and L L Black

Identification and management of viral diseases of vegetables

The main objective of this activity is to obtain information on the presence, distribution, and importance of known or new viruses in AVRDC target crops in Taiwan and other countries in the region. Knowledge of the effect of these viruses on yield and/or quality is an important aspect for devising control strategies.

Survey of viruses infecting peppers and tomato in Xian Province, China

Leaf samples were collected in farmers' fields from plants showing symptoms typical of virus infection, such as mosaic, mottle, veinclearing, veinbanding, and leaf deformation.

The pepper samples were from young seedlings (about five-leaf stage) as well as from mature plants, whereas tomato samples were from only mature, fruiting plants. One set was directly squashed onto nitrocellulose membranes for testing by indirect enzyme-linked immunosorbent assay (ELISA), another set was dried and later subjected to immunosorbent electron microscopy (ISEM).

The results of the virus surveys are shown in Table 77. Seventy percent of the pepper seedling samples were positive for broad bean wilt virus strain 2 (BBWV-2), and 39% were positive for cucumber mosaic virus (CMV). ISEM tests indicated the presence of two strains of CMV. In young pepper seedlings, tobacco mosaic virus (TMV), pepper mild mottle virus (PMMV), potato virus Y (PVY), and chili veinal mottle virus (ChiVMV) were not detected. In mature pepper plants, however, infection with PMMV was most serious, with 69% of samples giving a positive reaction. BBWV, CMV, ToMV

Table 77. *Virus survey of peppers and tomato in Xian (near Baoji City), China*

Host	No. samples collected	Positive samples collected (%)										
		Indirect ELISA[1]						ISEM + DEK[2]				
		TMV	ToMV	PMMV	PVY	ChiVMV	BBWV	CMV	CMV 1298[3]	CMV TW[4]	BBWV-2	TAV
Tomato	16	0	0	NT[5]	0	NT	NT	NT	25	38	0	60
Pepper a) [6]	23	0	NT	0	0	0	NT	NT	30	39	70	NT
b)	36	28	31	69	22	14	56	33	NT	NT	NT	NT
Bean	3	NT	NT	NT	NT	NT	NT	NT	32	32	0	NT
Weed	1	0	0	0	0	0	NT	NT	0	0	100	NT

[1] Indirect ELISA was conducted on nitrocellulose membranes.
[2] ISEM + DEK = immunosorbent electron microscopic examination: trapping of virus particles with virus specific antiserum (15 hours), followed by decoration with the same antiserum at 1:50 dilution (2 hours).
[3] 1298 = antiserum against CMV isolate 1298, a broad spectrum antiserum made against a CMV from *Alstromeria* sp.
[4] TW = antiserum against CMV isolate 522 from Taiwan.
[5] NT = not tested.
[6] a) samples taken at seedling stage; b) samples taken at maturity.

(Tomato Mosaic Virus), TMV, PVY, and ChiVMV followed with 56, 33, 31, 28, 22, and 14% positives, respectively. BBWV was also detected in an unidentified weed sample. The high percentage of BBWV-infected seedlings suggests that this virus is seed transmitted. To test this, seeds of eight popular pepper lines, collected from farmers' fields, were tested for seed-transmitted BBWV. Twenty seeds (3 × 20 seeds of each line) were placed in 1 ml of phosphate buffer and shaken for 2 days; the buffer and seeds were ground in 2 ml of additional buffer, then tested by DAS (double antibody sandwich) ELISA. There was no evidence of seed transmission.

Tomato was found infected with CMV and tomato aspermy virus (TAV). The latter is most likely a new virus recorded for China, but the find is not surprising given that the virus's major host, chrysanthemums, are widely grown in China.

Detection of tobamoviruses on pepper seeds from Vietnam

Four seedlots of chili produced by local farmers were tested for tobamoviruses. Of each seedlot, four batches of 25 seeds each were tested for seed-coat-borne (external) and embryo borne (internal) tobamoviruses. Each seed batch was shaken overnight in 2 ml of phosphate buffered saline (PBS), pH 7.4 (with 2% PVP and 0.05% Tween 20 added). After removal of the PBS buffer (seed wash), the seeds were thoroughly rinsed in sterile distilled water, before they were homogenized in 2 ml of new PBS. The seed washes and the seed homogenates were tested separately for ToMV, TMV, and PMMV by DAS ELISA. Small amounts of the seed washes and seed homogenates were also used for the inoculation of *N. glutinosa*. The development of local lesions on this host indicated the presence of infectious tobamovirus. ToMV was detected by ELISA on the seed coats of all four pepper lines; it was, however, not infectious, as evidenced by the absence of local lesions on *N. glutinosa*. All seedlots were also contaminated internally with infectious ToMV and PMMV. The PMMV was isolated and found to belong to pathotypes 0 and 1.2. The former was characterized by local lesions formed on *C. frutescens* Tabasco, *C. annuum* Tisana, *C. baccatum*, *C. chinense*, and *C. chacoense*, whereas pathotype 1.2 was characterized by mosaic on *C. annuum* Tisana, *C. frutescens* Tabasco, and *C. baccatum*, and local lesions on *C. chinense* and *C. chacoense*.

Knowledge of the types of tobamoviruses and their strains should become the basis for incorporating resistance into the chili landraces.

Contact: S K Green

Project 6. Economic and human nutritional impacts from enhanced peri-urban vegetable production

The objective of Project 6 is to develop information to enhance the understanding of researchers and policymakers about the socioeconomic and nutritional impacts of vegetables. Methodologies are developed to assess the potential contribution of vegetables in the nutritional and socioeconomic development of producers and consumers, and to conduct ex-ante and ex-post impact evaluation of vegetables and AVRDC technologies.

Nutrient content of the Center's principal crops is being analyzed to develop a comparative database, and food preparation methodologies are being developed that will enhance micronutrient availability.

Socioeconomics

During 1999, the socioeconomics unit at AVRDC concentrated on quantifying and ranking the dollar value of policy interventions in different food commodities in Taiwan, and on characterizing vegetable production in northern Vietnam.

The results suggest that the net nutritive gains from policy designed to reduce food prices are highest in vegetables. Among vegetables, only root and leafy vegetables give net positive nutrient gains from such policy interventions. The demand elasticity of calcium, one of the major micronutrients deficient in the Taiwanese diet, is highest from leafy vegetables, even higher than from milk and fish. This suggests that technological breakthroughs that reduce leafy vegetable prices could improve the nutritive value of the whole diet and help alleviate calcium deficiency in Taiwan.

Vegetable production characterization in northern Vietnam suggests that the main constraint to the expansion of vegetable production is the high labor requirement for marketing, and the marketing risk reflected in the uncertainty in vegetable prices. Vegetable research in northern Vietnam should focus on finding ways to improve marketing efficiency, expansion of vegetable production in the summer season, and reduction in labor and fertilizer costs.

Valuating the net nutritive gains of policy intervention in Taiwan

The new definition of food security emphasizes balanced diets, rather than simply meeting energy-protein requirements. In developed countries, such as Taiwan, concern over balanced diets stems from the health risks associated with excessive intake of saturated fat and cholesterol, which leads to heart attacks. In Taiwan, low consumption of certain nutrients is also a concern. Lack of calcium here, for instance, hinders bone development.

Nutrient demand elasticities can help predict effect of policy as it relates to different commodities. However, while the nutrient demand elasticities have been estimated, the dollar values of policy intervention are unknown. This study quantifies and ranks the nutritive gains resulting from changes in policy, in order that policy makers, researchers, and nutritionists will have a tool to evaluate their actions.

To estimate the value of nutritive gains of a policy in dollar terms, the nutrient cost of every nutrient *k* is first estimated as follows:

Nutrient cost of the *k*th nutrient

$$(R_k) = \sum_{i=1}^{n-z} E_i \Big/ \sum_{i=1}^{n-z} C_{ki} \qquad (1)$$

where C_{ki} is the amount of nutrient *k* (*1, 2,…, m*) provided from the consumption of commodity *I*; E_i is the expenditure by a consumer on commodity *i*; *n* is the number of all commodities present in the diet; and *z* is the number of those commodities that do not contain the *k*th nutrient.

The nutrient benefit or loss of a policy (*Vi*) can be estimated by multiplying the change in the level of nutrient quantities induced by policy with the nutrient cost. The change in the level of nutrient quantities with policy intervention are determined by multiplying the nutrient elasticities with average nutrients at the pre-policy level.

Policy results in direct costs or benefits to consumers (here cost to the exchequer is not included), because consumers alter their food budgets in response to price changes. These changes in budget due to policy intervention in the *i*th commodity (C_i) can be estimated by multiplying the changes in the quantities of different commodities consumed with the pre-policy market prices (except the *i*th commodity where the post policy price can be used). Changes in consumption resulting from a 1% change in price through policy intervention can be estimated by multiplying the demand elasticities with the respective average quantities consumed at the pre-policy level.

The net nutritive gains or loss of a policy is estimated as follows:

Net nutritive gains of a policy

$$\text{for commodity } i\ (G_i) = V_i - C_i \qquad (2)$$

A two-stage budgeting procedure is used (assuming that the consumer’s utility maximization decision can be decomposed into two separate stages) to estimate demand elasticities, which are critical in estimating net nutritive gains from policy. In the first stage, total expenditure is allocated over broad groups of goods; and in the second stage, group expenditures are allocated over individual commodities. A linear expenditures system (LES) was chosen to estimate demand elasticities for broader food groups, while an almost ideal demand system was used to estimate elasticities for individual commodities in each group.

In the first stage, food was divided into seven groups: cereals, eggs and milk, fruits, meat, seafood, vegetables, and others. The nonlinear seemingly unrelated regression method in Shazame version 8.0 was used to estimate the LES for these food groups.

In the second stage, the following commodities within each group were segregated based on number of observations: rice and others; eggs and milk; apple, banana, mango, melon, and orange; pork, chicken, beef, duck, and goose; fish, shrimp and crab, clams, and squid; and leafy, fruit, and root vegetables, and other vegetables, which mainly includes alliums and mushroom. The second stage was estimated using an iterative seemingly unrelated regression method.

The elasticities of 12 nutrients were estimated: energy, protein, fat, carbohydrate, calcium, phosphorus, iron, vitamin A, vitamin B1, vitamin B2, niacin, and vitamin C. The nutrient contents were taken from tables published by the Food Industry Research and Development Institute, Pintung University of Science and Technology, Taiwan.

The consumption and price data used in this study were from the four-season household consumption surveys conducted in 1998–99 by AVRDC. The surveys covered more than 350 households each season, for a total of 1457 households in 16 townships throughout Taiwan. Quantities and prices of all foods consumed in each meal within 24 hours, along with the number of people that participated in each meal and the source of the food, were recorded on a family and per-meal basis.

A total of 324 nutrient price elasticities and 12 nutrient income elasticities were estimated. The nutrient price elasticities include both own and substitution effects of a change in a commodity price. For example, meats do not have any vitamin A, but one percentage increase in their prices will decrease vitamin A availability (by 0.047%) through decreased consumption of vegetables and fruits. Similarly, a 1% decrease in vegetable prices not only increases the consumption of vitamins but also calcium (by 0.30%) and carbohydrate (by 0.08%) (Table 78).

The income elasticities are reported at the aggregated level for all food groups. Nutrient income elasticity of demand is between 0.8 and 1.0 for most nutrients, except for carbohydrate (0.45) and calories (0.67), for which elasticities are relatively low (Table 78).

At the commodity level, the demand elasticities of most nutrients are negative for most commodities (Table 79). However, substitution effect (i.e., when consumption of a commodity is decreased, the consumption of other commodities is increased) might dominate in some cases. An example is reduction in fat consumption through decreased poultry prices, which might be preferred to a policy aimed at raising pork prices. Interestingly, demand elasticity of calcium from leafy vegetables is highest (0.136), even higher than milk (0.096) and fish (0.12) (Table 79). Therefore, technological innovation that leads to a reduction in leafy vegetable prices could mitigate calcium deficiency in Taiwan.

The cost and benefit of policy designed to reduce prices are positive in all food groups, which implies that a 1% decrease in the price of any food group will increase the amount Taiwanese consumers budget for food and increase the nutritive value of that food. However, the magnitude of nutritive cost and benefit varies across food groups. The net nutritive gains from policy that reduces food prices by 1% is highest in vegetables.

Table 78. *Nutrient demand elasticities at the food group level in Taiwan, 1998-99*

Nutrient	Cereal	Eggs and milk	Fruit	Meat	Seafood	Vegetables	Others	Income
Calories	-0.0986	-0.0716	-0.0736	-0.2214	-0.0704	-0.0983	-0.0317	0.6737
Protein	-0.0925	-0.1193	-0.0554	-0.2118	-0.2096	-0.1475	-0.0353	0.8774
Fat	-0.0847	-0.1168	-0.0489	-0.5115	-0.0740	-0.1203	-0.0323	1.0048
Carbohydrate	-0.1071	-0.0249	-0.1648	-0.0232	-0.0192	-0.0821	-0.0299	0.4519
Calcium	-0.0830	-0.2091	-0.1041	-0.0584	-0.1774	-0.2994	-0.0286	0.9631
Phosphorus	-0.0950	-0.1449	-0.0647	-0.1393	-0.1750	-0.1623	-0.0330	0.8195
Iron	-0.0810	-0.0901	-0.1027	-0.1304	-0.1212	-0.2775	-0.0286	0.8354
Vitamin A	-0.0719	-0.0250	-0.1233	-0.0469	-0.0303	-0.4896	-0.0154	0.8047
Vitamin B1	-0.0894	-0.0927	-0.1047	-0.2654	-0.0628	-0.1807	-0.0237	0.8282
Vitamin B2	-0.0839	-0.1514	-0.1145	-0.1564	-0.1153	-0.2658	-0.0281	0.9209
Niacin	-0.0907	-0.0230	-0.0831	-0.2355	-0.1950	-0.1717	-0.0253	0.8289
Vitamin C	-0.0755	-0.0087	-0.4171	-0.0468	-0.0351	-0.3542	-0.0183	0.9482

The ranking of food *groups* with respect to the dollar value of the nutritive gains of a policy can be helpful in prioritizing research. But national and international multi-commodity research centers, such as AVRDC, need detailed commodity-level estimates. Our estimates suggest that leafy and root vegetables give net positive nutritive gain. Cereals (other than rice), pork, fish and squid, milk, and all individual fruits, prominently oranges and "other" fruit, produced net positive nutritive policy gain.

Contact: M Ali

Table 79. *Nutrient elasticities of major commodities consumed in Taiwan, 1998-99*

Nutrient	Fruit vegetables	Leafy vegetables	Root vegetables	Other vegetables	Pork	Poultry meat	Other meats
Calories	-0.0134	-0.0064	-0.0048	-0.0005	-0.1522	0.0406	0.0498
Protein	-0.0112	-0.0235	-0.0049	0.0027	-0.0870	-0.0318	0.0115
Fat	-0.0175	0.0004	-0.0009	0.0001	-0.3990	0.1363	0.1396
Carbohydrate	-0.0124	-0.0083	-0.0074	-0.0029	-0.0010	-0.0005	0.0003
Calcium	0.0420	-0.1361	-0.0050	0.0260	-0.0073	-0.0017	0.0014
Phosphorus	-0.0187	-0.0288	-0.0084	0.0027	-0.0494	-0.0266	0.0085
Iron	0.0259	-0.1205	-0.0059	0.0220	-0.0509	-0.0019	0.0037
Vitamin A	0.1662	-0.3332	-0.0170	0.0857	-0.0070	0.0017	0.0024
Vitamin B1	-0.0304	-0.0304	-0.0113	0.0025	-0.1853	0.0485	0.0650
Vitamin B2	-0.0006	-0.0837	-0.0118	-0.0010	-0.0673	-0.0088	0.0147
Niacin	-0.0363	-0.0168	-0.0086	-0.0118	-0.1057	-0.0289	0.0167
Vitamin C	0.0005	-0.1477	-0.0034	0.0392	-0.0014	0.0001	0.0005

Nutrient	Fish	Shrimp and crabs	Clam	Squid	Others seafood	Mango	Apple
Calories	-0.0446	-0.0034	-0.0014	-0.0030	-0.0040	-0.0014	-0.0072
Protein	-0.1562	-0.0154	-0.0056	-0.0134	-0.0122	-0.0008	-0.0010
Fat	-0.0441	-0.0012	-0.0008	-0.0013	-0.0032	-0.0006	-0.0007
Carbohydrate	-0.0051	-0.0003	-0.0004	-0.0002	-0.0010	-0.0057	-0.0156
Calcium	-0.1159	-0.0264	-0.0087	-0.0067	-0.0059	-0.0003	-0.0057
Phosphorus	-0.1306	-0.0125	-0.0049	-0.0108	-0.0079	-0.0004	-0.0034
Iron	-0.0565	-0.0040	-0.0168	-0.0053	-0.0227	-0.0043	-0.0077
Vitamin A	-0.0072	-0.0001	-0.0004	-0.0001	-0.0005	0.0017	-0.0094
Vitamin B1	-0.0355	-0.0011	-0.0012	-0.0017	-0.0039	0.0000	-0.0052
Vitamin B2	-0.0769	-0.0024	-0.0056	-0.0044	-0.0090	-0.0019	-0.0142
Niacin	-0.1580	-0.0077	-0.0044	-0.0096	-0.0097	-0.0008	-0.0063
Vitamin C	-0.0072	0.0000	-0.0015	-0.0002	-0.0001	0.0082	-0.0214

Nutrient	Banana	Melon	Orange	Other fruits	Eggs	Milk
Calories	-0.0030	-0.0056	-0.0096	-0.0249	-0.0068	-0.0281
Protein	-0.0010	-0.0093	-0.0009	-0.0090	-0.0076	-0.0405
Fat	-0.0002	-0.0033	-0.0003	-0.0071	-0.0075	-0.0467
Carbohydrate	-0.0074	-0.0095	-0.0236	-0.1154	-0.0049	-0.0094
Calcium	-0.0010	-0.0083	-0.0206	-0.0305	-0.0467	-0.0963
Phosphorus	-0.0016	-0.0030	-0.0077	-0.0204	-0.0160	-0.0569
Iron	-0.0030	-0.0238	-0.0007	-0.0411	-0.0003	-0.0252
Vitamin A	-0.0006	0.0276	-0.0619	-0.0390	0.0005	-0.0104
Vitamin B1	-0.0010	-0.0106	-0.0224	-0.0314	-0.0104	-0.0240
Vitamin B2	-0.0044	-0.0112	-0.0162	-0.0360	-0.0153	-0.0792
Niacin	-0.0026	-0.0028	-0.0140	-0.0277	-0.0031	-0.0038
Vitamin C	-0.0016	0.0360	-0.1746	-0.2328	-0.0002	-0.0003

Characterization of vegetable production in northern Vietnam

A vegetable production survey was conducted in four provinces in northern Vietnam in 1998–99. A total of 453 farmers were interviewed, including some non-vegetable farmers, mostly rice farmers, for comparison. The survey covered all crops grown from March 1998 to February 1999 and collected detail information on farmers, farm management practices, input use, and production constraints. The survey sites were divided into parcels—contingent pieces of land under one crop. Data for 1014 vegetable parcels and 932 non-vegetable parcels were collected.

Vegetable and non-vegetable farmers in northern Vietnam have similar family size, and their adult family members, including the family head, have a similar level of education. However, vegetable farms are slightly larger, and the children of vegetable farmers have a higher level of education, and vegetable farmer families receive more in remittances from kin engaged in off-farm employment.

Vegetable cultivation in the north is concentrated in September after the rainy season. However, some legumes, leafy vegetables, and cucurbits are also grown in January. Concentration of vegetable cultivation in a few months creates seasonality in supply. Most vegetables are harvested in November–January. Some are harvested in April, but almost no vegetables are available in July–October.

Animals are the main source of power for vegetable and cereal land preparation, although in some cases tractors or human labor is used. For harrowing fields, human power is more common in vegetable production than in rice production. Unlike rice farmers, corn and vegetable farmers use manual labor to build furrows.

Irrigation water is obtained from rivers or channels, and is usually supplemented with pump water or lake water. Water from rivers and lakes is collected in channels (either pumped or as rain drainage), which is then moved by pump (pump irrigation) or shoulder basket (manual irrigation). Channels are the main source of irrigation water for rice cultivation, while a significant proportion of vegetable and corn farmers get water directly from rivers (when crops are grown on river banks during the dry season) or lakes. Vegetable farmers use more manual irrigation and less pump irrigation than do their non-vegetable-growing counterparts.

Almost all farmers use fertilizer on every crop. And farmers report that fertilizer is readily available. Slightly more vegetable and corn parcels received farm manure treatment than did the rice parcels. A very small proportion of parcels received no

Table 80. *Labor use in vegetables in northern Vietnam, 1998–99*

Crop	Land preparation (%)	Management (%)	Harvest (%)	Marketing (%)	Total labor (days/ha)
Rice	8	73	18	1	223
Corn	12	68	17	3	284
Vegetables	10	52	18	20	456

Table 81. *Material input use in major vegetables in northern Vietnam, 1998–99*

Crop	Fertilizer nutrient (kg/ha)	Manure (t/ha)	Irrigation (no.)	Spray (no.)
Rice	192	6	3	1.8
Corn	294	6	3	1.9
Vegetables	308	8	4	3

Table 82. *Factor share in major vegetables in northern Vietnam, 1998–99*

Crop	Seed (%)	Manure (%)	Fertilizer (%)	Pesticide (%)	Labor (%)	Tot. cost (million VND)
Rice	6	13	15	7	59	6.350
Corn	5	12	23	5	55	6.414
Vegetables	6	10	16	5	63	11.814

Table 83. *Economics of major vegetable and cereal cultivation in northern Vietnam, 1998–99*

Crop	Yield	Revenue and return (million VND)			Benefit-cost
	(t/ha)	Gross revenue	Net revenue	Return on labor/day	ratio (%)
Rice	4.9	13.1	6.8	0.030	107
Corn	4.8	9.9	3.5	0.012	55
Vegetables	16.7	20.8	9.0	0.020	76

irrigation. Seventy-one percent of vegetable parcels received chemical spray treatment, compared to 93% of rice parcels.

Labor use in vegetables is far higher than in rice, and mostly higher than corn (Table 80). On average, vegetables require twice as much labor as does rice. This would amount to an additional job per crop season for each hectare of rice that is shifted to vegetable production. Year-round, this would amount to 2–3 additional jobs, depending on cropping intensity. It is important to note that in northern Vietnam, vegetable marketing consumes a much higher proportion of labor than does rice marketing. Actually, availability of labor for marketing is considered a major constraint to expansion of vegetable production in northern Vietnam.

Vegetable cultivation in northern Vietnam is very intensive, a fact indicated by higher material input use compared to rice or corn (Table 81). This implies that a shift from rice to vegetable cultivation could generate an enormous demand for agribusiness. And, with higher input use comes higher cost (Table 82).

With regard to chemical sprays, although the proportion of vegetable parcels receiving sprays was less than for rice parcels, the average number of sprays on vegetable parcels was much higher. But chemical spays account for only a small proportion of total cost, which suggests that the cost incentive to reduce pesticide use is small, despite questions of health and sustainability.

As the major share of total cost goes to labor, the demand for labor-saving technologies will be high. Fertilizer also claims a large share of total cost of vegetable production. Therefore, farmers might also demand fertilizer-saving technologies.

Average vegetable yields in northern Vietnam are reasonably high (Table 83). This can be attributed to climate, but also to good management practices, partly evidenced by high input use. Future research should focus on extending vegetable production in the summer season, and on developing input-saving technologies for winter production.

Vegetable production generates higher returns than does rice or corn (Table 83). However, many vegetable crops, despite their high yield, had either lower or even negative net return. This is an indication of marketing risk due to price fluctuation. Unless a farmer can accurately predict supply and demand at harvest time, it is difficult to make money.

On average, the benefit-cost ratio in vegetable cultivation is lower than in rice cultivation, but higher than in corn cultivation. The ratio ranges from negative to more than 300%. Similarly, return to

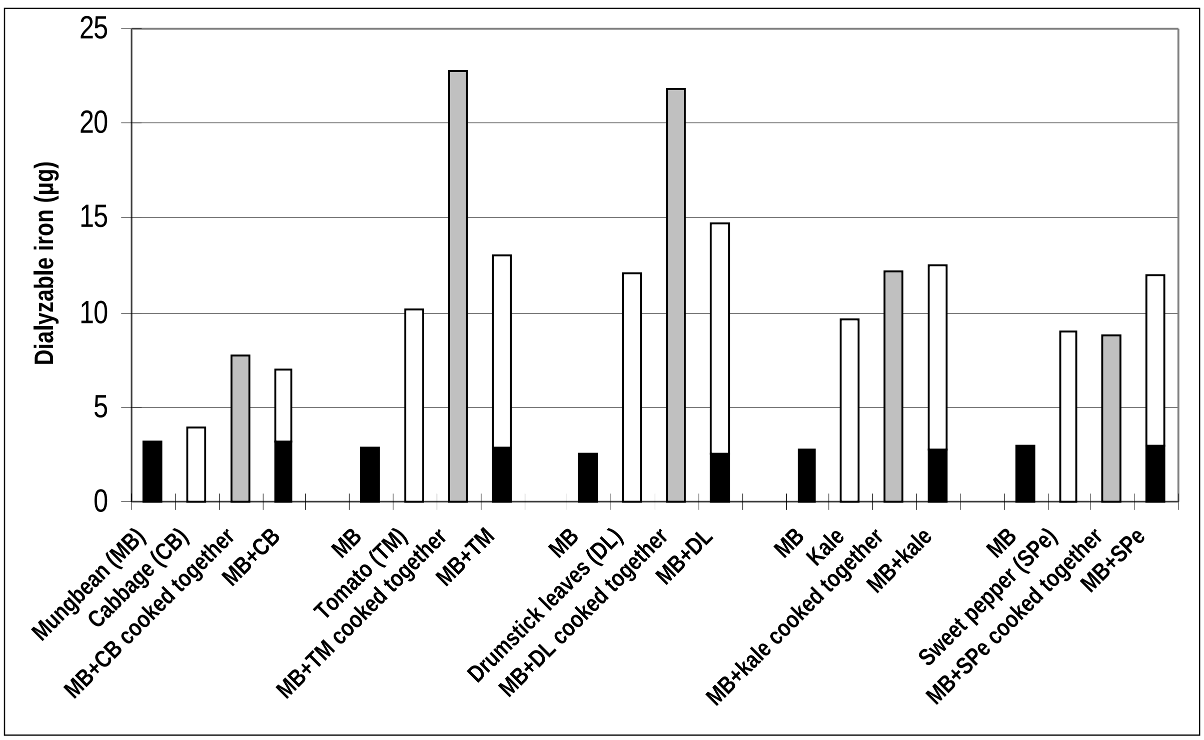

Figure 13. *Effect of selected vegetables on* in vitro *iron bioavailability of mungbean.*

labor in vegetable cultivation is lower than in rice, but higher than in corn. Low labor return has implications for future vegetable cultivation. In fast-developing Vietnam, the opportunity cost for family labor is increasing and the labor available for vegetable cultivation is decreasing. Unless labor-saving technologies are available, vegetable cultivation could be hampered by economic development.

Most farmers reported problems with insects and diseases, but many did not, reporting instead that they achieve good control with sprays, or by using low-cost labor to remove insects or infected plant parts. In terms of frequency of occurrence, cabbage white butterflies, diamondback moth, fruit worm, and leaf roller are the major insect pests recognized by vegetable farmers. Farmers who think that disease is not a problem, might be mistaking disease symptoms for insect damage. Again, looking at the frequency of occurrence, fusarium, downy mildew, late blight, soft rot, and damping off are the major constraints in the area according to farmers.

Contact: M Ali

Iron bioavailability of vegetables

This study was conducted to identify vegetables with high iron content and potential for improved bioavailability through cooking; to find more vegetable species able to enhance the iron bioavailability of iron-rich vegetables; and to develop methodologies for grouping vegetables based on their iron bioavailability enhancing ability.

Mungbean was cooked with equal amounts (1:1, mungbean:test ingredient, dry matter) of tomato, kale, sweet pepper, and drumstick leaves, and the resulting dialyzable iron was measured. Tomato and drumstick leaves cooked with mungbean raised dialyzable iron compared to the ingredients cooked separately, and the ingredients cooked separately and then mixed. Kale and sweet pepper showed no such enhancing effect (Figure 13).

Tomato was further tested with sweet potato, soybean, rice, lima bean, and wheat flour. Enhancement was observed in soybean and lima bean (Figure 14). Sucrose and citric acid are the dominant water-soluble constituents in tomato, but only citric acid is considered an iron enhancer. Equivalent amounts of sucrose and citric acid as are contained in tomato were added separately and together to mungbean before cooking. The ingredients together produced a greater enhancing effect on mungbean dialyzable iron (Figure 15). This suggests that combining a mild enhancer, such as citric acid, with certain compounds, such as sucrose, can produce a stronger iron dialyzability enhancing effect.

EDTA-2Na is a strong iron chelator. *In vitro* it competes with other chelators by binding iron quickly to avoid formation of precipitated iron

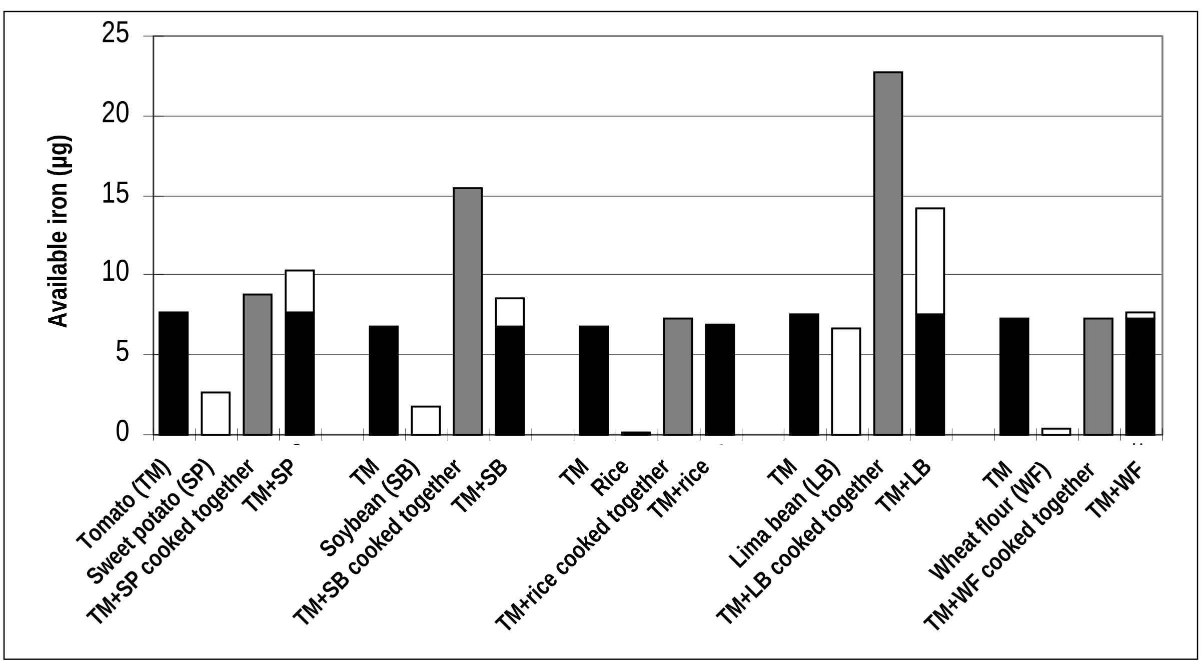

Figure 14. *Effect of tomato on* in vitro *iron bioavailability of selected vegetables.*

complex. It was used here as an enhancer. And according to studies, cooking can eliminate inhibitors generated by heat-labile factors. So, in this study, cooking and addition of EDTA (with a concentration 10-times the iron content of each vegetable), before plant cell destruction, were used as a means of rating vegetables according to their amount of enhancers and inhibitors. Eight vegetable samples were tested, and the results are presented in Figure 16.

Broccoli, cabbage, and mustard leaves were grouped in category one—containing large amounts of heat-related inhibitors and enhancers. The conclusion regarding inhibitors was drawn from the observation that cooking these vegetables produced a 4–12-fold increase in iron dialyzability. (Cooking is known to eliminate iron inhibitors.) The conclusion regarding enhancers was drawn from the observation that these cooked vegetables had iron dialyzability

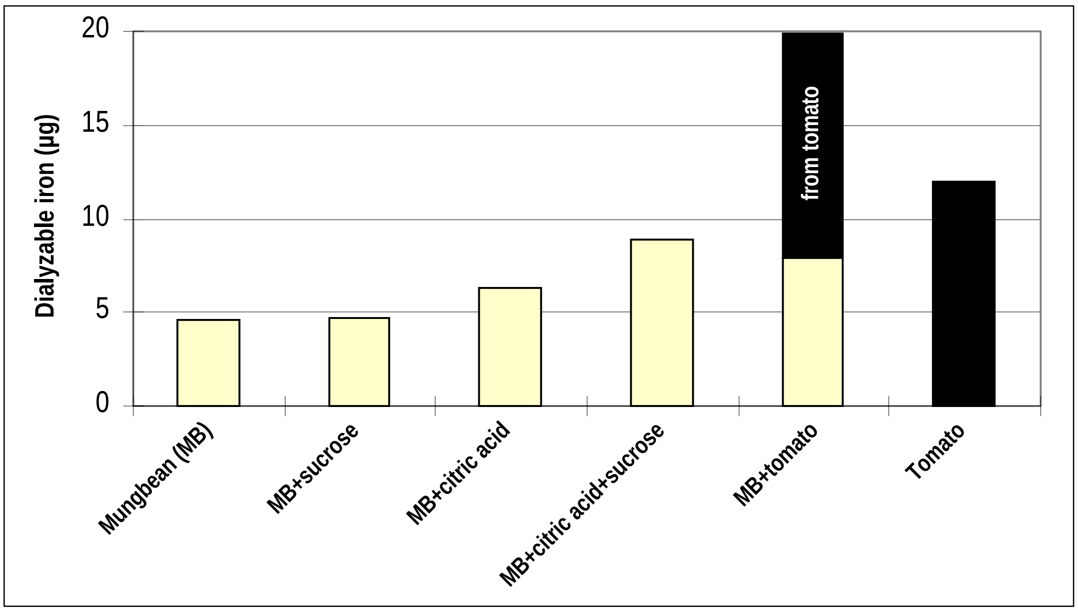

Figure 15. *Effect of adding sucrose and/or citric acid on* in vitro *iron bioavailability of mungbean.*

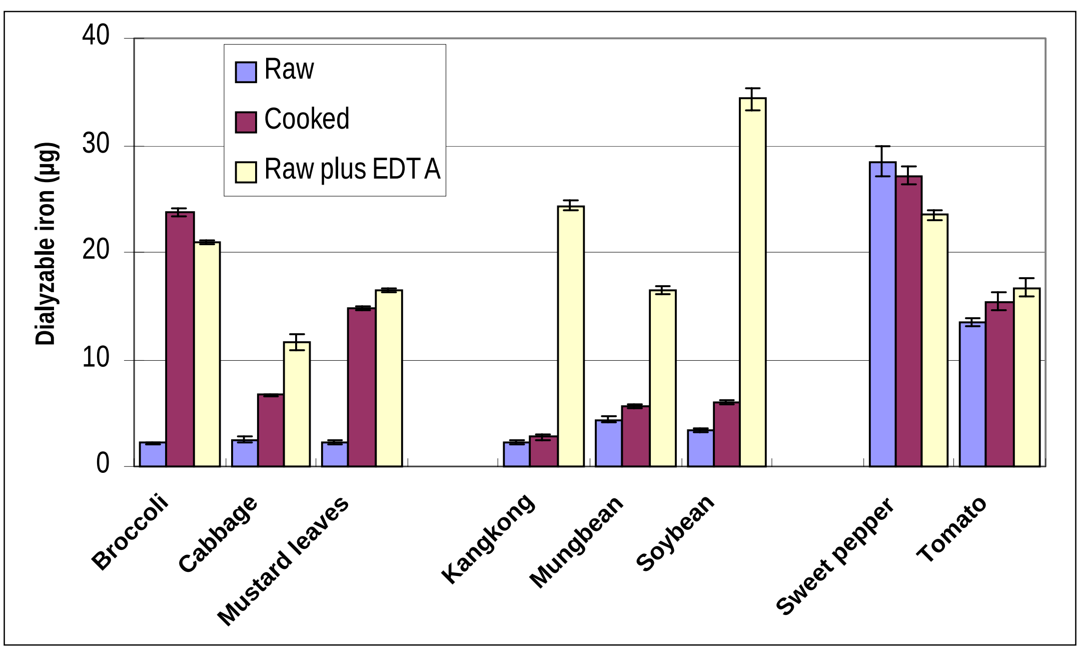

Figure 16. *Effect of addition of EDTA before blending on* in vitro *iron bioavailability of selected vegetables.*

comparable to raw samples with EDTA added, which implies that the vegetables contain enhancers at least equivalent to the added EDTA.

EDTA added to raw broccoli and mustard leaves, after cell disruption, produced similar levels of dialyzable iron as cooked, but, for cabbage, the added EDTA did not increase dialyzable iron as much as did cooking (Figure 17). This suggests that once the iron and inhibitors interacted after cabbage cells were disrupted, the effect became irreversible, even EDTA could not compete with the inhibitors.

Mungbean, soybean, and kangkong were grouped in category two—lacking heat-related inhibitors and enhancers. The lack of inhibitors was suggested by a lack of cooking enhancing effect. A 4–10-fold increase in dialyzable iron was observed in these three samples with added EDTA. But unlike category one, the effect of enhancers was not seen after cooking. This implies that there were not enough enhancers in these samples to chelate free iron and make it available.

Tomato and sweet pepper were grouped in category three—less inhibitors and more enhancers. Lack of apparent cooking enhancing effect was taken as evidence of a lack of inhibitors. Given the high iron dialyzability of sweet pepper and tomato, enhancement from addition of EDTA was not apparent. Thus, we conclude that these samples

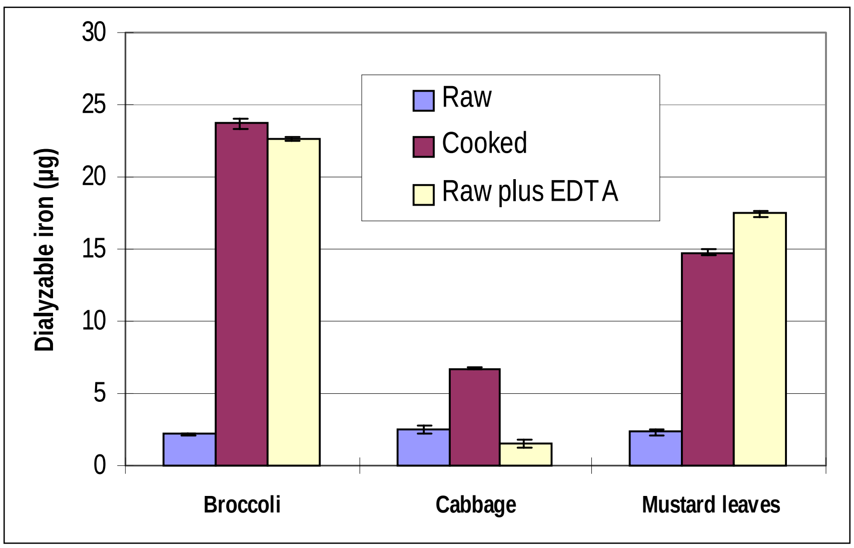

Figure 17. *Effect of addition of EDTA after blending on* in vitro *iron bioavailability of selected vegetables.*

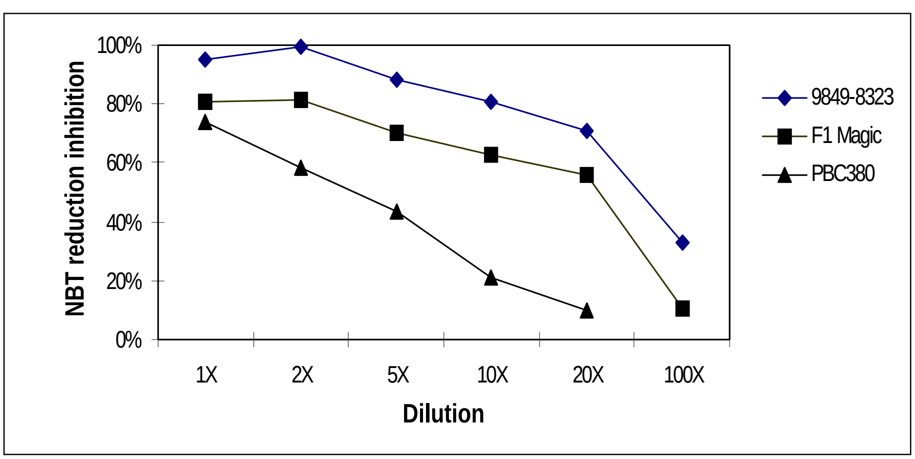

Figure18. *Super Oxide Scavaging activity of selected pepper varieties, based on nitro blue tetrazolium (NBT) reduction inhibition.*

contained more enhancers than did the vegetables in the other two categories. This is consistent with the observation mentioned above, that tomato enhances iron dialyzability of mungbean.

This study suggests that iron-rich vegetables, such as mungbean and soybean, lacking both inhibitors and enhancers, can have their iron bioavailability enhanced by a vegetable, such as tomato, that contains strong enhancers and few inhibitors. Legume-based foods, when cooked with tomato or drumstick leaves, can be a good source of iron.

Contact: S C S Tsou

Screening of vegetables for health related factors—superoxide scavenging

The importance of micronutrients in the human diet is clear, as is the fact that vegetables are an important source of micronutrients. Furthermore, epidemiological and animal model studies have demonstrated that consumption of vegetables and fruits is associated with lower incidence and mortality rates of cancers. However, even basic knowledge of many health-promoting phytochemicals in vegetables remains limited. This study was undertaken to help correct this deficiency.

Table 84. *Superoxide scavenging activity[1] of peppers and selected vegetables*

Sample no.	Sample name	Type[2]	Color	Extracts of: Water	Methanol	Hexane
Sweet and hot peppers						
1	9849-8323	HP	Orange	+++++	+	++
2	9852-5	SW	Red	+	±	+
3	9852-191	SW	Red brown	+	-	-
4	9852-431	HP	Dark red	+	-	-
5	9905-7545	HP	Yellow	++	+	-
6	9907-9399	S/H	Red	+++	±	-
7	9907-9437	SW	Yellow	+	±	+
8	9907-9440	SW	Red	+	-	-
9	9907-9658	SW	Orange	+	-	-
10	F1 Magic	HP	Red	+++++	-	+
11	F1 Yanka	HP	Orange red	+	±	-
12	PBC292	S/H	Red	+	±	-
13	PBC380	HP	Red	+++	±	-
Vegetables and plant materials						
14	Amaranth			+	+	-
15	Common cabbage			+	-	-
16	Fennel			+++	++	-
17	HP leaves, green			++	+	-
18	HP leaves, purple			++	++	-
19	SP leaves			++	++	-
20	Kangkong			++	+	-
21	Okra			+	+	-
22	Purslane			+++	-	-
23	Polyphenolics extract from tea[3]			++++		
24	Tomato			++	-	+
25	Tran-chi			+	-	-

[1] Intensity of activity is recorded based on the inhibitory percentage greater than 20% at a certain dilution of sample: +++++, 100× dilution; ++++, 20× dilution; +++, 10× dilution; ++, 5× dilution; +, 2× dilution; ±, 1× greater than 40% but 2× less than 20%; and -, 1× less than 40%.

[2] HP = hot pepper; SP = sweet pepper.

[3] Polyphenolics were extracted from commercial, partially fermented tea, using methanol.

A bioassay system using xanthine oxidase (XOD) and nitro blue tetrazolium (NBT) for evaluation of superoxide scavenging activity (SOS) of vegetables was established in AVRDC's nutritional and analytical laboratory in 1999. In nature, free radicals, such as superoxide anion (O_2^{-}•), hydroxyl and nitric oxide (HO• and NO•), and other reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2), are formed in the body. To escape ROS dependent toxicity, biological structures require physiological antioxidants. Imbalance between production of ROS and anti-oxidant defense can result in oxidative stress, including membrane lipid peroxidation, and the oxidation of proteins and DNA. The supply of exogenous antioxidant is thus crucial. The method used for assessing SOS activity of vegetables has proven relatively simple and can be used routinely in our laboratory.

Thirteen peppers, including six hot, five sweet, and two sweet/hot varieties were used as a test sample set for this method. Water, methanol, and hexane extracts were estimated for their SOS activity. The SOS activities of water extracts from four varieties of hot pepper were found to be strong (Table 84) and shown in a concentration-dependent manner (Figure 18). Heat treatment under 100°C for 10 min did not affect their activity (data not shown). Furthermore, capsaicin, beta-carotene, ascorbic acid, and quercetin (a major form of flavones in pepper) were examined and found not to be involved in SOS activity of peppers. These observations indicated that compounds responsible for SOS activity of pepper were water soluble, heat stable, and other than the major constituents of pepper, such as beta-carotene, vitamin C, and capsaicin, which are known to be related to other kinds of anti-oxidative activity. Three generally recognized anti-oxidative compounds, including glutathion, lycopene, and polyphenolics, were also tested for SOS activity. Only Polyphenolics showed strong SOS activity (Table 84).

Other vegetables and plant materials were also tested for SOS activity. They were purslane, okra, amaranth, common cabbage, fennel, kangkong, tomato, and leaves of sweet and hot pepper. All the water and methanol extracts showed moderate to strong inhibition of NBT reduction (Table 84). This suggests that the components involved in SOS might be present in all vegetables, but with widely varying concentrations and affinities to superoxide. Among the vegetables tested, water extracts from purslane and fennel showed high intensity of SOS activity (+++), but hot peppers 9849-8323 and F1 magic (+++++) were outstanding. More vegetables are being collected for SOS evaluation.

This study implies that vegetables provide anti-oxidants, responsible for SOS, in a wide range of amounts and in different combinations, and that it is possible to screen certain compounds, with a higher affinity to superoxide, among crops and varieties within species.

There is still no basis for recommending the use of specific commercially produced antioxidants to prevent disease. A mixed vegetable diet with higher antioxidant properties remains the best strategy for bolstering the body's defenses, while providing balanced nutrition.

Contact: S C S Tsou

Project 7. Computer-based decision-making tools

The objective of project 7 is to develop computer-based decision-making tools for use by national agricultural research and extension systems and non-governmental agencies in designing year-round vegetable production systems. Existing computer-based systems and databases were assessed and evaluated for application to vegetable production systems. No computer-based system was found that matched our purpose, and existing databases, although useful, were found insufficient. The Center's own accumulated data require processing before they can be put to use in the type of tool envisioned.

In 1999, the project was slowed due to staff vacancy, but the government of Japan agreed to fund the project in 2000, which will allow the Center to assign new resources to the project and accelerate activities in order to deliver the outputs described in AVRDC's latest five-year plan.

Contact: Meisaku Koizumi

Special project. Manila peri-urban vegetable project

Urban sprawl is common in Asia, and competes directly with urban and peri-urban vegetable production zones. New technologies could help to meet the unprecedented demands being placed on tropical Asian cities, to alleviate micronutrient deficiencies among the urban poor, recycle solid wastes, and reverse trends toward environmental catastrophe.

The AVRDC peri-urban project in the Philippines, sponsored by GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit), is designed to:

- stabilize the supply of safe and nutritious vegetables to metropolitan areas, such as Manila
- develop an approach for information acquisition, testing and dissemination suitable to other peri-urban areas in Asia

Contact: J R Burleigh

Characterization of environments suitable for technology transfer

Technology transfer requires that farmers possess the education and experience necessary to evaluate the usefulness of technologies. They also need access to information, access to resources to invest in new technologies, labor, and access to markets. They must also believe that their investments will pay off. This study was undertaken to characterize farmers' social and economic environments so that constraints to technology transfer can be identified and so that effective methodologies might be developed.

A survey of *barangay* (community) Castellano and neighboring *barangay* Nieves found that: vegetable growers spend an average of 6.6 years in school and complete primary education, they have 16.6 years of farming experience, 28% own their land (mean farm size 1.1 ha), 65% are tenants (mean farm size 0.64 ha), 7% rent land, and 94% own their homes. One hundred percent of farms are irrigated, 28% of the soil area is classed as silt loam, and therefore excellent for vegetable farming. Seventy-eight percent of farmers do not borrow money, and among the 22% who do, 18% borrow from family or friends and 4% borrow from money lenders or banks. The maximum amount borrowed is 35,000 PHP. Mean household size is 4.42 persons, with a mean of 1.58 adults per household as laborers. Mean gross income is 197,000 PHP, of which 98% is from vegetable farming. Return on investment ranges from 56% for mustard to 909% for onion. Return from pak-choi, the project's principal target crop, is 87%. The ratio of total cost of production to gross income is 0.53 for pak-choi and 0.01 for onion. Seventy-four percent of households own a television, 76% own a radio, 3% own a truck. Eighty-one percent of farmers sell their pak-choi (for example) to local assemblers, whereas only 19% sell directly to markets. The mean yield of pak-choi on 15 farms in Nueva Ecija in the wet season 1999 was 2.8 t/ha.

These data suggest that farmers in San Leonardo (the project's principal site) possess the education and experience needed to assess new technologies. Because 93% of farmers are owners or tenants, we assume they value the long-term productivity of their farms. And gross income figures suggest that San Leonardo vegetable farmers are not poor, and can perhaps invest in new technologies. Formal borrowing is minimal, but informal borrowing, in the form of seed and fertilizer supplied by assemblers, is common. Such arrangements tie farmers to a marketing system controlled by the assemblers—the money owed must be paid at the time of sale. Considering that only 3% of farmers own a vehicle to transport produce to market, assemblers are virtually indispensable, whatever the terms of their loans. Few farmers (3%) obtain technical information from television and radio; rather they rely on friends and relatives (29%), and sales agents (22%). Researchers and government technicians were sources of technical information for 8 and 7% of respondents, respectively.

All farmers interviewed (119) reported using chemicals to control pests and diseases. In fact, use of pesticides is synonymous with pest management. Yet, 85% of farmers perceive insecticides to be less than fully effective. Neighboring farmers most often provide recommendations on choice of insecticide. Organophosphates, such as Brodan, Selecron, Ascend, and Hostathion, are preferred because they are considered effective, relatively inexpensive, and available. Pak-choi and mustard receive more insecticide treatments per day of crop duration than do radish and onion, but onion receives the largest quantity (Table 85). Only 20% of farmers knew about enemies of pests, but among these farmers, all knew that killing predators with insecticides would lead to increases in pest infestations.

Safe handling and storage of pesticides is a concept, but not a practice among farmers. Most (82%) apply pesticides while walking into the wind. Most (93%) wear clothing that might provide partial protection from spray drift (e.g., short or long pants, short- or long-sleeved shirts), but only 3% wear masks and gloves. Clearly, farmers are exposed to pesticide drift and that might explain why many respondents reported episodes of headache (77%), weakness (65%), dizziness (49%), vomiting (45%), and stomach pain (26%) following application. Nonetheless, farmers persist in using unsafe practices.

The study suggests that vegetable production is profitable, but that profitability of pak-choi lags behind other crops, such as onions and radish, which are part of the cropping sequence employed by farmers in Castellano. Farmers, therefore, approach pak-choi production with less intensity and interest. Nevertheless, technologies that improve pak-choi productivity and/or decrease production expenses should be marketable among farmers in San Leonardo. Regarding unsafe use of pesticides; if we are to foster a change in practices, we must first understand the reasons for farmers' *laissez-faire* attitude.

Perceived appropriateness of AVRDC technologies to leafy vegetable production systems

Farmer opinion about integrated pest management (IPM)—raised beds, rain shelters, and organic fertilizer—for pak-choi management has changed as a result of the project's on-farm activities in San Leonardo. Initially perceived as having low sustainability, at the end of the second year of the project farmers rated those practices as having moderate sustainability. Here, sustainability refers to a farmer's perception of his/her capacity to dedicate resources to implement new practices. About 90% of farmers perceive IPM to require moderate labor inputs and time, yet 82% consider implementation of IPM practices to be complicated and therefore not adaptable. Even farmer-cooperators, those intimately associated with IPM activities, want a "silver bullet" (a potent pesticide) to solve pest problems. It is imperative, therefore, that training documents and training exercises express the interrelationships of pest intensity, crop damage, and economic environment, and therefore the complexity of IPM, in a way that is understandable to farmers. Farmer adoption of IPM practices would lead to reduced pesticide use, reduced pesticide residues on farm produce, and the improved health of consumers and producers.

Farmers acknowledge that screen shelters reduce insect damage, yet they consider shelters too expensive and too labor intensive to be adopted.

The number of farmers who visited research sites or otherwise heard of the management innovations being implemented in San Leonardo increased from 53 in 1998 to 81 in 1999. We interpret this increase as a measure of the interest generated by our work among potential users.

Table 85. *Number of insecticide applications and average quantity of product used in vegetable production in San Leonardo, wet season 1998*

Vegetable	Number of applications: range	average	crop duration	Quantity (liters/ha)
Pak-choi	3-10	7	31 days	4.8
Radish	2-10	6	45 days	2.67
Mustard	4-10	7	31 days	3.17
Onion*	2-12	5.9	80-95 days	5.25

* Dry season 1999 data.

Effects of technology transfer on food consumption patterns among farmers and urban dwellers

We conducted a quarterly survey of 239 households in San Leonardo and Gapan to generate base-line data against which changes in food consumption can eventually be measured.

As expected, the survey revealed seasonality in vegetable supply. One-day total food consumption among all households ranged from a mean of 1115 g in April–June to 942 g in October–December; a drop of 15%. Meanwhile, vegetable consumption dropped a full 40%, and total energy consumption dropped only 5%. Consumption of vitamins A and C dropped 35 and 33%, respectively, due to reduced vegetable consumption—vegetables account for 67% of Filipinos' vitamin A intake and 84% of their vitamin C intake. This project focuses on technologies to improve vegetable production during the hot-wet season in order to reduce seasonality of supply and the resulting vitamin deficiency. But at present, we can only speculate about changes that might occur as a result of technology transfer.

Farmers consume 1110 g of food per day, whereas urban dwellers consume 961 g, a difference of 13%. But farmers eat more vegetables, 227 g/day compared to 175 g/day consumed by urban dwellers, a difference of 23%. In contrast, per capita vegetable consumption in Metro Manila is only 87 g/day, 62% less than the farmers in San Leonardo. As expected, consumption of vitamins A and C by residents of Metro Manila is also deficient, by 38 and 34% of the recommended daily allowance, respectively.

Price and income elasticities can be used to assess consumer response to changes in vegetable prices resulting from variability in supplies. Price elasticity is a measure of percent decline in demand (and as such is represented by negative values) after a 1% increase in price, or a percent increase in demand after a 1% decrease in price. If the elasticity value is greater than 1, then the percent decline in demand is greater than the percent increase in price. If the elasticity value is less than 1 then the percent decline in demand is less than the percent increase in price. The survey revealed price elasticities for meat and vegetables of -1.015 and -0.553, respectively. These values indicate that demand for vegetables is less affected by price increases than is demand for meat. However, compared to cereals (-0.329), vegetables are more affected by price increases. Price elasticity values for individual vegetables indicate that demand for leafy types (value of -0.969) is more affected by price increases than is demand for tomatoes (-0.412). That is, with equal increases in price, the demand for leafy vegetables will be more affected than will the demand for tomatoes.

Income elasticity values represent percent increases in demand (and as such are represented by positive values) that result from a 1% increase in income. A value of 1 indicates that income and demand increase equally, in percentage terms. Values greater than 1 indicate that a 1% increase in income leads to >1% increase in demand, whereas values less than 1 indicate that a 1% increase in income leads to <1% increase in demand. In our study, income data for respondents were not available so we used household expenditures as a substitute. Expenditure elasticity values for meat and vegetables were 1.632 and 0.775, respectively, indicating that the demand for meat increases more per unit increase in household expenditure than does the demand for vegetables. Households buy more meat than vegetables as income increases. The difference in choice between meat and vegetables is reflected in budget allotments as well: 27% of household budget goes to purchase meat, but only 7% to purchase vegetables.

Review of the absolute values for price and income elasticities of vegetables (-0.553 and 0.775, respectively) suggests that demand is slightly more responsive to income than to price. Therefore, technologies that improve income will increase consumption, perhaps more readily than technologies that reduce price.

Constraints to technology adoption for pak-choi

There are three main constraints to adoption of the project's pak-choi technologies: 1) pak-choi does not receive intensive management by farmers, 2) the capital/output ratio for pak-choi is high relative to onion, and 3) farmers persist in their search for effective pesticides rather than adopt more intensive management practices.

Farmers must be convinced that monitoring pests prior to pesticide application, use of screen shelters to reduce insect damage, and reduction of fertilizer cost through sound crop management, will reduce their expenses and raise their incomes.

Soil and crop nutrition

Peri-urban vegetable production systems in *barangay* Castellano are characterized by excessive use of inorganic fertilizers and pesticides. Farmers apply up to 92, 218, and 368 kg/ha of nitrogen-containing fertilizers to pak-choi, radish, and onion, respectively, and burn 70–380 t/ha of rice hulls every year or every 2–3 years. Farmers believe these practices contribute to sustainability.

Between 30 and 50% of the above-ground biomass of onion, radish, and pak-choi is discarded at harvest as nonmarketable or waste. This discarded material contains 30–50% of the total nutrients taken up by the plants. The nutrients contained in the edible parts end up in metropolitan areas, such as Manila. To ensure the sustainability of production systems in

Nueva Ecija, and therefore ensure long-term supplies of vegetables to urban consumers, nutrient cycling must be practiced.

Research presented here suggests alternative fertilization practices for peri-urban vegetable production systems in Nueva Ecija, a principal supplier of leafy vegetables to Metro Manila consumers.

Effects of burned rice hulls on soil properties and pak-choi yield

Burning rice hulls on cropland is a common practice among vegetable farmers in San Leonardo. It is done primarily to control weeds. The ash is incorporated in the soil prior to seeding. The project is interested in the long-term effects of the practice on soil factors and on crop yield.

In a replicated trial carried out at the project site, 147 t/ha of rice hulls were burned. Soil organic matter (SOM), exchangeable K, and soil porosity increased, while bulk density and particle density decreased (Table 86). Weeds were reduced in crop 1, which was seeded immediately after incorporation of the ash (Table 87). Weeds were also reduced in crop 2, indicating a residual effect. Yield generally was unaffected, although treatment 5 (147 t/ha rice hulls + inorganic fertilizer) did show a significant yield increase over the control, treatment 1 (inorganic fertilizer alone) (Table 87). The increase in SOM should be explored further, as our measures probably included undecayed and decayed organic matter. Based on these findings, rice hull burning reduces weeds and might increase SOM. Further study is needed to determine if repeated incorporation of ash affects yield.

Effects of composted vegetable refuse from households in contrast to chicken manure and inorganic fertilizer on growth performance of pak-choi, radish, and onion

The project carried out a replicated yield trial of pak-choi, radish, and onion, to determine the effects of composted household (vegetable) waste (HW) and chicken manure (CM) (actually 50% chicken manure and 50% carabao manure), with and without inorganic fertilizer. The cropping sequence followed for the trial at Central Luzon State University (CLSU), Muñoz, was typical of that followed by farmers at the project site in San Leonardo. Pak-choi, radish, and onion received 12, 9, and 17 t/ha of organic fertilizer (HW or CM), respectively. They received 120-30-30, 90-30-30, and 170-40-40 kg/ha N-P-K of inorganic fertilizer (as recommended), respectively. Treatments included organic fertilizers

Table 87. *Effect of rice hull burning, prior to seeding crop, on weed numbers and yield of pak-choi*

No.	Application		Weed numbers (per 0.5m^2)		Marketable yield (t/ha)	
	Rice hull (t/ha)	N-P-K (kg/ha)	Crop I	Crop II	Crop I	CropII
1		90-30-30	30a	25a	4.55a	3.90b
2	74	90-30-30	10b	12b	4.70a	3.95b
3	74	45-30-30	12b	12b	4.05a	3.35b
4	147	90-30-30	4c	3c	5.35a	4.60a
5	147	45-30-30	4c	2c	4.10a	3.40b

Note: Mean recovery of carbonized rice hull from rice hull is 31.5%.
Second crop did not receive rice hull.
Means followed by the same letter in a column are not statistically different using Tukey's HSD Test.

Table 86. *Soil properties during the first and second crops in plots treated with burned rice hulls, December 1998– February 1999*

No.	Application		Organic matter (%)		Exchangeable K (meq/100g)	Bulk density g/cm^3	Particle density g/cm^3	Porosity (%)
	Rice hull (t/ha)	N-P-K (kg/ha)	Crop I	Crop II				
1		90-30-30	1.76b	1.70b	0.20c	1.36a	2.33a	41.36b
2	74	90-30-30	2.94a	3.00a	0.49b	1.26b	2.25a	43.68b
3	74	45-30-30	3.14a	3.19a	0.50b	1.27b	2.25a	43.11b
4	147	90-30-30	3.20a	3.23a	0.80a	0.91c	1.90b	52.56a
5	147	45-30-30	3.15a	3.17a	0.79a	0.90c	1.90b	51.93a

Means within each cropping period with similar letters are significantly different using Tukey's HSD Test.
Note: Mean recovery of carbonized rice hull from rice hull is 31.5%.

alone and in combination with recommended rates (RR) and half recommended rates (½RR) of inorganic fertilizer.

RR or ½RR inorganic fertilizer produced about equal yield (Table 88, treatments 4 and 5), with the exception of pak-choi crop 5. Only the radish crop and final pak-choi crop showed a significant benefit from HW or CM alone, while the onion was found to benefit from HW alone (Table 88, treatments 1, 4, and 5). Organic fertilizers alone had no effect on yield of crops 1, 4, and 5, all pak-choi crops.

Only pak-choi crops 1 and 5 benefited from 6 t/ha of organic fertilizer (½HW or ½CM) added to ½RR inorganic fertilizer. The other crops yielded just as well with ½RR inorganic fertilizer alone. However, crop 4 treated with ½RR + ½CM yielded higher than the ½RR alone. (The ½RR +½HW treatment showed no such benefit.) This study, which looked solely at crop yield, does not justify substituting organic for inorganic fertilizer.

Effects of farmer practices and introduced management practices on yield of pak-choi

Two treatment plots were placed on each of five farms. Treatment 1 was the farmer practice of transplanting seedlings in low beds to which nitrogen at 100 kg/ha was applied. Treatment 2 was the introduced technology of transplanting seedings in lines in beds raised 20 cm over which screen was stretched on bamboo arches. Raised beds were treated with inorganic fertilizer at 45-10-10 kg N-P-K/ha plus 4.5 t/ha of chicken manure compost. Analysis of variance (ANOVA) with farms as repetitions was done to determine treatment effects.

The introduced technology package was clearly superior to the farmer practice (Table 89). Yield was increased by 21%, which can be explained by the increase in plant density (29%) and increase in plant height (12.6%). The farmer plots received nine pesticide applications, whereas treatment 2 plots received only three; a reduction of 66%.

Table 88. *Marketable yield (t/ha) of pak-choi, radish, and onion as affected by fertilizer treatment in a pak-choi, radish, onion, pak-choi, pak-choi, pak-choi cropping sequence*

		Marketable yield (t/ha)					
		Crop I	Crop II	Crop III	Crop IV	Crop V	Crop VI
No.	Treatment	Pak-choi[1]	Radish[1]	Onion	Pak-choi	Pak-choi	Pak-choi[2]
1	nil	3.7c	19.4c	12.9d	12.2d	7.1d	1.8c
2	HW	5.2c	26.5b	21.3bc	17.2bcd	9.9cd	3.6b
3	CM	5.2c	26.5b	18.0cd	14.9cd	9.9cd	3.5b
4	½ RR	17.0b	29.7b	20.7bc	16.4cd	9.9cd	6.5ab
5	RR	20.0ab	34.3ab	25.1ab	20.4bcd	19.3a	6.1ab
6	½ RR + ½ HW	21.0a	30.8b	25.7ab	23.2abc	14.5b	6.6ab
7	½ RR + ½ CM	22.0a	31.5b	25.5ab	31.9a	21.0a	5.1ab
8	½ RR + HW	21.7a	32.8b	27.3a	24.2abc	12.3bc	9.1a
9	½ RR + CM	23.2a	40.8a	24.2ab	27.1ab	15.1b	9.4a

RR = recommended rate of inorganic fertilizer application, 120-30-30, 90-30-30, and 170-30-30 kg N-P-K/ha for pak-choi, radish, and onion, respectively. CM = chicken manure; HW = household waste.

[1] Part of first year accomplishment.

[2] Severe diamondback moth damage in all plots.

Table 89. *Yield and yield components of pak-choi on farmer-practice plots and introduced technology plots, October–December 1999*

Treatment	Fresh yield (t/ha)	Marketable yield (t/ha)	Percent marketable yield	Plants per m²			Plant height (cm)
				Days after emergence			
				8	20	35	
Farmer practice	20.2b	14.0b	70.6a	100b	99b	99b	25.8b
Introduced technology	28.9a	17.7a	61.3b	271a	216a	140a	29.5a

Soil factors associated with yield of pak-choi

In an effort to better understand variability in pak-choi yield, we took soil samples from 21 farms and analyzed them for organic matter, pH, texture, available P, exchangeable K, total soil N, cation exchange capacity, available N, and amount of NPK applied as fertilizer. Soil factors were regressed on yield by using stepwise regression with $\alpha = 0.05$ as the acceptance level. When cation exchange capacity was used as a constant, only available P and exchangeable K emerged as significant factors and partial correlation coefficients were -0.634 and -0.777, respectively. The negative sign indicates that yield was depressed as P and K values increased, which is counter to our understanding of plant response to these elements. These results suggest that due to continuous heavy application of burned rice hull, P and K have accumulated to an excessive level.

Technologies to increase tomato productivity during the hot-wet season

In the Philippines, tomatoes are primarily grown in the lowlands in the dry season. Hundreds of hectares are planted; consequently, net returns are low due to market glut. In contrast, during the rainy season, particularly in Nueva Ecija, tomato production is restricted to a few small hilly areas, supplies are limited and high prices make tomatoes almost unaffordable to consumers. For example, the retail price of tomatoes during the wet months can reach 80 PHP/kg (about US$1.75/kg). There is justification, therefore, based on economics and nutrition, to introduce technologies shown to enhance tomato productivity during the hot-wet season: tomato grafted onto eggplant rootstock for flood tolerance and resistance to bacterial wilt (BW), and sheltered raised beds to limit exposure to water logged soils and heavy rains, which can be particularly damaging during pollination.

Two trials were conducted on the Central Luzon State University campus. Trial 1 tested the performance of a local variety, Apollo, and a line from AVRDC, CLN5915, grafted onto eggplant line EG203, and onto BW resistant tomato line H7996. The trial was conducted under screen shelter on beds raised 30 cm. Trial 2 tested the performance of Apollo and CLN5915 grafted onto EG203 under screen shelter and in open field.

Yield was subjected to analysis of variance to determine treatment effects. In trial 1, transplanted in September, mean yields for Apollo grafted onto EG203 and H7996, and nongrafted were 15.6, 14.4, and 2.7 t/ha, respectively, whereas mean yields for

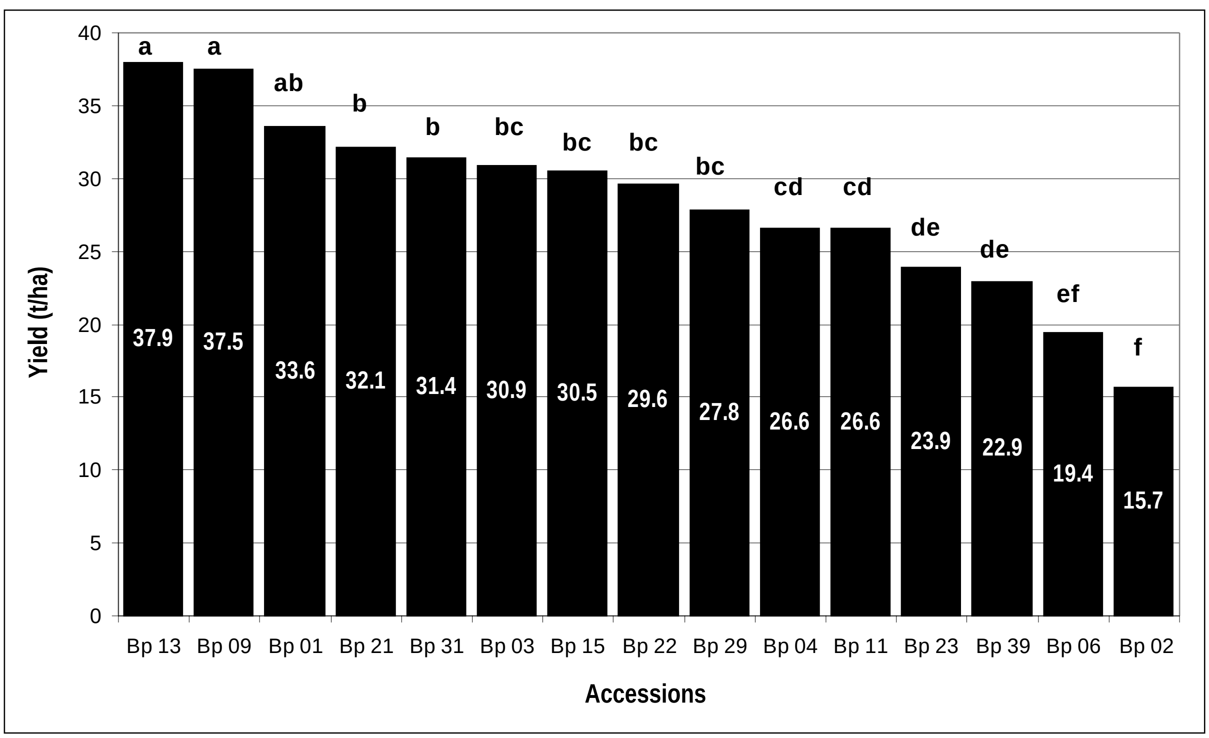

Figure 19. *Yield per ha of pak-choi accessions grown in a net house.*

CLN5915 grafted onto EG203 and H7996, and nongrafted were 14.7, 25.2, and 14.1 t/ha, respectively. Yield of nongrafted Apollo was significantly (P = 0.105) less than yields of other treatments. Based on single degree of freedom orthogonal comparisons, mean yield of CLN5915 across graft levels (18.0 t/ha) was significantly (P = 0.014) greater than that of Apollo (10.9 t/ha), and grafted lines (17.5 t/ha) yielded significantly (P = 0.015) more than nongrafted (8.4 t/ha) lines.

In trial 2, transplanted in September, mean yields for Apollo grafted onto EG203 and Apollo nongrafted were 21.2 and 18.4 t/ha, respectively, and the difference was not significant. Mean yields of CLN5915 grafted onto EG203 and CLN5915 nongrafted were 15.8 and 10.8 t/ha, respectively, and the difference was not significant. But, when yields of Apollo across graft levels were contrasted with CLN5915 across graft levels, yield of Apollo (19.8 t/ha) was significantly greater than yield of CLN5915 (13.3 t/ha). Yields under shelter and in open fields across graft levels were 18.0 and 15.3 t/ha, respectively, and the difference was not significant. There was no shelter × graft level interaction. When graft across varieties was contrasted with nongraft, mean yields (18.5 and 14.5 t/ha) were significantly (P = 0.096) different.

In both trials, grafted plants yielded more than nongrafted plants, but Apollo across graft levels was not clearly superior to CLN5915. There was no shelter effect, which might reflect the absence of severe flooding.

Three on-station trials and one on-farm trial were conducted by the Bureau of Plant Industry–Laguna. In on-station trial 1, eight tomato cultivars were grafted onto eggplant EG203 rootstock and transplanted in December. There were differences in cultivar yield within graft level (grafted, nongrafted), but no differences between graft levels within cultivar. When grafted onto EG203, FMTT-22 and CHT-261 yielded 46.2 and 48.2 t/ha, respectively, significantly more than local cultivar, Apollo, grafted onto EG203 (29.4 t/ha). Nongrafted FMTT-22 and CHT-261 yielded 36.6 and 40.8 t/ha, respectively, significantly more than nongrafted Apollo (15.9 t/ha).

On-station trial 2 was designed to test the interaction of shelter, variety, and graft level. Plants were transplanted in July. There was a shelter × cultivar interaction. Apollo yielded 3.7 and 3.2 t/ha in open field and shelter, respectively, but FMTT-586 yielded 8.4 and 11.4 t/ha, respectively. Across graft level and shelter, FMTT-586 yielded 9.9 t/ha, whereas, Apollo yielded 3.4 t/ha, and that difference is significant (P = 0.05).

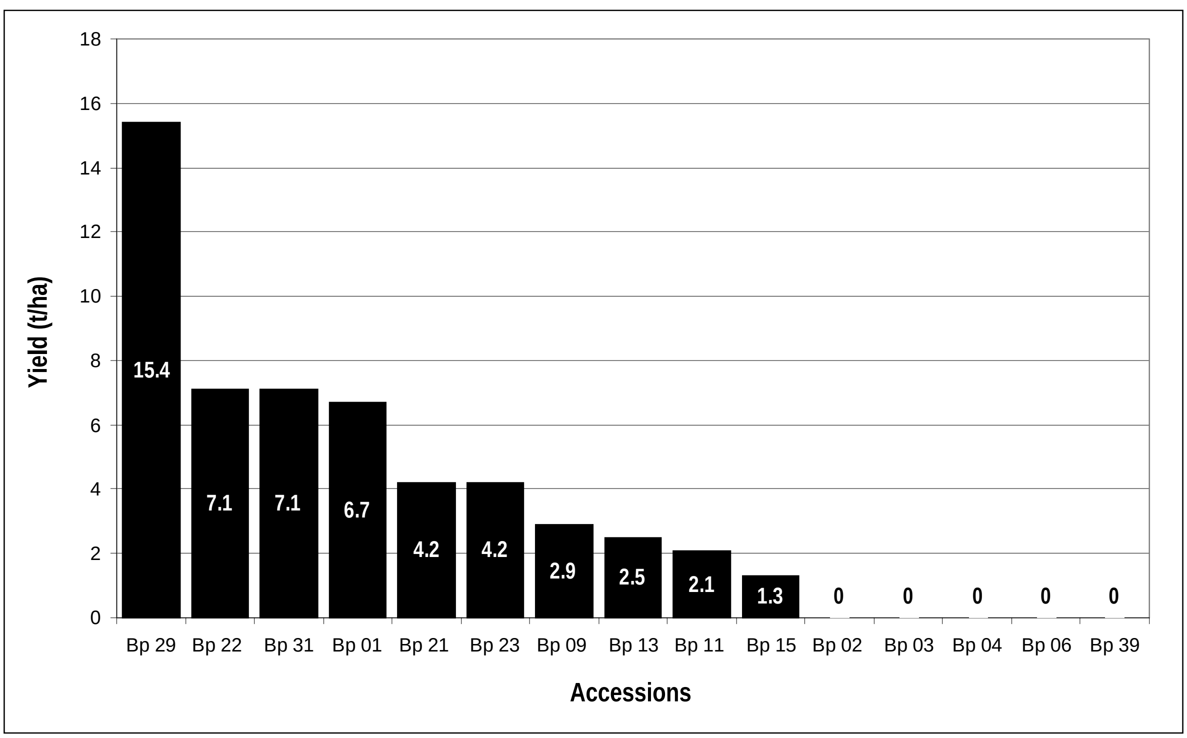

Figure 20. *Yield per ha of pak-choi accessions grown in open field.*

Trial 1 was conducted in the dry season, when flood tolerance from grafting is less important. Consequently, the nonsignificance of grafting among cultivars is expected. But, trial 2 was conducted during the wet season and there was no graft effect on cultivar yield. Other studies have provided strong evidence for grafting as a means to combat the effects of flooding and BW infection, but if those deterrents to yield are not present, or are present but not severe, then grafting becomes an exercise in futility. These data suggest that probability of flooding and BW infection should be taken into account when grafting is being considered as a management option.

On-station trial 3 tested the effect of hormones on off-season tomato production. When Nevirol and Tomatotone at 2% were applied to pistils of Apollo flowers, yields were 3.7 and 3.7 t/ha, respectively, and those yields are not different from the yield of nontreated plants (4.9 t/ha). The yield means across three cultivars, FMTT-22, CL-143, and CHT-261, treated and nontreated with Tomatotone, were 14.6 and 12.7 t/ha, respectively, and the difference is not significant (P = 0.05).

FMTT-589 and CL-143 were grown on-farm at three locations in nonreplicated trials. Yields across cultivars were 10.3, 21.3, and 0 t/ha at Batangas, Cavite, and Laguna, respectively. Zero yield at Laguna was attributed to frequent and heavy rain and to strong winds, which affected vegetative growth. We believe, but cannot document, that similar conditions were the cause of low yields in Batangas, in contrast to yields in Cavite.

Identification of leafy vegetable cultivars for year-round production in the tropics

Leafy cultivars belonging to the genus Brassica (*Brassica rapa* L. cvg. pak-choi; *B. juncea*, Indian mustard; *B. rapa* L. cvg. Chinese cabbage, non-heading Chinese cabbage; *B. oleracea* L. cvg. alboglabra, Chinese kale; *B. rapa* L. cvg. caisin, choy sum) were evaluated for their performance in fields at Central Luzon State University, Muñoz. They were seeded in raised beds in net houses (18 × 18 m) constructed of galvanized pipe with 16 mesh screen. The experiment followed a random complete block design. To contrast performance in net houses and open field, pak-choi was also seeded in an adjoining field, but in a non-replicated trial. We report here yield data from pak-choi as illustrative of relative performance under net houses and in open field. Yields were analyzed by ANOVA and by Tukey's HSD pairwise mean comparison test.

In the net house, yields ranged from 15.7 to 37.9 t/ha (Figure 19). In contrast, yields in the open field ranged from nil to 15.4 t/ha (Figure 20). There were cultivar differences in the net house. Bp 13 (Hua-Guan F_1) and Bp 09 (No. 341 F_1) yielded significantly more than all other accessions, with the exception of Bp 01 (Shanghai Green). Pak-choi was severely infested by cabbage webworm and diamondback moth (DBM) in the open field, but infestations were nil in the net house. Flea beetles did gain entry into the net house, but damage was minimal.

Another experiment was conducted at the Bureau of Plant Industry–Laguna. Eighty leafy vegetable cultivars were seeded on raised beds, 1 × 4 m and covered with 32 mesh net tunnels in a replicated trial on four occasions. There were few differences in yield among cultivars within species. Yields from February, March, and June plantings were similar; November was the least favorable month (Table 90). Most leafy species yielded about the same across plantings, but there were exceptions: yields of Chinese kale and celery were low, whereas yield of kangkong was high.

Table 90. *Mean yield of leafy vegetable cultivars across months*

Species	Yield (t/ha)				
	Feb	Mar	Jun	Nov	Mean
Indian mustard	10.9	15.6	13.8	4.3	11.0
Nonheading Chinese cabbage	14.1	12.8	17.0	7.2	12.8
Chinese kale	6.3	5.3	9.7	3.4	7.1
Kangkong	22.8	28.5	27.3	8.4	20.1
Choysum	18.7	14.2	13.1	6.4	12.3
Pak-choi	15.5	12.7	12.3	9.9	12.6
Lettuce	17.7	5.7	17.9	14.5	13.9
Celery	5.7	-	5.9	4.5	5.4
Month mean	13.9	11.8	14.6	7.3	

Kangkong is not a host to DBM and cabbage webworm and might be a candidate to replace leafy brassicas in those areas where damage by insect pests is severe.

Integrated pest management for peri-urban vegetable production

Replicated field trials were conducted on two farms to contrast farmer practice of pesticide treatment with treatments based on field monitoring of pest intensity, and nil pesticide. On farm 1 there were two crops of pak-choi, two of onion, and one radish crop. On farm 2 there was one crop of pak-choi, two of onion, and one radish crop. We noted the pesticides used, frequency of application, and dose. Pest numbers were counted twice weekly and yield was recorded. Treatment effects were analyzed by ANOVA and pairwise mean comparison.

Pak-choi trials

Replicated trials of pak-choi, onion, and radish were conducted on two farms in San Leonardo. There were three treatments for each farm/crop combination: treatment 1 was the farmer practice for pesticide use, treatment 2 was pesticide use as determined by researchers, and treatment 3 received no pesticide.

Results were mixed. For farm 1, crops 1 and 2, cabbage webworm larvae were fewer and yields greater in farmer practice plots than in researcher managed plots. In contrast, researcher managed plots from farm 2 had fewer diamondback moth (DBM) larvae, fewer damaged plants, less incidence of web blight, and higher yield than did farmer practice plots (Table 91). The researcher managed plots received nine pesticide treatments compared to the five treatments on the farmer managed plots, but the volume of pesticide used by researchers was 21% less than the volume used by the farmers. Yields were extremely low in plots managed by farmers and researchers, and nil where no pesticide was used. We learned that the farmer practice of applying an insecticide immediately at crop emergence is more effective for cabbage webworm management than our strategy of delaying treatment until larvae are detected. Yet, cabbage webworms are not always a threat, and therein lies the problem: pesticides are often applied when there are no pests present, or when infestation is below the level at which action makes economic sense (action threshold, in this case unknown), but 1st instar larvae often escape detection because they are small and move to the plant's growing point soon after hatching, where they are enclosed by young, developing leaves. By the time larvae are visible, meristematic tissue has been destroyed and the plant dies. We believe, therefore, that the farmer practice of treating pak-choi at emergence during periods of high risk of cabbage webworm is a necessary part of IPM. Only when improved methods of detection are available can we defer treatment.

Onion trials

Over four onion trials there were 35.7% fewer sprays made to researcher plots than to farmer practice plots, and 66% less product applied. Mean yields across farms and crops were 13.7, 14.1, and 12.5 t/ha for farmer practice, researcher managed, and nil pesticide plots, respectively. There were no yield differences between farmer practice and researcher managed plots for any trial, but in two of the four trials yields from farmer practice (22 t/ha) and

Table 91. *Effect of pesticide treatments on number of diamondback moth and cabbage webworm larvae, percent damaged plants, web blight incidence, and marketable leaf weight in pak-choi on Farm 2 of R. Manalo, 6 September –12 October 1999*

Pesticide treatment	Pesticide sprays number	Pesticide sprays liters/ha	Diamondback moth larvae/0.25m² 27 DAS	Cabbage webworm larvae/0.25m² 13 DAS	Damaged plants (%) 27 DAS	Web blight incidence (%) 27 DAS	Marketable yield kg/m²	Marketable yield t/ha
Farmer practice	5	20	1a	0.67 b	47.79 b	35.50 a	0.07b	0.80
Researcher managed	9	15.7	0.33 b	0.78 b	29.72 c	11.31 b	0.23 a	2.3
Nil pesticide	0	0	0 b	5.11 a	100.0 a	0 b	0 c	0

Means in a column with common letter are not significantly different using Bonferroni test.
DAS = days after sowing.

researcher managed (20.6 t/ha) plots were higher than yields from nil pesticide plots (18 t/ha). In trials where yield was affected by treatment, the mean incidences of plants infected by *Colletotrichum gloeosporiodes* (cause of twister disease) were 3/m^2 in the nil pesticide plots, and 2/m^2 in the researcher managed plots. That is, fungicide sprays by researchers reduced incidence of *C. gloeosporiodes* by 33% and increased yield by 12–18%. Farmers mixed fungicide maneb with insecticides for each application (nine), whereas researchers made one application each of maneb and benomyl separately. We believe the farmer practice of mixing fungicides with insecticides and the poor coverage of plant surfaces by the spray account for the difference in disease incidence between farmer practice and researcher managed treatments.

Radish trials

Results from two farms show that farmers made a mean of nine pesticide treatments and applied 17 liters/ha of product, whereas researchers made a mean of 2.5 treatments and applied 4.3 liters/ha. Mean yields across farms were 6.1, 7.6, and 6.5 t/ha for farmer practice, researcher managed, and nil pesticide plots, respectively, and those yields are not significantly different. Pesticide treatments did not consistently reduce numbers of DBM larvae or prevent damage to foliage. Incidence of feeding damage by DBM ranged from 80–100% across treatments. Clearly, pesticide treatments were ineffective. Low root yields suggest that crop loss did occur, but we cannot conclude that that loss was due to DBM alone.

Pesticide residue analysis

Three samples of pak-choi (each 1 kg) were collected before harvest from each treatment/repetition to compare pesticide residue on farmer managed, researcher managed, and nil pesticide plots. The samples were placed in plastic bags, stored in a cool box and taken immediately to the National Pesticide Analytical Unit at the Bureau of Plant Industry (BPI), Quezon City, for pesticide residue analysis. We also purchased pesticides from agricultural stores in Gapan and Talavera and submitted them to BPI to check whether active ingredients conformed with information on the pesticide package labels.

Results show that residues of chlorpyrifos were significantly higher in farmer practice plots than in researcher and nil pesticide plots (Table 92) and exceeded the established maximum residue level of 0.05 mg/kg set by the Association of Southeast Asian Nations. Although chlorpyrifos and methamidophos were not applied to researcher managed and nil pesticide plots, residues were detected. Chlorothalonil was applied to researcher managed plots and residues were detected (0.004 ppm), but farmer practice plots were not treated yet residues were present (0.005ppm), as they were in the nil pesticide plots (0.005ppm). Assuming that the analytical procedures used by BPI were sound, these results suggest that spray drift might play an important role in pesticide residue levels. We do not know the proximity of fields treated with methamidophos relative to our plots.

Of the 17 pesticides submitted to BPI for analysis of purity, two gave markedly different quantities of active ingredient than was listed on the label. Both samples came from the same store in Gapan. A commonly used insecticide, chlorpyrifos (31.5 EC), had listed 210 g/liter active ingredient, but the quantity determined by analysis was 57.87 g/liter, a difference of 72%. Another insecticide, BPMC, was declared to have 105g/liter active ingredient, but the amount determined by analysis was 284.99 g/liter, 63% more than the label amount. BPI cites FAO specifications for plant protection products in stating that the active ingredient for products with 100 to 250 g/liter should be within 6% of the declared content. Three additional pesticides taken from the same store in Gapan and all 12 from a store in Talavera gave active ingredient amounts within FAO specifications.

There is speculation among plant protection specialists in the Philippines that reduced efficacy of some pesticides might be due to repackaging of materials with inert ingredients added to replace

Table 92. *Pesticide residue on pak-choi, July 1999*

Pesticide treatment	Pesticide and amount detected in ppm: Chlorpyrifos	Fipronil	Cypermethrin	Methamidophos
Farmer practice	0.19a	<0.01	ND	0.83a
Researcher managed	0.04b	<0.01	0.13	0.41 a
Nil pesticide	0.06b	ND	ND	0.68 a

Analysis done by the National Pesticide Analytical Unit at the Bureau of Plant Industry, Quezon City, Philippines. Residue values with common letter are not significantly different.
ND = not detected.

active ingredient. We believe additional testing should be done to determine if a pattern of faulty labeling exists among certain products and among certain sellers of agricultural chemicals.

Pesticide bioefficacy tests

We conducted two field trials in San Leonardo to test the bioefficacy of pesticides on pak-choi pests and diseases: trial 1 tested 12 insecticides on DBM and cabbage webworm infestations, and trial 2 tested 3 fungicides on infection by *Rhizoctonia solani*, the cause of web blight on crucifers.

No cabbage webworm larvae were observed in plots treated with diafenthiruron, whereas there were 7 larvae per meter row in control plots. Numbers of DBM larvae were reduced to 1.3/m-row from 11/m-row in control plots. Pak-choi yield from control plots was nil, but 4.4 t/ha was harvested from plots treated with diafenthiruron. Cypermethrin as Cymbush 5EC, but not as Arrivo and Sherpa 5 EC, significantly reduced numbers of cabbage webworm and DBM larvae, from 7 to 0.3 and from 11 to 2.7/m-row, respectively. And yield of treated plots was 3.65 t/ha. Diafenthiruron and Cypermethrin (Cymbush 5 EC) were superior to chlorpyrifos but not to profenofos, two common insecticides used on pak-choi.

Iprodione, but not chlorothalonil followed by mancozeb, reduced incidence of infection by *R. solani*, and increased yield of pak-choi.

There are differences in efficacy among insecticides and fungicides used for pest management in pak-choi. Chlorpyrifos is the insecticide of choice for pest control in pak-choi because it is cheap and available, but our data indicate that better choices exist. Iprodione is not sold in San Leonardo, but it is clearly superior to available fungicides.

Survey of Spodoptera by using sex-pheromone traps

Insect pests *Spodoptera litura* and *S. exigua* feed on many crops, and their host plants are grown year round in the project area. Host plant preferences and fecundity in relation to different host plants of both species are unknown, but it is unlikely that these factors play a major role in the abundance of Spodoptera species. From the larvae collected, only a few parasites emerged. Therefore, we believe parasites are not responsible for population fluctuations. Pheromone traps do not permit evaluation of numbers as a function of pesticide treatment because adult male moths are attracted across treatment boundaries. Climate data collected in Cabanatuan City showed an average daily temperature between 20 and 30°C, which is optimal for insect development. Also, relative humidity values recorded were favorable for development. We were unable to demonstrate a quantitative relationship between daily rainfall and insect numbers.

Identification of local beneficial arthropods of major insect pests on pak-choi

A wasp from the family Braconidae was identified from a larva of *Plutella xylostella*. Two species of fungi (based on color of mycelium) were observed on larvae of *S. litura*. Nuclear polyhedrosis virus (NPV) symptoms were observed on one larva of *S. litura*. Many larvae of cabbage webworm were infected with a protozoan belonging to the phylum Microsporidia (identified by the Federal Biological Control Centre for Agriculture and Forestry in Germany). Quantification of the Hellula larvae infected in the field with Microsporidia is difficult. Larvae were transferred to the laboratory for rearing on pak-choi, and because only older larvae show symptoms under stress, there is a chance that infection is transferred from larva to larva in the rearing cages. In February 2000, 500 Hellula larvae were placed singly in small plastic containers. Three died with Microsporidia symptoms after 2 days. Symptoms included immobility of the larvae, slow development, and color change from yellow-brownish to gray.

Of 511 *H. undalis* larvae collected from July 1998 to November 1999, none was infested with a parasite. A total of 547 *P. xylostella* larvae were collected from July 1998 to February 2000; one larva in October 1998 was parasitized by a Braconid wasp. For *S. litura*, 83 larvae were collected. Two died from a fungus infection, one had NPV symptoms, and one was parasitized by a Diptera.

Development of IPM training materials

The project has prepared a training poster and a pictorial guide to assist in the identification of insect pests and diseases on pak-choi in the San Leonardo area. The poster and the guide contain information about the three major insect pests, *Hellula undalis*, *Plutella xylostella*, and *Spodoptera litura*, and the disease web blight. In addition to the poster, information sheets for each pest were developed. These sheets contain information about host plant and damage, pest morphology, monitoring procedures, and pest management. And a booklet was designed that helps farmers determine when management intervention makes economic sense (based on number of larvae or number of infected plants). All materials, except the pictorial guide, were evaluated by farmers and Local Government Units from the San Leonardo area. Results of the evaluation were favorable and the materials were used in farmer training.

Biological control of the podborer, *Maruca vitrata* Fabricius on yardlong bean, *Vigna unguiculata* sp *sesquipedalis,* in lowland areas of the Philippines

Mass rearing of M. vitrata

We observed that females laid 42% more eggs when there were 10 pairs per cage than when there were fewer. Eggs were laid on upper leaf surfaces, on undersides of leaves, and on flowers. No eggs were found on stems or pods. It is very difficult to accurately count the number of eggs laid on cowpea. Therefore, we assumed that the number of eggs laid per female was the same as the number of first instar larvae observed. Furthermore, we assumed that only 70% of the eggs laid had hatched.

Upon hatching and then feeding for two days, first instar larvae were transferred to 50-ml plastic containers and given an artificial diet. Weight of pupae was greatest when larvae were fed a diet of 40 g of pods, 14 g of a commercial Spodoptera diet, and 3 g of potato dextrose agar in 150 ml of water. Adult *M. vitrata* moths survived significantly longer when fed sugar (7.4 days) and honey-sugar (7.9 days) than when fed water alone (4.9 days).

Survey of indigenous enemies of M. vitrata

During 1999, a total of 763 Maruca larvae were collected. Of these, 26 larvae were infested by an Agathidinae wasp, one larva by a fungus, and one larva by a Tachinidae. The wasp isolated from *M. vitrata* was identified by a Taiwanese research institute as *Bassus* sp (family Agathidinae). *Bassus* sp is a solitary-living larval parasitoid, but its efficacy has not been determined. *Agathis vulgaris* is the only insect belonging to the family Agathidinae that has been utilized for pest management in the tropics. Therefore, little is known about these insects.

In addition to these larval parasitoids six Braconidae, and *Trichogramma evanescens*, emerged from Maruca eggs, collected in April 1999 on the Central Luzon State University (CLSU), Muñoz, campus.

The insect pests *Aphis craccivora* Koch, *Maruca vitrata* Geyer, *Nephtottetix virescens* (Distant) and *Ophiomya phaseoli* (Tryon) were identified as major pests on yard long bean in Muñoz in 1999. *O. phaseoli* was observed to be a secondary pest on pods infested previously with *M. vitrata* larvae.

Seventeen percent of *M. vitrata* larvae collected from bean flowers and only 3% collected from pods were infested by the parasitoid *Bassus* sp.

Efficacy of neem and diatomaceous earth on black bean aphids

Mean numbers of aphids per yardlong bean plant 10 days after treatment with different neem-diatomaceous earth formulations were 996.4 for water, 144 for azadirachtin (100 mg/liter), 25.2 for azadirachtin (100 mg) + diatomaceous earth (1g/liter) and 2 for azadirachtin (100 mg) + diatomaceous earth (2g/liter). All treatments were significantly different from water alone (Tukey's HSD test).

Building partnerships

Technology transfer in the Philippines requires support from local government units (LGUs). We refer here to mayors, barangay captains, and extension agents. Municipalities have the authority to assign responsibility to extensionists and grant or withhold resources. Because of the hierarchical nature of municipality governance and social structure, extensionists and farmers follow the lead of elected officials. Therefore, farmer support of technology adoption is linked to official support. To further the testing and adoption of technologies among farmers in San Leonardo, we have enlisted the support of LGUs in San Leonardo and Marilao.

Memorandum of agreement (MOA) and memorandum of understanding (MOU)

An MOA was signed on 15 June 1999 by CLSU President Dr. Rodolfo C. Undan, representing the CLSU-AVRDC-TUM (Technical University of

Munich) peri-urban vegetable project, and by Mayor Eulinio Nagaño, representing the local government of San Leonardo, Nueva Ecija. Dr. Undan and Engr. Leoncio Duran, Mayor of Marilao, Bulacan, signed an MOU on 15 November 1999. Both agreements aim to 1) encourage sustainable vegetable production practices that enhance year-round vegetable supplies to urban areas, and 2) evaluate a combination of farmer participatory and farming systems research methods for the development and dissemination of peri-urban vegetable production technologies.

Capability building and technology promotion

Evaluation of training materials

Selected farmer leaders and extension workers evaluated training materials on 18 February 2000. Integrated nutrient management (INM) and IPM information materials were rated excellent, while an INM flip chart, IPM poster, and IPM booklet were rated good, which indicates room for improvement. It was suggested that more information be provided to clarify IPM and INM concepts, and that a larger typeface be used. All respondents recommended that the materials be reproduced so that more people can benefit.

Field days

Two field days showcasing production of leafy vegetables using net barriers and organic + inorganic fertilizer were held, one on 11 March 1999, the other on 17 February 2000. A total of 43 farmer leaders, 4 extension workers, 29 researchers, and 14 local government officials attended. Attendees expressed satisfaction and gave positive feedback about the technologies. They said that the net barriers could be used for other vegetables.

Training

Training on management of pak-choi was conducted on 7 March 2000 for farmers growing pechay in Nieves and Castellano, and with extension workers assigned to those areas.

Technology fairs

Grafted tomato for off-season production, solid waste management for peri-urban vegetable production, and management of pak-choi were showcased at technology fairs conducted by local government units and some state colleges and universities.

Scientific conferences

Two papers were presented at local and national scientific conferences. *Grafted tomato for off-season production* was judged best paper, crops sector, and *Waste management for peri-urban vegetable production* was judged best paper, agricultural resources sector, at the CLSU Agency In-house Review of Completed and On-going R&D Projects. The papers were also presented at the annual conference of the Crop Science Society of the Philippines, 10–13 May 1999, General Santos City.

Print and broadcast media

The peri-urban vegetable project was showcased in several local and national newspapers, and on radio and television.

Other linkages were developed. The Land Bank of the Philippines, through its Technology Promotion Center (TPC) Project, has earmarked money to document the cost and return from grafted tomato seedlings production. If found feasible, TPC will produce grafted seedlings for farmer cooperators. TPC is also interested in validating the use of net barriers for pak-choi production. If such production is found feasible, TCP will provide loans to farmers.

Program III

Collaboration in research and germplasm management

The principal aims of Program III are to build up the research capacity of national agricultural research systems and to promote international multidisciplinary collaboration in vegetable research and development through networking. To these ends, projects in Program III focus on collection, conservation, and exchange of germplasm; publishing, communications, information exchange, and documentation; and training. The program also provides management support to the Center’s farm operations, bilateral and regional programs and special projects, and coordinates the Center’s collaborative links with national and international agricultural research centers, universities, and advanced laboratories.

Project 8. Germplasm conservation, characterization and exchange

The objective of Project 8 is to improve production and increase biodiversity through collection and exchange of germplasm. Within the project there are two subprojects 1) *ex-situ* conservation of vegetable germplasm for preservation and exchange and 2) enhancing the efficiency of vegetable germplasm utilization. The activities in subproject 1 include 1) a vegetable germplasm collection conserved *ex-situ* in the Center's Genetic Resources and Seed Unit (GRSU) and 2) vegetable accessions conserved at GRSU regenerated for preservation and exchange. Subproject 2 has four activities: 1) vegetable germplasm utilization enhanced through widespread distribution, 2) genetic diversity in the vegetable germplasm collection characterized and analyzed, 3) documentation done for effective genebank management, and 4) strategies for producing healthy seeds for preservation and exchange developed. In addition, there are two special projects: 1) collection, conservation, and utilization of indigenous vegetables and 2) duplication at the Crop Genetic Resources Center, Taiwan Agricultural Research Institute (TARI), of vegetable germplasm conserved at AVRDC.

Collection, conservation, and utilization of indigenous vegetables

Special project on conservation of indigenous vegetables

July 1999 marked the implementation of a new project "Conservation and Utilization of Indigenous Vegetables." This project is funded by the Asian Development Bank (RETA 5839) and will be coordinated by AVRDC. The main objective of the project is to improve the conservation and utilization of indigenous vegetables in South and Southeast Asia. This objective will contribute to the long-term goals of improved human nutrition and reduction in poverty. Five countries will participate in the project: Bangladesh, Indonesia, Philippines, Thailand, and Vietnam. The countries were chosen on the basis of the following criteria: they are within an area of known vegetable genetic diversity and have a rich cultural heritage that includes the use of many traditional vegetable species; they are also suffering genetic erosion at a fast rate due to development. These countries are also part of various vegetable research networks coordinated by AVRDC.

The scope of the project includes the following components: 1) conservation and utilization of the genetic resources of indigenous vegetables, 2) human resources strengthening in the conservation and utilization of indigenous vegetables, 3) identification of species of indigenous vegetables with potential for inclusion in production systems, and 4) identification of species and varieties of vegetables for processing.

Conservation of indigenous vegetable germplasm

In this component, the following activities will be undertaken: 1) collection of indigenous vegetable germplasm (about 2500 accessions, or about 500 per country, will be collected) 2) conservation of collected genetic resources; and 3) multiplication of collected germplasm for exchange and utilization.

Human resources strengthening

The project will provide research fellowships and research internships equivalent to 40 person-months to staff of the collaborating countries. Training will be provided in genetic resources conservation, diversification of the agricultural environment, adaptation of indigenous vegetables to production systems, and processing to enhance year-round availability of vegetables.

Evaluation for potential in production systems

About a tenth of the collected species will be included in performance evaluation trials to identify species that have high potential in production systems.

Evaluation for potential for processing

New methods of processing will be explored. For example, potential for sprouting and utilization as shoots will be evaluated. The effect of traditional as well as new methods of processing and food preparation on availability of micronutrients will also be studied. About a tenth of the collected species will be utilized in this evaluation.

Table 93. *Priority indigenous vegetables for collection, conservation and utilization.*

Genus	Species	Bangladesh	Indonesia	Philippines	Thailand	Vietnam	Countries
Amaranthus	spp	X	X	X	X	X	5
Solanum	spp	X	X	X	X	X	5
Benincasa	*hispida*	X		X	X	X	4
Corchorus	spp	X		X	X	X	4
Luffa	spp	X		X	X	X	4
Alternanthera	spp	X	X		X		3
Canavalia	spp	X		X	X		3
Centella	*asiatica*	X	X		X		3
Coccinia	spp	X		X	X		3
Cucurbita	spp			X	X	X	3
Cucumis	*sativus*	X		X	X		
Lablab	*purpureus*	X		X	X		3
Lagenaria	*siceraria*			X	X	X	3
Momordica	spp	X		X	X		3
Oenanthe	spp		X		X	X	3
Portulaca	*oleracea*	X	X		X		3
Psophocarpus	*tetragonolobus*	X		X	X		3
Talinum	*triangulare*		X	X	X		3
Trichosanthes	spp	X		X	X		3
Vigna	spp			X	X	X	3
Abelmoschus	spp			X	X		2
Allium	spp			X		X	2
Basella	*alba*	X		X			2
Brassica	spp	X		X			2
Cajanus	*cajan*			X	X		2
Cosmos	spp		X		X		2
Emilia	*sonchifolia*		X		X		2
Enhydra	*fluctuans*	X			X		2
Hibiscus	spp		X	X			2
Lactuca	*sativa*		X	X			2
Limnophila	spp		X		X		2
Moringa	*oleifera*	X		X			2
Ottelia	*alismoides*	X			X		2
Oxalis	spp		X				2
Phaseolus	*lunatus*			X	X		2
Plantago	*major*		X		X		2
Spilanthes	spp		X		X		2
Acalypha	*indica*		X				1
Achyranthes	*aspera*		X				1
Ageratum	*conyzoides*		X				1
Ancilema	spp		X				1
Andrographis	*paniculata*		X				1
Anethum	*graveolens*				X		1
Apium	*graveolens*			X			1
Bidens	spp		X				1
Blumea	spp		X				1
Capsicum	spp			X			1
Chenopodium	*album*	X					1
Clitoria	*ternatea*			X			1
Coleus	*atropurpureus*		X				1
Commelina	spp		X				1
Coriandrum	*sativum*				X		1
Cyanotis	*eristata*		X				1
Cyclea	*barbata*		X				1
Daucus	*carota*			X			
Desmodium	*trifolium*	X					1
Elephantopus	*scaber*		X				1
Erichtites	spp		X				1
Eryngium	*foetidum*				X		1
Fagopyrum	*cymosum*				X		1
Forrestia	*marginata*		X				1
Glinus	*oppositifolius*				X		1
Glycine	*max*			X			1
Grotophyllum	*pictum*		X				1
Gynura	*crepidoides*		X				1
Hemigraphis	*colorata*		X				1
Hydrocotyle	*sibthorpioides*		X				1
Impatiens	*balsamina*		X				1
Ipomoea	*aquatica*	X					1
Jussiaea	*repens*	X					1
Justicia	*gandarusa*		X				1
Lycopersicon	spp			X			1

Planning workshop

A planning workshop was held at AVRDC headquarters on 16–18 August 1999. After representatives of the participating countries and counterpart staff of AVRDC presented papers, a list of species was drawn up. Representatives from each country listed indigenous species deserving priority based on agreed criteria. The species had to be seed producing, primarily used as a vegetable, herbaceous, and hold some national priority with regard to conservation and utilization. The list of priority species and the countries that chose them are shown in Table 93. Species chosen by three or more countries will be given priority. (Collecting forms, characterization data sheets, and taxonomic keys have already been compiled.)

Contact: L M Engle

Duplication of germplasm at the Crop Genetic Resources Center, Taiwan

AVRDC and TARI's Crop Genetic Resources Center are collaborating on regeneration and characterization of vegetable germplasm. The purpose is to duplicate stored germplasm and related information. In 1999, a total of 3505 accessions (1406 *Glycine*, 1026 *Vigna radiata*, 332 *Capsicum*, 265 *Solanum*, 86 *Luff*a, 77 *Allium*, 51 *Lycopersicon*, 44 *Abelmoschus*, 44 *Brassica*, 43 *Amaranthus*, 41 *Cucumis sativus*, 29 *Lagenaria*, 24 *Cucumis melo*, 23 *Benincasa*, 12 *Cucurbita*, and 2 *Trichosanthes*) were sent to TARI.

Contact: L M Engle and Huang Y-K

Vegetable germplasm collection for food security and biodiversification

This ongoing activity is done in collaboration with national agricultural research systems and AVRDC's research and training outreach offices. Its purpose is to assemble and conserve efficiently at GRSU a comprehensive collection of vegetable germplasm for utilization in crop improvement programs and help preserve biodiversity. The collection also includes indigenous and regionally important species.

Germplasm collection maintained at AVRDC

A total of 218 accessions were acquired in 1999 from 20 countries. The collection now holds 45,806 accessions, of 75 genera and 191 species (Table 94). The new acquisitions included 71 accessions collected in Vietnam, 60 Capsicum accessions from the Center's pepper breeding unit, 22 Chinese cabbage from the Center's olericulture unit, and 16 Solanum accessions from the Center's country (Taiwan) program, and 9 selections of *Solanum*

Condt. Table 93.

Genus	Species	Bangladesh	Indonesia	Philippines	Thailand	Vietnam	Countries
Malva	*verticillata*	X					1
Marumia	*muscosa*		X				1
Melastoma	*malabaricum*		X				1
Mentha	*merdinah*		X				1
Mucuna	*curanii*			X			1
Nasturtium	*officinale*	X					1
Neptunia	*oleraceae*		X				
Ocimum	spp				X		1
Osmorhiza	*aristata*		X				1
Oxystelma	*esculentum*				X		1
Pachyrrhizus	*erosus*			X			1
Paederia	*scandens*		X				1
Phaseolus	*vulgaris*			X			1
Physalis	*angulata*				X		1
Pilea	spp		X				1
Polygonum	*odoratum*				X		1
Raphanus	*sativus*			X			1
Raphistelma	*hooperianum*				X		1
Rorippa	spp		X				1
Rumex	*vesicarius*	X					1
Sagittaria	*sagittifolia*				X		1
Sesuvium	*portulacastrum*				X		1
Sonneratia	*caseolaris*		X				1
Stichnos	*ligustrina*		X				1
Suaeda	*maritima*				X		1
Trianthema	*portulacastrum*				X		1
Xanthium	*strumarium*			X			1

aethiopicum from AVRDC's Africa Regional Program. The rest were donated by private individuals, government agencies, and various research projects, such as the AGRISUD-Battambang Program in Cambodia.

Contact: L M Engle

Vegetable accessions conserved at GRSU regenerated for preservation and exchange

The regeneration of new acquisitions and stored accessions with low viability and/or low quantity is an ongoing activity of GRSU. The objective is to produce enough seeds for the base and active collection.

Table 94. *Accessions of vegetable germplasm conserved at GRSU as of December 31, 1999*

Crop	Total no. of accessions	Accessions acquired in 1999
Principal crops		
Glycine	14,142	4
Capsicum	7341	66
Lycopersicon	7184	0
Vigna radiata	5616	4
Solanum	2341	40
Brassica	1618	28
Allium	1071	5
Sub-total	39,313	147
Other Crops		
Vigna unguiculata	1384	0
Phaseolus	585	3
Vigna mungo	481	0
Luffa	461	2
Cucumis	387	4
Abelmoschus	276	0
Amaranthus	258	8
Cucurbita	247	2
Vigna unguiculata ssp *sesquipedalis*	237	4
Pisum	214	0
Lablab	180	0
Vigna unguiculata ssp *unguiculata*	63	4
Others	1720	44
Sub-total	6493	71
Total	45,806	218
No. of genera	75	32
No. of species	191	31
No. of countries	137	20

A total of 2355 accessions of 10 crop groups were regenerated in 1998–99 (Table 95). The shallot and garlic germplasm collections were maintained in a field genebank.

Within-accession variation in regenerated mungbean

During regeneration it is not unusual to detect variants within an accession. Usually, the curator makes a decision on whether to split the accession into variants or to bulk the accession. Genetically segregating materials are bulked, whereas mixtures of true breeding materials are split into different accessions.

Within-accession variation in seed coat color and luster has been observed in regenerated mungbean. This study was conducted to observe the extent and nature of such variation. The degree of genetic segregation as measured by within-plant variation was also determined.

One hundred and twenty mungbean accessions originating from seven countries were used in the study. Three pods were harvested from each plant (20 plants of each accession). Seeds harvested from one plant were placed in a paper envelope. Seed coat color, luster, hilum color, and 100-seed weight were recorded for each plant. These traits were compared with the traits of the original seed.

The accessions can be classified into five types: 1) Accessions that did not show within-accession variation in seed traits and were similar to the original seed. These accessions were considered homogeneous and genetically similar to the original

Table 95. *Number of germplasm accessions regenerated in 1998-99*

Crop Species	No. of accessions
Glycine max	1138
Vigna radiata	395
Capsicum	277
Garlic	257
Onion	67
Shallot	33
Solanum	69
Momordica	37
Brassica	33
Lycopersicon	28
Amaranthus	20
Beta	1
Total	2355

seed. Of the 120 accessions studied, 23 accessions (19%) belonged to this group.

2) Accessions that were mixtures of different types. Two accessions (2%) showed within-accession variation. These two accessions did not show within-plant variation. These accessions were considered to consist of mixtures. The mixtures were separated and the accession split into different types.

3) Regenerated material that was different from the original material. Six accessions (5%) had no seeds similar to the original seeds. These regenerated seeds were rejected. Regenerated seeds from these accessions were discarded. The accessions will be replanted for verification.

4) Accessions that contain off-types. Eleven accessions had 95% of the plants with seeds similar to the original seeds. Off-type seeds were removed and discarded.

5) Segregating accessions. For the rest (78 accessions or 65% of the total), the percentage of those similar to the original seed ranged from 5 to 90%. It was observed that in this group there were seeds from the same plant that exhibited different traits. This was considered to be due to genetic segregation in a heterozygous material. The seeds harvested from the same accession were thus bulked.

Due to the presence of within-accession variation in the mungbean collection, a large percentage of which is probably due to genetic segregation of heterozygous material, it is recommended that regenerated material be examined on a per-plant basis to determine if the genetic integrity of the accession has been maintained through the regeneration procedure, to identify and remove off-types, and to determine if the material consists of mixtures of different types or is heterozygous and segregating. This will be the basis for bulking, splitting, or rejecting the regenerated seeds of the accession.

It has always been difficult to decide whether a variant is an off-type and should be rogued-out, or is a mixture and should be split, or is the result of genetic segregation. The above procedure will provide a less subjective basis for making such decisions.

It is worth noting that although mungbean is often classified as a highly self-pollinated crop, the presence of a high degree of heterozygosity suggests that a significant amount of cross-fertilization, probably insect mediated, occurs.

Percent germination in species of Solanum after one week post-harvest ripening

Post-harvest ripening is known to increase initial seed viability in some plant species. This experiment was done to determine initial viability of seeds from newly harvested fruit and effect of post-harvest ripening on germination of eggplant seeds. The material included 54 accessions of *Solanum melongena*, three accessions of *S. aethiopicum*, and one accession of *S. sisymbriifolium* from different countries. They were among the accessions regenerated in 1998–99, harvested from April to June 1999. In one group, seeds were extracted immediately after harvest. In the other group, the harvested fruits were put inside net cages and allowed to ripen further (ambient temperature about 25ºC) for one week, by which time the fruits were soft. Seeds were extracted using the wet extraction procedure and put inside net bags and transferred to the drying room (15ºC, 15% RH) for two weeks. Initial viability based on percent germination ranged from 6.3 to 98.5% in *S. melongena* that did not undergo postharvest ripening. For *S. aethiopicum* the range was 39.5–57.8%, and for *S. sisymbriifolium* it was 35.3%. The lower percent germination in *S. aethiopicum* and in *S. sisymbriifolium* might be due to dormancy.

In all species, significant differences were observed in percent germination of seeds from newly harvested fruits and seeds from fruits that underwent post-harvest ripening. In *S. melongena*, mean germination rate immediately after harvest was 85.5%, compared to 78.7% after one week post-harvest ripening. In *S. aethiopicum*, germination rate immediately after harvest was 70.8%, compared to 28.3% after post-harvest ripening. The effect of post-harvest ripening on *S. sisymbriifolium* was the same as for *S. aethiopicum*. Post-harvest ripening increased germination 3.3–67.5%. The reason for the differences observed need to be studied further.

Contact: L M Engle

Vegetable germplasm utilization enhanced through widespread distribution

More than 20,000 samples, including breeding lines, were sent out from headquarters in 1999 (Table 96). About 96% went to 89 countries, and about 3% went to AVRDC regional offices. More than 4000 samples

(21% of the samples sent out) came from the AVRDC genebank (Table 97). The recipients were another genebank for duplicate storage, government organizations, international projects in developing countries, private companies, private individuals, and universities. The materials were used for various research activities, demonstrations, and home gardens.

A little more than 200 samples from the genebank were given to other AVRDC units for various research.

Table 96. *Recipients of germplasm from AVRDC in 1999*

Recipient	No. of samples	Total
External		20,044
Taiwan	3751	
Korea	3290	
USA	1720	
India	1082	
China	1029	
Vietnam	705	
Philippines	572	
Cambodia	526	
Bangladesh	390	
Others (80 countries)[1]	6467	
Regional Center/Program		543
ARP	231	
ARC	148	
Bangladesh project	127	
REDCAHOR	37	
Internal		225
Breeding		
soybean	23	
peppers	12	
eggplant	8	
alliums	1	
Physiology	77	
Entomology	42	
Analytical Lab	24	
Pathology	21	
Crop and Soil Management	17	
Total		20,812

[1] Angola, Argentina, Australia, Austria, Barbados, Belize, Bhutan, Botswana, Brazil, Burkina Faso, Bulgaria, Canada, Cape Verde, Congo, Costa Rica, Curacao, Czechoslovakia, Denmark, Dominican Rep., Ecuador, Egypt, Ethiopia, Fiji, France, Gambia, Germany, Ghana, Haiti, Hong Kong, Indonesia, Iran, Israel, Italy, Ivory Coast, Jamaica, Japan, Jordan, Kenya, Kyrgyzstan, Laos, Malawi, Malaysia, Mali, Marshall Is., Mauritius, Mexico, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Caledonia, Nicaragua, Nigeria, Pakistan, Palau, Papua New Guinea, Paraguay, Portugal, Republic of South Africa, Reunion, Samoa, Sao Tome and Principe, Seychelles, Singapore, Slovak, Spain, Sri Lanka, St. Christopher and Nevis, St. Vincent and Grenadines, Sudan, Swaziland, Tanzania, Togo, Trinidad and Tobago, United Arab Emirates, United Kingdom, Vanuatu, Zambia, Zimbabwe.

[1] ARC = AVRDC's Asian Regional Center, Thailand; ARP = AVRDC's Africa Regional Program; Bangladesh project = AVRDC-USAID Bangladesh Project; REDCAHOR = Collaborative Network for Vegetable Research and Development for Central America, Panama, and Dominican Republic.

Material transfer agreement (MTA) implemented

Since November 1999, each seed shipment has been accompanied by 1) a copy of the Guiding Principles of the Asian Vegetable Research and Development Center on Intellectual Property Rights, which includes Protocol 1 on Genetic Resources, Protocol 2 on Breeding Lines, Elite Germplasm, and Hybrid Parental Lines, and Protocol 3 on Inventions and Materials Related and Derived from Genetic Engineering, 2) two copies of MTA on Genetic Resources or MTA on Improved Genetic Materials,

Table 97. *Recipients of materials from the Genetic Resources and Seed Unit (31 December 1999)*

Classification	No.	No. of samples	Purpose
Genebanks	1	3570	Duplicate storage, research (genetic identification, core collection, evaluation, RAPD, breeding and genetics
International projects	6	274	Trials, screening for resistance to insect pests and diseases
Government organizations	16	212	Trials, screening for resistance to rust, bacterial wilt, insects, early maturity, breeding and genetics
Universities	15	183	RAPD, demonstration material, identifying resistant genes in species, susceptible check to *Alternaria solani*, trials, research
Private companies	9	68	Trials
Individuals	6	47	Trials, home garden
Seed companies	4	30	Trials, observation and crossing, research
Total		4384	

3) seed shipment list, 4) seed treatment protocols (if any is recommended), and 5) a phytosanitary certificate issued by the Council of Agriculture, ROC. So far, the response has been satisfactory. Signed MTAs are being returned by recipients.

Contact: L M Engle

Strategies for producing healthy seeds for preservation and exchange

Effect of seed treatments on elimination of pepper mild mottle virus and Xanthomonas campestris *pv.* vesicatoria

Seed-borne pathogens can reduce seed viability and even block seed movement due to quarantine regulations. Germplasm utilization can, therefore, be enhanced by production of pathogen-free seeds. AVRDC hosts the largest germplasm collection of peppers in the world, and seed production of peppers is routinely conducted at the Center in order to fill seed requests. Therefore, seed health research on peppers was initiated. Pepper mild mottle virus (PMMV), a tobamovirus, and *Xanthomonas campestris* pv. *vesicatoria* (Xcv), the causal agent of bacterial spot, are two important seed-borne pathogens. Tobamoviruses can usually be eliminated by trisodium phosphate (TSP) treatment. Several seed treatments have been developed for Xcv. Double treatment (called AA treatment in the following text) of soaking in acetic acid, then in Clorox® bleach, can eliminate the pathogen. The objective of this study was to determine the efficacy of TSP and/or AA treatment on the elimination of PMMV and Xcv from pepper seeds, considering the interaction of the treatments and their effects on seed viability.

Three experiments were conducted. Each followed a factorial treatment arrangement in completely randomized design with two or three replications. The two factors in each experiment were treatment and entry. Pepper seed lots used in Experiment I and III were Blue Star (F_2), Passion (F_2), VC10a (Yolo Wonder), and Szechwan, which were harvested from PMMV infected fruit. For Experiment III, the seeds were artificially contaminated with Xcv by coating with bacteria (strain XVT28, race P1) with 1% (w/v) carboxymethyl cellulose. One seed lot each of Queen Star, a commercial hybrid cultivar and its F_2 seeds, and two seed lots of Early Calwonder (ECW) were used in Experiment II. The F_2 seeds of Queen Star and one of the ECW seed lots were harvested from fruit showing bacterial spot symptoms, and the other two seed lots were contaminated artificially.

The procedures for TSP treatment included: 1) soaking seeds in 10% (w/v) $Na_3PO_4.12H_2O$ at 100 g seed per 250 ml TSP for 30 min, 2) removal of TSP solution by centrifugation, 3) soaking in fresh TSP for another 2 hours, 4) removal of TSP solution, rinsing in running tap water for 3 min, and 5) repeating centrifugation and rinses three more times. The procedures for AA treatment included: 1) soaking 2 g seeds in 10 ml of 1.3% (v/v) acetic acid, and shaking for 4 hours, 2) rinsing the fermented seeds with tap water three times, 3) soaking the seeds in 10 ml of 4× dilution of Clorox (or 1.25% [w/v] sodium hypochloride) for 5 min, and 4) rinsing under running tap water for 15 min. Double treatments (either TSP or AA first) were applied to determine whether there is interaction effects, and whether the treatments can be applied continuously.

Following treatment, seed extracts prepared from seed coats (as exterior part) or embryos (as interior part) were inoculated on detached tobacco leaves (*N. tabacum*) to detect infectious PMMV. Appearance of local lesions indicated the presence of infectious virus. Xcv was detected by infiltrating seed extracts (soak seeds in peptone buffer for 1 hour, sonicate for 1 hour, and concentrate 10× by centrifugation) on leaves of ECW, which is susceptible to all races infecting peppers. Lesions would indicate the presence of a large amount of live Xcv (greater than100 CFU/g of seeds); absence of lesions but detection of Xcv from the infiltrated area would indicate the presence of a small amount of live Xcv (less than 100 CFU/g of seed); absence of lesions and no Xcv detected from the infiltrated area would indicate the absence of live Xcv. In Experiments II and III, seeds were dried after seed treatments and tested for germination one month later.

AA treatment was not effective against PMMV, because it could not eliminate internal virus (Table 98). However, infectious PMMV could not be detected in interior and exterior parts of contaminated seeds following TSP treatment. Applying TSP treatment before or after AA treatment did not affect the efficacy of TSP. For eliminating Xcv, AA treatment was more effective than TSP (Table 98). However, AA treatment could not eliminate the large amount of Xcv in some of the artificially contaminated seed lots. This kind of high contamination is unlikely to exist under natural conditions. TSP treatment can reduce the amount of Xcv without affecting the efficacy of AA treatment. Germination of these pathogen-contaminated seed lots was reduced by seed treatment, particularly AA treatment (Table 98). Whether the reduction in germination is specific for pathogen-infected seeds needs to be studied further. In conclusion, if pepper seed lots were detected positive for PMMV and Xcv, TSP and AA treatments could be applied consecutively to eliminate both pathogens. However, germination of treated seeds might be reduced.

Effect of seed treatments on viability of pepper seeds

Seeds can be treated before sowing to eliminate potential seed-borne pathogens, in order to produce healthy seeds. In pepper, common seed treatments include fungicide or hot water treatment (used mostly for fungal pathogens), acetic acid and/or Clorox treatment (used mostly for bacterial pathogens, such as *Xanthomonas campestris* pv. *vesicatoria* [Xcv]), and trisodium phosphate (TSP) treatment (used mostly for tobamoviruses). It is not known whether pepper varieties have specific or similar responses to seed treatments. Therefore, this study was done to determine the effect of various seed treatments on percent germination of pepper seeds.

Twenty seed lots (10 each from sweet pepper and hot pepper) were used in this study. They were produced between 1992 and 1997. Seven treatments were applied: treatment 1 (T1), no treatment, used as control; T2, hot water treatment (seeds soaked in 50ºC water bath for 30 min); T3, TSP (for procedure see previous report); T4, TSP followed by AA (acetic acid and Clorox) treatment (for procedure see previous report); T5, AA followed by TSP; T6, AA; and T7, Clorox (soak in 4× Clorox or 1.25% [w/v] sodium hypochloride for 5 min and rinse under running tap water for 15 min). Seeds were dried after treatment and tested for germination one month later. The experimental design was a factorial completely randomized design with three replications. Group comparison among the treatments was conduced by partitioning the mean square in analysis of variance (ANOVA). The groups selected for comparison were T1 vs. T2 to T7 (non-treated vs. treated), T4, 5, 6 vs. T2, 3, 7 (treatments with AA vs. those without AA), T4, 5 vs. T6 (double treatments vs. single AA treatment), and T2 vs. T3, 7 (non-chemical treatment vs. chemical treatments).

Results of ANOVA showed significant effects of treatment, entry, and treatment × entry. Overall, seed treatments increased germination rate in both hot pepper and sweet pepper entries (Table 99). However, there were different responses among entries. Among hot pepper entries, the treated seeds

Table 98. *Efficacy of seed treatments in elimination of pepper mild mottle virus (PMMV) and* Xanthomonas campestris *pv.* vesicatoria *(Xcv) from pepper seeds*

Treatment[1]	Exp. I[2]		Exp. II[4]		Exp. III[7]			
	PMMV[3]		Xcv[5]	G.(%)[6]	PMMV[3]		Xcv[5]	G.(%)[6]
	Interior	Exterior			Interior	Exterior		
Control	+	+	++/+	85.9 a	+	+	++	61.9 a
TSP	-	-	+/-	84.9 a	-	-	++/-	45.0 b
TSP/AA	-	-	-	67.1 b	-	-	+/-	24.2 d
AA/TSP	-	-	-	64.9 b	-	-	+/-	34.6 c
AA	+	-	-	64.6 b	+	-	+/-	30.8 c

[1] Control – no seed treatments; TSP – trisodium phosphate treatment; TSP/AA – seeds were treated with TSP and then with acetic acid; AA/TSP – AA first then TSP; AA – AA only.
[2] Seeds in Experiment I were contaminated with PMMV naturally.
[3] Results of PMMV detection from seed coats (exterior) or embryos (interior); + means presence of infectious virus and, - means absence of infectious virus.
[4] Seeds in Experiment II were contaminated with Xcv naturally or artificially.
[5] Results of Xcv detection; ++ means presence of a large amount of live Xcv (>100 CFU/g of seed; + means presence of a small amount of live Xcv (<100 CFU/g of seed); - means absence of live Xcv.
[6] Percent germination (G.) was determined one month after seed treatments. The values presented are means of two replications over seed lots. Germination was not tested in Experiment I. Means within the same column followed by the same letter are not significantly different at P = 0.05 by Duncan's Multiple Range Test.
[7] Seeds used in Experiment III were the same as Experiment I, which were coated with Xcv before seed treatments.

(T2 to T7) had a 10.6% increase in germination compared to the non-treated one (T1). And 7 out of 10 entries had significantly higher germination rates after seed treatment, while the others had similar germination. Mean percent germination of sweet pepper entries over treatments was 7.7% higher compared to the non-treated control. All sweet pepper entries had similar or significantly higher germination after treatment, except PBC 491, which showed significantly lower germination. In a previous study, it was observed that germination of pathogen-contaminated seeds might be reduced by seed treatment. It is possible that PBC 491 was contaminated with some seed-borne pathogens. The increase in germination in some entries might have been due to the reduction of seed-borne pathogens. Based on the results, the tested seed treatments could be applied routinely to disinfect original seed prior to seed production. All treatments with AA (T4, T5, and T6) resulted in lower germination than the non-AA treatments (T2, T3, and T7). We have observed that AA-treated pathogen-contaminated seed lots have lower germination than the non-treated ones. Therefore, AA treatment should be used only when the seed lots are detected positive for Xcv. When AA and TSP treatments were applied consecutively (T4 and T5), germination was similar or significantly lower (2 out of 20 entries) than AA treatment (T6) alone. Thus, the double treatment should only be used when seeds are detected positive for both Xcv and tobamoviruses. Hot water treatment (T2) is a common treatment for disinfecting seeds. However, results showed that T2 resulted in similar or significantly lower germination than did TSP and Clorox treatments. This indicates that pepper seeds might be more sensitive to heat than to TSP or Clorox.

Contact: J F Wang

Table 99. *Effect of seed treatment on germination of pepper seeds (mean percent germination of different treatment groups[1])*

Entry	T1 vs. T2-7	T4,5,6 vs. T2,3,7	T4,5 vs. T6	T2 vs. T3,7
1. PBC 148	31.5 vs. 51.3 * [3]	49.7 vs. 52.8	48.8 vs. 51.5	54.0 vs. 52.3
2. PBC 461	6.0 vs. 20.1 *	22.3 vs. 17.8	20.5 vs. 26.0	17.0 vs. 18.3
3. PBC 462	47.5 vs. 44.3	45.8 vs. 42.7	44.8 vs. 48.0	42.5 vs. 42.8
4. PBC 549	75.0 vs. 76.5	69.7 vs. 83.3 *	72.3 vs. 64.5	81.0 vs. 84.5
5. PBC 569	69.5 vs. 80.3 *	80.0 vs. 80.7	79.3 vs. 81.5	71.0 vs. 85.5 *
6. PBC 583	38.0 vs. 56.6 *	53.2 vs. 60.0 *	50.5 vs. 58.5	63.0 vs. 58.5
7. PBC 593	51.5 vs. 74.2 *	69.0 vs. 79.3 *	68.3 vs. 70.5	76.5 vs. 80.8
8. PBC 602	92.0 vs. 88.6	84.2 vs. 93.0 *	84.8 vs. 83.0	93.5 vs. 92.8
9. PBC 619	7.0 vs. 19.4 *	20.5 vs. 18.3	23.0 vs. 15.5	21.0 vs. 17.0
10. PBC 743	43.5 vs. 56.6 *	57.2 vs. 56.0	57.3 vs. 57.0	52.0 vs. 58.0
Mean H [2]	46.2 vs. 56.8	55.3 vs. 58.4	54.9 vs. 55.6	57.2 vs. 59.0
11. PBC 196	26.5 vs. 24.3	16.5 vs. 32.0 *	16.3 vs. 17.0	37.0 vs. 29.5
12. PBC 275	16.5 vs. 34.3 *	34.0 vs. 34.7	35.8 vs. 30.5	27.5 vs. 38.3 *
13. PBC 347	41.5 vs. 47.2	42.0 vs. 52.3 *	31.0 vs. 64.0 *	39.0 vs. 59.0 *
14. PBC 458A	16.5 vs. 41.0 *	38.5 vs. 43.5	34.8 vs. 46.0 *	42.0 vs. 44.3
15. PBC 470	67.0 vs. 86.4	85.8 vs. 87.0	85.3 vs. 87.0	77.5 vs. 91.8 *
16. PBC 491	50.0 vs. 36.9 *	22.8 vs. 51.0 *	22.8 vs. 23.0	45.0 vs. 54.0
17. PBC 682	26.5 vs. 32.8	25.3 vs. 40.2 *	26.5 vs. 23.0	33.5 vs. 43.5 *
18. PBC 710	16.5 vs. 21.6	14.0 vs. 29.3 *	14.5 vs. 13.0	33.8 vs. 27.0
19. PBC 787	54.0 vs. 74.2 *	72.7 vs. 75.7	73.8 vs. 70.5	76.0 vs. 75.5
20. PBC 825	79.5 vs. 72.8	69.2 vs. 76.5 *	67.0 vs. 73.5	68.0 vs. 80.8 *
Mean S [2]	39.5 vs. 47.2	42.1 vs. 52.2	40.8 vs. 44.8	47.9 vs. 54.4

[1] T1: Control; T2: hot water treatment; T3: trisodium phosphate (TSP) treatment; T4: TSP followed by acetic acid (AA) treatment; T5: AA followed by TSP; T6: AA treatment; T7: Clorox treatment.

[2] Mean H: mean over Entry # 1 - 10, which are hot peppers; Mean S: mean over Entry # 11 - 20, which are sweet peppers.

[3] Significant difference between each treatment group within each entry was indicated by *. Means were significantly different within each entry based on LSD at 0.05 level. LSD (T1 vs. T2-7) = 5.02; LSD (T456 vs. T237) = 3.8; LSD (T45 vs. T6) = 5.69; LSD (T2 vs. T37) = 5.69.

Project 9: Collaborative research and networks for vegetable production

The objective of Project 9 is to increase the capacity of national agricultural research systems (NARS) to perform regional collaborative research, and to enhance the adoption and impact of research innovations. To this end, AVRDC fosters and supports effective regional and inter-regional research collaboration. In particular, the Center facilitates this collaboration using participatory research planning methods, and engages directly in collaborative research with NARS partners and advanced laboratories.

The following reports summarize the work of AVRDC's collaborative programs in Bangladesh, Korea, Philippines, the Republic of China, and the Collaborative Vegetable Research and Development Network for Central America, Panama and the Dominican Republic. The activities of the South Asia Vegetable Research Network (SAVERNET) are reported as part of Program I.

AVRDC–USAID Bangladesh project

The AVRDC project entitled *Technology development and transfer for sustainable vegetable production and enhanced nutritional status in Bangladesh*, funded by the United States Agency for International Development (USAID), has been in operation, in collaboration with the Bangladesh Agricultural Research Institute (BARI) and Bangladesh Agricultural Research Council (BARC), since June 1993. The project has been providing valuable advanced breeding lines/varieties of different vegetable crops to various agriculture research institutions. Such collaboration has enabled BARI and other research organizations to develop and release several promising high yielding vegetable varieties, which will increase the productivity and consumption of vegetables in Bangladesh, and enhance food and nutritional security. In cooperation with non-governmental organizations (NGOs), the project has also been active in technology transfer, in the form of on-farm demonstrations, assistance with establishing home gardens, and training of farmers, trainers, and scientists on various aspects of vegetable production.

Contact: D P Singh

Introduction of germplasm

In 1999, about 216 germplasm accessions of 16 vegetables from AVRDC and other sources were provided to BARI and the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) for evaluation and utilization.

Tomato

Twenty-nine lines of tomato were evaluated at BARI, Joydebpur, during winter 1998–99. TM0999 produced the maximum number of fruit per plant. The yield range was 31.4–91.2 t/ha, the highest being from TM0972. Total soluble solids (TSS) content was high in TM0993, TM0994, TM0995, and TM0997 (6.06–6.37°brix). In terms of yield, TM0968, TM0971, TM0972, TM0974, TM0975, TM0977, TM0978, and TM0979 are the most promising lines.

Beta-carotene and cherry tomato

Yield trials of high beta-carotene (ß-gene) tomato entries were successfully carried at two Bangladesh locations: BARI at Gazipur (north of Dhaka) and with the Mennonite Central Committee (MCC) near Maijdi in Noahkhali district. Both trials were conducted in the peak vegetable season from November 1998–April 1999. Entries, selected fruit characters, and yields are given in Table 100. Mean entry yields were large in both trials, indicating that many of the entries are adapted to peak season conditions at the two locations. The mean yield at MCC was slightly lower, possibly because the trial was conducted in a farmer's field rather than at a research station. Several fresh market entries performed well at both locations, including CLN1314B, CLN1314E, and CLN1314G. The cherry tomato entries as a group yielded less than the fresh market entries, but that was expected. These entries will be evaluated in demonstration trials and on-farm in Bangladesh during 1999–2000. At the same time, large-scale seed multiplication of the entries is being carried out at AVRDC for international distribution.

Garlic

Fifteen virus-free garlic lines were evaluated at BARI's Spices Research Centre (SRC) during rabi (winter, December–February, cool/dry) 1998–99. The yield of GC0014, at 6.9 t/ha, was superior to that of any other line.

Muskmelon

Twenty-five muskmelon lines were evaluated during summer 1999 at BARI, Joydebpur. The highest yield per plant was obtained from MM104 (8.6 kg), followed by MM117 (7.9 kg), MM118 (7.7 kg), and MM107 (6.4 kg).

Watermelon

Twenty-eight varieties of watermelon were evaluated during summer 1999 at BARI. The highest yield was obtained from WM146 (31.4 t/ha); WM140, WM125 and WM142 all yielded more than 23 t/ha. WM132 was best for TSS content (11°brix) followed by WM125 (10.1°brix).

Research trials

Regional yield trials of promising tomato lines during winter 1998–1999

Six promising tomato lines (and Ratan as the check) were tested at BARI, Joydebpur, and its four regional stations. TM0944, TM0945, and TM0949 were promising at Joydebpur and Hathazari; TM0854-2-2 and TM0854-2-3 were best at Jessore and Ishurdi; and TM0949 was best at Jamalpur. Further testing is needed to confirm the results.

Two promising processing tomato lines (TM0928 and TM0931) were evaluated along with Lalima at five locations. Lalima was the best at Joydebpur, but the poorest at Jessore and Hathazari. TM0928 was better at Hathazari and Jessore, but was the poorest at Joydebpur. The evaluation needs to be repeated.

Four promising cherry tomato lines were evaluated at BARI and its four regional stations. The yield of HTM006 was higher (but not significantly) than that of the other lines. The trial needs to be repeated.

Three beta-carotene-rich tomato lines (along with TM0835 [Apurba] as check) were evaluated at Joydebpur, Hathazari, Ishurdi, and Akbarpur. TM0922 produced the highest yield at Ishurdi and Hathazari (72.2–72.4 t/ha), and TM0835 (check) was best at Akbarpur and Joydebpur (54.1–58.9 t/ha).

Regional yield trial of advanced early garden pea lines

Two promising lines of garden pea (GP006 and GP018) were evaluated (along with BARI Motor Shuti-1 as check) during rabi 1998–99. GP018 was early with reasonable yield at all the locations. This promising line is ready for release for early pea cultivation.

Table 100. *Characteristics of selected high beta-carotene tomato lines in Bangladesh*

Entry	Beta-carotene (mg/100g)[1]	Fruit size (g)	Disease resistance[2]	BARI yield (t/ha)	MCC yield (t/ha)
CLN1314G	6.59	182	BW, TMV, I	85.7a-c	71.0ab
CLN1314A	4.16	177	BW, TMV, I	63.2f-g	67.0a-c
CLN1314E	4.60	211	BW, TMV, I	78.5b-d	60.5a-e
CLN2070A	7.07	58	BW, TMV, I	47.2hi	58.0a-e
CLN2071C (ck)	4.33	44	BW, TMV, I	35.8j	43.9c-g
CaroRed (ck)	3.60	82		NT	39.6d-g
CLN1466D (ck)	1.18		BW, TMV, I, GLS	88.2 ef	80.1a
Trial mean	5.75	65		64.4	49.0

Means followed by the same letter within columns are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[1] Beta-carotene contents for entries were determined at AVRDC.

[2] Disease resistance: BW = bacterial wilt tolerance, TMV = resistance to tobacco mosaic virus (conditioned by the *Tm*2[2] allele), I = Fusarium wilt race 1 resistance, GLS = gray leaf spot.

NT = not tested; BARI = Bangladesh Agricultural Research Institute; MCC = Mennonite Central Committee (NGO).

Seed multiplication for screening against excess-moisture and drought in mungbean

AVRDC provided 500 mungbean accessions to BSMRAU during 1998 for screening for drought and excess moisture tolerance. The first step was to multiply seed. The germplasm was planted out in kharif I (March–May), and 316 plants produced flowers and seeds. Seed yield per plant ranged between less than 1 g and almost 60 g. Of the 316 plants, 59 yielded more than 30 g and nine produced more than 40 g of seeds.

Effect of grafting in watermelon

Agricultural Research Station Pahartali conducted a trial from August to December 1998 to determine whether grafting watermelon (variety Top Yield) onto bottle gourd rootstock can improve the growth and yield of the watermelon. Compared with nongrafted plants, the grafted watermelons had longer vines and more lateral branches, they produced both male and female flowers on higher nodes, and they flowered earlier: but none of these differences was significant. However, grafting did result in significant ($P<0.05$) increases in number of fruit per plant, TSS content, yield (56.9 t/ha from grafted plants, 3.5 times the yield of the nongrafted plants) and tolerance to fusarium wilt (43% of nongrafted plants died, compared with only about 3% of grafted plants).

Bacterial wilt resistance screening under field conditions

Twelve tomato lines supplied by AVRDC were evaluated at BARI, Joydebpur, during late rabi (winter) season, 1998–99. BL986 and BL1004 had no bacterial wilt infection. Slightly infected were L180 (4.16%), SX7611 (4.35%), and BL985 (4.35%). The highest yield was obtained from SX7610 (64.6 t/ha), followed by BL1004 (60.0 t/ha) and BL986 (59.4 t/ha).

Twelve eggplant varieties received from AVRDC, along with one local variety (Dohazari), were evaluated at Agricultural Research Station Pahartali during December 1998 to April 1999. All the lines showed resistance to bacterial wilt in the field (natural infection). After artificial inoculation, EG195 showed no wilting up to 28 days after inoculation, and only 20% of EG193 plants wilted, but the wilting rates of the other entries ranged from 55 to 100%.

Tomato yellow leaf curl virus resistance screening

Tomato yellow leaf curl virus (TYLCV) is a serious disease of tomato in Bangladesh. In rabi 1998–99, 14 *Lycopersicon* accessions were screened for resistance to this virus. The susceptible check (ATY13) showed the highest disease incidence, with 75% of plants showing symptoms. Five other entries (ATY1, 5, 7, 15, and 21) also showed some susceptibility (17–27%). ATY 10, 11, 14, 16, 17, 18, 22, and 23 showed no visual symptoms.

Thirteen pepper lines from AVRDC were also screened for resistance to TYLCV. Entries were planted in a screenhouse and in the field. Virus-like symptoms were seen on most of the accessions, but only one (PTY4) showed a positive reaction in a DNA hybridization test with a Bangladesh probe. In another trial, of five accessions of chili from AVRDC, only PBC176 and PBC491 showed no TYLCV infection in the field, but none of the entries showed a positive reaction to a DNA hybridization test.

Disease incidence and yield of advanced mungbean lines

During kharif-II season (June–November) 1998, a trial was conducted at BSMRAU with 68 advanced lines of mungbean obtained from AVRDC. The seeds of those 68 lines were planted for the second time in the kharif-I season 1999. To provide an environment conducive to viral infection, rows of a susceptible (spreader) line (Barisal local) were planted alternately with rows of the advanced lines. The unusual weather conditions during the season were already favorable for the spread of mungbean yellow mosaic virus (MYMV). Even so, most lines showed a great degree of tolerance to MYMV. In most cases, less than 10% incidence of MYMV was seen at flowering stage. Some 18 genotypes yielded more than 1 t/ha.

Impact analysis of okra and summer tomato cultivation

A study was undertaken by the Agricultural Economics and Statistics Section of the Horticultural Research Centre (HRC), BARI, to assess the impact of new technologies on types of vegetable cultivation, profitability, consumption patterns, extent of adoption, etc. The study was conducted in Manikganj, Jessore, Rangpur, and Chittagong districts. The average land holding of the farmers in the study areas was 0.99 ha, of which 0.33 ha was under vegetable cultivation. A total of 212 farmers were interviewed for the okra survey and 49 for the summer tomato survey.

Okra

BARI Dherosh-1, a new virus-resistant okra variety, has been cultivated for the past two years: the present cropping intensity is 252%. Use of this new variety has reduced the need (and cost) for pesticides, and the average area under okra cultivation on each farm has increased, from 0.13 ha in 1996 to 0.17 ha in 1997 and to 0.21 ha in 1998, thus increasing employment opportunities. The labor and power requirements for okra cultivation are 230 person-days and 26 animal-pair-days per hectare.

The average yield of okra was 11.4 t/ha, providing a gross margin of BDT 39,560/ha (about US$790/ha) and a benefit/cost ratio of 2.68 on a full-cost basis. The return to labor per day was BDT 220 (about US$4.4) against the daily wage rate of BDT 50 (about US$1). About 77% of the okra was sold immediately after harvest, and only about 9% was consumed by the farm family.

Consumption of all vegetables in the summer averaged 10 kg/family/week (238 g/person/day). In the winter, consumption was 14 kg/family/week (333 g/person/day).

The sampled farmers learned about improved technology for okra cultivation from NGOs. The index of adoption (area cultivated using improved technology as a percentage of total area under cultivation) of okra was 40. About 89% of sampled farmers said they would continue growing this crop in the next year.

Summer tomato

Most farmers in the study area started growing tomatoes in 1991–92, but summer tomato cultivation began only in 1996–97, with a cropping intensity of 241%. The area under summer tomato cultivation was 0.11 ha per farm in 1996 and 1997, but increased a little to 0.12 ha per farm in 1998. Most (78%) farmers grew summer tomato in the highlands. The labor requirement for summer tomato cultivation is 356 person-days per hectare, so the adoption of this crop has greatly increased employment opportunities.

The average yield of summer tomato was 12.3 t/ha; farms in Jessore produced the highest yields (17.1 t/ha). On average, gross margin was BDT 230,695/ha (about US$4600/ha) and the benefit/cost ratio was 5.15, on a full-cost basis. The return to labor per day was BDT 662 (about US$13.20) against the daily wage rate of BDT 50 (about US$1). About 71% of summer tomato produce was sold immediately after harvest and 20% was consumed by the farm family.

Average daily consumption of all vegetables per person was 167 g in the summer and 250 g in the winter.

The farmers obtained seeds/seedlings and information on improved technologies through NGOs.

The index of adoption for summer tomato was 31. The scarcity of supplies of Tomatotone hormone was a crucial constraint.

Socioeconomic study on food habits of tribal people

The Agricultural Economics and Statistics Section of HRC, BARI, Joydebpur, conducted a study of the food habits, especially the vegetable consumption, by tribal people in different parts of Bangladesh. Sixty households were surveyed in each of five areas over three seasons (kharif-I, kharif-II, and rabi). The main findings from the study were as follows:

- Area under vegetable cultivation ranged from 0.02 ha/farm (Cox’s Bazar) to 0.42 ha/farm (Khagrachari).
- The tribal people with the largest vegetable growing area were the Chakma people in Khagrachari (0.42 ha/farm) and the people with the smallest vegetable area were Rakhain people from Cox’s Bazar (0.02 ha/farm).
- Almost all of the respondents cultivated vegetables in their homestead areas in all seasons. Average areas under homestead cultivation were 0.03 ha/farm in kharif-I and 0.07 ha/farm in kharif-II and rabi.
- The respondents consumed about 70% of their vegetable production; the rest was sold in local markets.
- Vegetable consumption was recorded for the peak and lean periods of vegetable availability in each of the three seasons at each location. Over the peak periods, the Garo people in Sherpur had the highest average daily vegetable consumption (132 g/person) and the Rakhain people in Cox’s Bazar the lowest (59 g/person). Over the lean

periods, average daily vegetable consumption ranged from 32 g/person in Dinajpur (Saotal) to 61 g/person in Sylhet (Monipori). Over all seasons and all locations, average daily vegetable consumption was 81 g/person in the peak period and 45 g/person in the lean period. Consumption varied across income groups.

- In all of the study areas, vegetables were in shortest supply in kharif-II.
- The average yield of vegetables was low in all the tribal areas.
- The major constraints to vegetable production were found to be non-availability of high yielding variety seeds, high price of seeds, insecticides, and other inputs, non-availability of irrigation facilities, and lack of information on improved methods of cultivation.

The investigators made the following recommendations:

- Tribal people should be offered short-term training on improved production technologies and on awareness of the nutritional value of vegetables.
- Tribal people should have access to quality seeds at the right time and at fair prices.
- The Department for Agricultural Extension and NGOs should implement extension programs on vegetable cultivation in tribal areas.

Technology transfer

Field demonstrations through BRAC, rabi season 1998–99

The Bangladesh Rural Advancement Committee (BRAC) gave more than 200 demonstrations of new varieties of different vegetable crops.

- **Tomato**: six varieties were demonstrated with 40 farmers. BARI-3 and Ratan performed extremely well and were liked by the farmers. Apurba was not popular with the farmers. All varieties fetched similar prices.
- **Eggplant**: three varieties (Kazla, Nayantara, and Shingnath) were demonstrated with two farmers. Kazla proved to be the superior because of its high yield, followed by Nayantara.
- **Radish**: all four varieties demonstrated were equally good, and high in yield.
- **Dwarf bean**: only one variety, BARI Jhar Seem-1, was demonstrated. Its yield was not high (7.4 t/ha).
- **Peas**: Motor Shuti 1 and 2 gave high yields and were in good demand among the farmers.
- **Bottle gourd**: BARI Lau-1 exhibited excellent performance (62 t/ha).
- **Coriander**: BARI Dhania-1 gave good yield and fetched a good price. Its green leaves were well accepted by farmers.
- **Okra**: BARI Dherosh-1 was quite good. The variety continued to be virus free and was well accepted by farmers.

Field demonstrations through PROSHIKA, rabi season 1998–99

The NGO PROSHIKA gave about 270 demonstrations, as follows:

- **Tomato**: Six varieties (Apurba, Chaiti, Shila, Lalima, BARI-3, and Ratan) were tested at 15 locations with 88 farmers. Chaiti was the earliest to flower—62 days after sowing, with a range of 53–72 days at different locations. Apurba first flowered 81 days after sowing (range 75–87 days), gave the highest yield (83.9 t/ha, range 75–95 t/ha), and had the highest average fruit weight (115 g, range 100–136 g) and the most fruit per plant (24, range 22–33). In an evaluation of Chaiti, BARI-3, and Ratan at nine locations with 40 farmers, Chaiti was first to flower (60 days); average fruit weight was 71 g, yield 65.4 t/ha.
- **Eggplant**: Three varieties were demonstrated at two locations in Manikganj. Singhnath gave the most fruit per plant, followed by Nayantara. Fruit weight ranged from 70 to 220 g, the highest was Kazla followed by Nayantara. Singhnath yielded more than the newer varieties, but none gave a satisfactory yield. When only Kazla and Singhnath were tested with four farmers at two other locations (Savar and Pakundia), Singhnath was again superior.
- **Cabbage**: When Agradut and Atlas-70 (a popular hybrid) were demonstrated at five locations, their yields were not significantly different: Agradut yielded 6–8 t/ha and Atlas-70 yielded 8–10 t/ha.
- **Cauliflower**: The BARI-released variety Rupa was demonstrated with Snow Crown F_1 at six locations with 14 farmers. Curd formation started

at almost the same time in both varieties. Snow Crown was superior in terms of average curd weight and average yield, but Rupa, being an open-pollinated variety, is more popular with the farmers because it can produce seeds.

- **Bottle gourd**: BARI Lau-1 was demonstrated along with BADC-recommended Khet Lau at five locations with 40 farmers. BARI Lau-1 had far superior yield and earliness at all the locations.
- **Coriander**: BARI Dhania-1 variety was compared with a local variety at three locations with 80 farmers. The BARI variety matured a few days later than the local variety, but had a better yield performance.

Field demonstrations through Gonokallyan Trust (GKT), rabi season 1998–99

During rabi 1998–99, GKT conducted 115 field demonstrations of newer vegetable varieties.

- **Tomato**: The six varieties (mentioned above) were planted in the fields of 23 farmers. The fruits of Apurba, BARI-3, and Ratan were liked by most of the farmers. Ratan and BARI-3 outyielded the other varieties. Chaiti, BARI-3, and Ratan were tested by 20 farmers, who liked all the varieties.
- **Radish**: Tasakisan and Mino Early performed better than Pinky and the local check Red Bombay. Druti also performed well wherever it was demonstrated.
- **Bottle gourd**: BARI Lau-1 performed better than did Khet Lau.

Field demonstrations through MCC, rabi season 1998–99

In all, 63 trials of different vegetable crops were allotted to MCC.

- **Tomato**: Six varieties were demonstrated in eight districts. Chaiti had the best yield (range and average) and fruit size. Farmers liked it for its good yield, taste, and large fruit size, and because there was good demand for it in the market. Ratan was still favored by several farmers for its yield.
- **Cabbage**: Agradut was not found to be better than Atlas-70 in terms of head size and yield.
- **Cauliflower**: Rupa was not preferred over Snow Crown by the farmers.
- **Radish**: Most of the farmers preferred the color, taste, and softness of Pinky over Mino Early.
- **Eggplant**: Kazla was liked by the farmers
- **Bush bean**: BARI Jhar Seem-1 yielded well.

Mungbean demonstrations through BARI

Some 920 demonstrations of six improved varieties of mungbean were undertaken. In all locations, the improved varieties performed better than local cultivars with respect to yield (>1000 kg/ha) and other agronomic traits.

Selection of partner NGOs

A workshop was held on 26 April 1999 to identify NGOs to participate in the project's technology transfer program. A two-day training program was organized on 29–30 June 1999 at BARI to brief the trainers of the 23 selected NGOs on conducting the kharif-I demonstration trials, and on data collection.

During kharif-I season, the 23 partner NGOs were involved in implementing 2796 demonstrations and 9800 homestead gardens in 45 thanas in 34 districts. About 12,600 farmers were involved in these activities covering most of the agroecological zones of Bangladesh. The main crops for the demonstrations and homestead gardens were summer tomato, okra, kangkong, red amaranth, yard-long bean, bottle gourd, and stem amaranth. Most of the crops appeared to perform well: data on comparative yield performance are now being compiled and analyzed.

About 50 demonstrations on okra seed production were given in eight thanas through four NGOs; the aim was to make the seed production technologies available to farmers. These demonstrations were much appreciated by the NGOs, the seed growers, and the farmers, and there is an increasing demand to expand these demonstrations in the future.

During kharif-II 1999, about 1455 demonstrations of six vegetable crops (country bean, batisak [*Brassica chinensis*], chinasak [*Brassica parachinensis*], radish, kangkong, and tomato) were given in 45 thanas through 23 NGOs. In addition, about 19,700 homestead gardens were also established. Three vegetable crops (country bean, red amaranth, and yard-long bean) have been selected for homestead gardening.

Non-availability of quality seed is one of the main barriers to vegetable cultivation in Bangladesh, and poor farmers cannot afford quality seed. With the aim of making seed production technologies available to farmers, 50 demonstrations were organized on seed production of kangkong in 15 thanas through six NGOs.

There is a high demand for tomato in the kharif season, so there is wide scope for expanding summer tomato cultivation in Bangladesh. However, bacterial wilt is a serious problem in tomato cultivation, particularly in the kharif season. Grafting tomato onto bacterial wilt resistant eggplant rootstock can mitigate this problem, and 225 demonstrations of this technique were organized in 19 thanas through 10 NGOs.

Field days

During 1999, about 15 field days demonstrating baby corn, chili, eggplant, brocolli, summer tomato, okra, red amaranth, yard-long bean, and BARI Mungbean-2, 3, 4, and 5 were organized at various sties. They were attended by almost 1000 farmers, some local Department of Agricultural Extension workers, researchers, NGO personnel, and local people. The demonstrations concentrated on BARI summer tomato and BARI Mungbean varieties. BARI Tomato-4 and 5 performed excellently in most places: all the farmers were impressed and showed keen interest in cultivating the crop in the next year on a larger scale. BARI mungbean varieties also performed well in many places and impressed all who attended the demonstrations. All other vegetables performed well, to the satisfaction of farmers, partner NGOs, and extension workers. Farmers who attended these field days participated actively in the discussions, and asked for more demonstrations in their areas.

Exchange visits among NGOs

Exchange visits among NGOs is a new dimension of technology transfer and dissemination of AVRDC vegetable technologies. Banchte Shekha organized a visit for 25 of its demonstration farmers and field staff to see the demonstrations given by the Society for Social Service (SSS) in Tangail during the last week of September 1999. In return, SSS organized a visit of 10 persons to Banchte Shekha, Jessore. These exchange visits provided an opportunity for interaction among farmers and staff of two leading NGOs, which, it is hoped, will have a positive impact on technology dissemination.

Trainer training

During 1999, more than 650 trainers from partner NGOs attended 21 training courses on various vegetable technologies, organized by BARI regional stations and NGOs.

Farmer training

During 1999, partner NGOs and BARI regional stations organized more than 600 training courses, covering most of the agroecological zones of Bangladesh. The purpose was to make vegetable production technologies, developed by different research institutions, available to farmers. Almost 18,000 farmers attended these courses.

Monitoring of technology transfer and research activities

In order to check on project progress, assess the impacts of technology transfer, and decide on future directions, a monitoring and evaluation study was conducted throughout Bangladesh during kharif-I (July–September) 1999. The survey was specifically designed to evaluate the demonstration and homestead activities of the project. The collected information is still being analyzed, but preliminary analysis indicates that certain varieties of yard-long bean, okra, kangkong, bottle gourd, red amaranth and stem amaranth are well accepted by farmers and partner NGOs in most areas where the vegetables were introduced. Red amaranth variety BARI Lalsak-I did well in most places, except in southern and eastern areas. Summer tomato varieties BARI-4 and BARI-5 also showed good performance in most locations, despite moderate incidence of leaf curl virus.

Training, workshops, and publications

Eight BARI scientists attended specialized AVRDC training courses in Taiwan and Thailand during 1999.

A review workshop on vegetable research and development activities of the BARC/BARI–AVRDC–USAID Project was organized on 28–30 January 1999 at BARC, Dhaka. Twenty-two lectures were presented in the technical sessions, which were attended by more than 80 participants from NARS, NGOs, government organizations, international organizations, and private enterprise.

Vegetable cultivation technology packages for kharif-I, kharif-II, and rabi season have been developed by the Project and distributed to all partner NGOs. These manuals are very helpful to the partner NGOs in implementing demonstrations and homestead activities.

The Project printed 10,000 copies of two posters on the varieties of different vegetable crops released by BARI, one poster for winter crops and the other for summer crops.

Twenty-four units of seven titles of AVRDC publications were given to BARC's library.

AVRDC–Korea outreach program

The objective of research collaboration between AVRDC and the Korean Sub-Center is to increase farming productivity and profitability in Korea by developing improved varieties, especially of Chinese cabbage, tomato, pepper, mungbean, and soybean. As part of the crop improvement program, the Korean Sub-Center has introduced various germplasm accessions from AVRDC and implemented collaborative research activities with the National Horticultural Research Institute (NHRI) and the National Crop Experiment Station (NCES), Korea.

In 1999, a new mungbean variety was released by NCES for mungbean sprouts production. The variety, Jangan, has bruchid resistance introduced from an AVRDC mungbean breeding line, AV1-3-1 (Table 101). The AVRDC line was introduced in 1992 and used for making cross combinations to introduce the *Br* gene that confers resistance to bruchid (*Callosobruchus chinensis* L.), a major storage pest. Through repeated backcrosses, the resistant gene was successfully introduced in the background of a local variety, Keumseong, a productive and once-over harvest mungbean variety bred by Chonnam Agricultural Research and Extension Services.

Table 101. *Yield and agronomic characteristics of new mungbean variety,* Jangannogdu

Variety	First harvest	Plant height (cm)	Bruchid damage (%) Field[1]	Bruchid damage (%) Chamber	Yield[2] (t/ha)
Jangan	Aug 13	55	0	0	1.43
V1973A	Aug 16	61	7	100	1.18

[1] Field infection was scored at 60 days after harvest.

[2] Average yield of regional yield trials at two locations, 1997-1999.

The newly bred variety bears yellow flowers, black pods at maturity, and dull green seeds. It is shorter and more lodging resistant than V1973A, a mungbean variety bred by AVRDC and introduced in Korea by NCES. The new variety showed strong resistance against bruchids in field and growth chamber tests. The variety is 18% higher yielding (1.43 t/ha) than V1973A, locally known as Seonhwa.

Many other germplasm accessions received from AVRDC are being evaluated and used in several breeding programs. Cytoplasmic male sterile lines of Chinese cabbage and cherry tomato accessions are a few such examples.

Other activities in 1999 included evaluation of entries in AVRDC's 9th International Chili Pepper Nursery, and generation advance and seed multiplication of Korean breeding lines of legumes.

Contact: D G Oh

AVRDC–Philippines outreach program

The Philippines outreach program tests and adapts vegetable varieties and technologies from AVRDC and transfers them to farmers. Research is concentrated on mungbean, soybean, tomato, pepper, and onion. Germplasm from AVRDC is evaluated in preliminary yield trials (PYT) and general yield trials (GYT) in wet and dry seasons. Lines with promising yield, resistance to pests and diseases, and market preference, are further evaluated in regional yield trials (RYT) conducted at 8–10 testing stations throughout the country, in collaboration with other Bureau of Plant Industry and Department of Agriculture stations, agricultural schools, colleges, and universities. Varieties considered suitable for release to farmers are recommended, by the technical working group, to the approving committee of the National Seed Industry Council (NSIC).

The Bureau of Plant Industry–Los Baños National Crop Research and Development Center (BPI–LBNCRDC) at Los Baños, Laguna, was identified as a national center for tropical lowland crops in 1988. Research is focused on varietal improvement and cultural management of vegetables (including legumes) and ornamental crops. BPI–LBNCRDC was also mandated to produce breeder and foundation seed of NSIC-approved varieties, for multiplication at other BPI centers, local and national government units, and private seed companies. Developed varieties that have high yield and can be adapted to the multiple cropping schemes of lowland farmers play a vital role in productivity, profitability, and food security.

Contact: A A Virtucio

Seedboard varieties

Mungbean variety PSB-Mg6 (Centennial Mungo) was recommended in 1998 as part of the nation's centennial celebration, but was approved in 1999. It was developed from a cross between VC2755 and VC1482-E, both AVRDC lines. It was evaluated at 12 cooperating stations from 1995 to 1997, in eight wet season and 13 dry season trials. The variety has yield potential of 1.2 t/ha—13% more than the check. The plant matures in 58 days and shows moderate resistance to cercospora leaf spot and virus.

PSB-Mg7, another mungbean variety approved in 1999, was developed from a cross between VC1168-B and VC1973-A, both AVRDC lines. In 14 yield trials at 11 cooperating stations, this variety was a consistently high yielder with 1.13 t/ha in the wet season (16% higher than the check) and 1.08 t/ha in the dry season (11% higher than the check). A dull-seeded variety, its 100-seed weight is 5.4–6.3 g. The plant matures in 57 days and has moderate resistance to cercospora leaf spot and virus.

Table 102. *Number of entries evaluated in various crops, dry and wet seasons 1999*

Crop	Number of entries evaluated			
	IES	PYT	GYT	RYT
Mungbean	25	76	31	9
Soybean	46	29	11	10
Tomato		74	11	10
Eggplant	27	13		
Chili	20	23		
Okra	118			
Onion	12			
Shallot	13			
Garlic	15			
Squash	25			
Sweet potato		20	6	
Total	301	235	59	29

IES = introduction, evaluation, and selection; PYT = preliminary yield trials; GYT = general yield trials; RYT = regional yield trials.

PSB-Tm9 is a tomato variety developed from a cross between VC48-1 GS and Tamu Chico III, from AVRDC. A fresh market determinate type, the variety is recommended for both wet and dry seasons. Because of its heat tolerance, it has a potential yield of 25 t/ha (7% higher than the check) in wet seasons. Each plant produces 1.3 kg of fruit during the dry season and 0.85 kg in the wet season. The semi-globe, moderately firm fruit can be stored under ambient conditions for up to 44 days from harvest. The variety is moderately susceptible to radial cracking and early blight.

Varietal evaluations

The number of entries of various crops evaluated in 1999 are shown in Table 102. Okra had the highest number of entries in the introduction, evaluation, and selection (IES) scheme because it has been identified as a promising crop for export.

The RYTs in 1999 were conducted at up to 12 sites by the National Technical Working Group for Legumes and Vegetables. Results of the regional trials are highlighted below.

Mungbean

Nine mungbean lines were evaluated in eight to nine locations throughout the country. The wet season trial was planted on 10 February 1999. Three entries outyielded the local check (Table 103), but the differences were not significant. Seed size of EGM4195 was comparable to that of the check. The two AVRDC lines matured significantly (but marginally) later than did the check.

Table 103. *Performance of best mungbean entries in regional yield trials, various locations, dry season 1999*

Entry	Yield (kg/ha)	100-seed weight (g)	Days to maturity
IPB46-49-0	676 a	5.2 b	52 c
EGM4195	612 a	6.3 a	54 a
EGM4190	588 a	5.2 b	54 a
Mg50-10A (local ck)	585 a	6.2 a	53 b
Grand mean (of nine entries)	561	5.6	53
CV%	20.43	3.39	1.05

Means followed by the same letter within a column do not differ significantly.

The wet season trial, also of nine entries, was planted on 28 June 1999. Only one entry, EGM4310, outyielded the check (Table 104); its seed size was comparable to that of the check, but it matured significantly (although marginally) earlier.

Soybean

Ten soybean entries were evaluated at BPI-LBNCRDC, Los Baños; entries were planted on 11 February 1999.

The yield of EGSy98-4-27 was comparable to those of the national checks (Table 105). However, it had larger seeds and matured significantly earlier than did the highest yielding check.

Table 104. *Performance of best mungbean entries in regional yield trials, various locations, wet season 1999*

Entry	Yield (kg/ha)	100-seed weight (g)	Days to maturity
EGM4310	611 a	5.2 ab	51 a
PSBMg6 (national ck)	548 a	5.3 a	50 b
IPBM87-35-15	493 a	4.8 c	51 a
EGM4190	434 a	4.9 bc	51 a
Grand mean (of nine entries)	438	4.8	51
CV%	38.34	4.4	0.82

Means followed by the same letter within a column do not differ significantly.

Table 105. *Performance of best soybean entries in regional yield trials at BPI-LBNCRDC, dry season 1999*

Entry	Yield (t/ha)	100-seed weight (g)	Days to maturity
PSBSy6 (national ck)	3.3 a	15.4 b	102 a
EGSy98-4-27	3.2 a	19.0 ab	98 b
PSBSy8 (national ck)	3.1 a	19.6 ab	93 c
EGSy98-31-4	3.1 a	19.2 ab	104 a
Grand mean (of 10 entries)	2.9	19.1	99
CV%	10.07	6.07	0.96

Means followed by the same letter within a column do not differ significantly.

Tomato

Ten tomato lines were evaluated. Entries were transplanted on 10 February 1997, and harvested (four harvests) between 5 and 20 April.

ANT7 and ANT22, both AVRDC lines significantly outyielded the check variety (Table 106). ANT7 had larger fruit than either ANT22 or the check, and the AVRDC lines matured slightly (but not significantly) earlier than did the check.

AVRDC–ROC cooperative program

Bilateral vegetable research and development in Taiwan

The goal of the subproject is to increase the capacity of the national agricultural research system in Taiwan, to stabilize summer vegetable production, and to reduce seasonality of vegetable supply. The project continued to conduct adaptive research (trials) in cooperation with the NARS of the host country. The Republic of China (ROC) Council of Agriculture (COA) supports the project. Promising AVRDC vegetable varieties/lines are evaluated in the field in different seasons and locations in Taiwan in cooperation with various District Agricultural Improvement Stations (DAIS). The research and trials aim to complement the NARS and to identify promising vegetable varieties and improved cultural practices for release in Taiwan. To date, 15 AVRDC improved varieties of various crops, including mungbean, soybean, vegetable soybean, Chinese cabbage, processing tomato, fresh market tomato,

Table 106. *Performance of best tomato entries in regional yield trials at various locations, dry season 1999*

Entry	Yield (t/ha)	Fruit size (g)	Days to maturity
ANT7	18.1 a	40 a	55 a
ANT22	15.1 ab	28 b	55 a
DSF861-5	12.7 bc	29 b	57 a
BPI-Tm-1 (ck)	9.3 c	26 b	57 a
Grand mean (of 10 entries)	10.4	34	57
CV%	27.9	18.9	4.9

Means followed by the same letter within a column do not differ significantly.

and cherry tomato, have been released. Most of these varieties now make major contributions to vegetable production in Taiwan (Table 107).

Regional yield trials

In 1998–99, a total of 35 regional yield trials were conducted, in cooperation with Tainan, Taichung, Kaohsiung and Taoyuan DAIS, to evaluate AVRDC's improved varieties/lines of vegetable soybean, mungbean, fresh market and cherry tomato, and lettuce at different locations and in different seasons (spring, summer, and autumn).

In the vegetable soybean trials, nine lines were evaluated in 10 trials against three check varieties. The lines showed significant differences in pod yields. TS82-02V-03 gave the highest yield of 9.3 t/ha over seven locations in spring 1999, and also had the highest protein content at 44.4%.

Mungbean is a speciality in Chiayi. The local growers and consumers prefer large dull-seeded lines. The mungbean trials by AVRDC and Tainan DAIS identified three lines—NS81-36, VC6040A, and NS85-03—which outyielded the check (Tainan No 5). Their yields were in the range 1.81–2.06 t/ha.

Table 107. *Planted area and estimated production of AVRDC improved vegetable varieties in Taiwan, 1998*

Crop and varieties	Area planted to varieties: ha	Area planted to varieties: % of total production area of that crop	Production (t)
Fresh market tomato Taichung-ASVEG #4, Hualien-ASVEG #5	235	29	14,091
Cherry tomato Tainan-ASVEG #6	484	59	24,200
Mungbean Tainan #3 and #5	237	100	210
Soybean Kaohsiung #9 and #10, Tainan #1 and #2	793	100	2,300
Vegetable soybean Kaohsiung #1, Kaohsiung #2 and #3	2090	24	15,675

In fresh market tomato trials in spring 1999, three hybrids (FMTT552, FMTT553, and FMTT556) were tested against the check varieties Hualien ASVEG #5 and Taichung ASVEG #4 in three locations in Lanyang area. Mean yields ranged from 66.4 to 71.2 t/ha compared to 71.5 t/ha from the best of the checks, Hualien ASVEG #5. In the summer, five hybrids were evaluated in the Taichung area against the check, Taichung ASVEG #4. FMTT553, a large-fruited variety with dark green shoulders, gave the highest mean yield of 75.5 t/ha; average fruit weight was 155 g. The check yielded 74.8 t/ha with 122-g fruit. In trials of cherry tomato, none of the entries gave higher yields than the check, Tainan ASVEG #6 (CHT154).

Among the four lettuce varieties evaluated, LT86 gave the highest average yield, 28.6 t/ha, across spring and summer seasons in Taoyuan. The other two entries, LT40 and LT45, also outyielded the checks Takii and local variety Min Fun #3, but matured later than the local variety.

Variety evaluation trials

AVRDC continued to identify vegetables for recommendation to the host country NARS, to diversify the production and consumption of vegetables. In 1998–99, snap bean, yard-long bean, broccoli, cauliflower, and various green leafy vegetables were included in the project. Summaries of trial results and lists of promising accessions of these vegetables are presented in Table 108.

Samples of leafy vegetables were analyzed for nutrient content, and results are summarized in Table 109. Kale varieties (including *B. carinata*) were rich in vitamin C. Vitamin C, calcium, iron, and nitrate contents varied between spring and summer seasons within species.

Technology transfer

A fresh-market tomato hybrid developed by AVRDC is undergoing the process of naming and release by Taoyuan DAIS. This variety has large fruit with the dark green shoulder preferred by local consumers.

In order to transfer grafting technology to NARS and farmers in Taiwan, a field day and a four-day training course on grafting techniques for summer tomato production were conducted. The field day was held on 6 August 1999 in Taipao, Chiayi, to demonstrate the growth, productivity, fruit quality, bacterial wilt incidence, and flooding tolerance of grafted cherry tomato. The field day attracted more than 60 farmers and nursery operators in the Chiayi–Tainan area.

The training course was offered to local nursery operators, extension workers, and farmers in September 1999. The course comprised lectures, hands-on practice, and visits to grafted-tomato production areas and a nursery that raises grafted seedlings. Twenty participants completed the course, which was supported by the ROC Council of Agriculture and conducted by the AVRDC Technology Promotion and Services Unit in cooperation with Tainan DAIS. Topics included:

- an overview of cherry tomato production and problems of summer production and continuous cropping, such as high temperature, diseases, and flooding
- important diseases in summer and continuous cropping systems
- application of grafting techniques in tomato production—principles and methodology
- results of on-farm trials including economic assessment

Stock seed production and distribution

AVRDC produced stock seeds of released vegetable varieties for NARS, with the COA's support. In total, 2154 kg of cherry tomato, soybean, vegetable soybean, and mungbean seeds were produced and distributed in 1998–99.

Contact: N C Chen

Table 108. *Promising accessions of vegetables identified in the variety evaluation trials*

Crop	Number of entries	Yield range (t/ha)	Promising accessions
Bush snap bean	49	3.7-7.2 (Au) 3.0-17.1 (Sp)	BN248, BN259, BN260, BN268, BN269, BN281
Pole snap bean	38	3.3-21.6 (Au) 3.5-32.4 (Sp)	BN318,BN321, BN322, BN323, BN325
Yard-long bean	22	7.5-22.8 (Au) 6.5-15.4 (Sp)	VU057, VU072, VU097, TUN206, TUN 209, TUN210
Broccoli	13	9.8-14.2	Dark Horse F_1, Green Treasure, Triumph No.3
Cauliflower	15	12.2-24.4	White Shot F_1, Hybrid 501, Fremont F_1, Milkyway F_1
Amaranth	41 (Sp) 19 (Su)	1.1-5.8 (Sp) 1.2-2.9 (Su)	TOT1807, TOT2215, TOT2263, TOT2265, TOT2353
Kale	12 (Sp) 8 (Su)	4.6-13.3 (Sp) 1.5-16.0 (Su)	LV019, LV020, LV021, CN103, CN104
Mustard	11 (Sp) 6 (Su)	6.4-12.8 (Sp) 2.6-4.6 (Su)	LV008, TB473, TB559, CN078
Paitsai	12 (Sp) 8 (Su)	3.9-15.0 (Sp) 3.1-5.0 (Su)	CN098, CN099, TB518, TB550
Rape	16 (Sp) 11 (Su)	7.5-16.4 (Sp) 1.6-5.4 (Su)	TB439, TB570, TB571, TB599

Sp = spring crop; Su = summer crop; Au = autumn crop.

Table 109. *Nutrient contents of leafy vegetables*

Crop	Number of accessions	Dry matter (%)	Sugar (%)	Fiber (%)	Vitamin C (mg/100 g fresh matter)	Calcium (mg/100 g dry matter)	Iron (mg/100 g dry matter)	Nitrate (ppm)
Spring								
Amaranth	8	9.0	7.9	10.0	51	1769	50	2975
Kale	2	9.0	11.0	13.4	120	1048	16	3991
Mustard	6	5.2	8.4	13.3	65	828	40	3932
Paitsai	5	4.7	7.5	12.7	59	1320	62	3589
Rape	5	4.6	6.0	13.7	57	909	36	4239
Summer								
Amaranth	6	8.3	2.5	10.6	32	2330	22	3675
Kale	4	6.3	7.1	11.7	103	2131	28	4090
Mustard	3	6.2	15.1	11.6	80	1288	22	3754
Paitsai	3	5.5	13.4	12.0	65	1639	23	4165
Rape	5	5.4	10.3	12.3	70	1804	28	4168

REDCAHOR

Collaborative Vegetable Research and Development Network for Central America, Panama and the Dominican Republic

The Collaborative Vegetable Research and Development Network for Central America, Panama and the Dominican Republic (REDCAHOR) is a regional, coordinated effort aimed at evaluating genetic resources, validating varieties suited to growers' needs, and studying alternative methods for managing pests. The idea is to generate technological options and strengthen national varietal improvement programs, and teamwork, in the vegetable sector. The member countries conduct joint research activities aimed at solving problems affecting the crops to which they attach the greatest priority. A leader is assigned to each research project and common protocols are defined, so that results can be shared and materials exchanged. From June 1998 to June 1999, the Network conducted 54 research projects involving 66 researchers from 23 national institutions.

Contact: C G Kuo

Introduction of genetic resources

Tomato

Studies were aimed at selecting cultivars resistant to viruses, late blight caused by *Phytophthora infestans*, and bacterial wilt caused by *Ralstonia solanacearum*.

The selection of genotypes for resistance to whitefly (*Bemisia tabaci*) transmitted geminivirus complex was hindered by the fact that there was no significant infection in the field because of Hurricane Mitch. However, Nicaragua and Panama were able to make some observations, which were not conclusive but helpful. Nicaragua identified seven lines (i.e., 10660, TA02288, L00170, L06674, L02094, 6225, and L01830) as promising, and Panama three (05641, 08433, and 17337) that warrant further investigation.

Pepper

An average of 112 accessions were evaluated in each country, with a view to selecting plants resistant to viruses, to the pepper weevil, to bacterial wilt, and to early or late blight. In the Dominican Republic, PP977431, SN46, PP602, PP154, PBC590, PP977174 were promising in terms of fruit size, fruit form, fruit color. In Panama, 86 lines were found tolerant/ resistant to bacterial wilt. In Costa Rica, PP977122 and PBC830 were resistant to viruses with had good agronomic characteristics. Well-adapted sweet pepper or cayenne pepper were characterized and found to be acceptable for use in national selection and validation programs. Panama selected varieties (PP977116 and 6457) resistant to bacterial wilt, the most important constraint to pepper production in the country. Certain varieties of hot peppers were also evaluated and might be used by national programs.

Costa Rica reported identifying a sweet pepper variety (UCR-589) that shows great potential in terms of production and quality. This variety is being evaluated during the 1999-2000 growing season.

Cucurbitaceae

In Costa Rica, trials of summer squash (*Cucurbita pepo*) and winter squash (*C. moschata*) revealed great variability in yield, which might be attributable to the type of material used, or to the fact that the seeds came from plants in which pollination had not been controlled. REDCAHOR has also organized short courses, workshops and projects that have enabled researchers in the region to use molecular markers in the creation of a core collection of *C. moschata*.

Regional trials of commercial cultivars

The objective of these trials is to evaluate systematically the commercial cultivars and the advanced lines available, in terms of adoption, production, and market potential.

Tomato

Validation trials were conducted in two locations in each country. Each trial consisted of 22 cultivars and two checks (one regional and the other national). In all cases, quality, yield, and the incidence of the most important insect pests and diseases were evaluated.

In the case of fresh tomato, Costa Rica reported positively on the performance of the cultivars MTT-13 and IDIAP T-5, developed in Nicaragua and Panama, thus illustrating the potential of local research and the advantages of regional cooperation. In the Dominican Republic, resistance to nematodes and viruses was also evaluated. Heat Master, Acclaim, Saladinha, and Emperador were found tolerant to nematodes.

In trials of processing tomato: in Guatemala, Elios yielded 29 t/ha; in Honduras, Gem Pride yielded 110 t/ha, Sun 6216, 108 t/ha, APT391, 105 t/ha, Marina, 103 t/ha, Yaqui, 101 t/ha, Bright Pearl, 99 t/ha, and Veronica, 98 t/ha; in Panama, IDIAP–T7 yielded 64 t/ha; in the Dominican Republic, Gem Pride yielded 71 t/ha. In the Dominican Republic, IDIAP T-3 and F7332 yielded 58 t/ha and 56 t/ha, respectively. Despite displaying virus symptoms, they have potential in a zone where viruses are the most important threat to production. In Panama, it was decided that IDIAP-T7 is still the best option in terms of resistance to bacterial wilt.

Sweet pepper

The whitefly-transmitted geminivirus complex and weevils (*Anthonomous eugenii*) have restricted sweet pepper production in the region. Trials of sweet pepper were carried out in two different localities in each country, using one regional control and one line commonly used by producers.

Onion

Research on onions was conducted in the rainy (winter) and dry (summer) seasons. Thirty-three cultivars were evaluated in terms of yield, tolerance to pests and diseases, shape, color, precocity, and pryuvic acid.

For the dry season, several varieties, Nikita (Rio Colorado), Cougar (Peto), Mercedes (Peto), Yellow Granex (Sunseeds), and XPH 6700 (Asgrow), were acceptable in the market based on their shape size, color, neck size (thin), compactness, and dryness. Certain red and yellow onions did well in Santa Ana, Costa Rica, and Comayagua, Honduras. In Guatemala, the cultivars were evaluated in terms of both production levels and their susceptibility to *Alternaria porri*, *Botrytis* sp and *Peronospora* sp.

It was not possible to obtain results during the rainy season because of Hurricane Mitch.

Summer squash and winter squash

No conclusions could be reached due to bad weather and the lack of suitable cultivars. However, partial results were obtained in Costa Rica, Nicaragua, and the Dominican Republic. In Nicaragua, Criollo Mexicano and Criollo Nicaraguense varieties yielded promising results, 14 t/ha and 12 t/ha, respectively.

In the Dominican Republic and Panama, several trials were conducted with cultivars of zucchini, pumpkin, and summer squash. Dahifa variety, contributed by the IDIAP, Panama, had good thickness and good production at 9 t/ha.

Integrated pest and disease management

Emphasis was placed on development of varieties resistant to the whitefly-geminivirus complex, biological control of diamondback moth (*Plutella xyllostella*) of crucifers, development of options for managing pepper weevil (*Anthonomus eugenii* Cano), and on the biological management of larvae in tomato and onion.

Biological control of Plutella xyllostella *in cabbage*

The work focused on using three parasitoids from AVRDC headquarters, and it involved three stages: 1) quarantine of parasitoids; 2) multiplication; and 3) release and efficacy study. The introduced parasitoids had high survival rates and showed a high grade of dependency on the pest. *Diadegma semiclausum* and *Cotesia plutellae* had high parasitism in three areas (Sebaco, San Ramon, and Jinotega) in Nicaragua. The work deserves further study to evaluate the frequency of parasitoids by area and the pest density.

Because introduced parasitoid, *D. semiclausum*, was observed to be similar to native *D. insularis*, researchers at ZAMORANO investigated the reproductive processes of both species. Results suggest they are the same species.

The National University of Nicaragua (UNA) was responsible for multiplication of parasitoids. Preliminary results are available from UNA-INTA.

Evaluation of practices used to manage pepper weevil

Six chemical, biological, and cultural management options were evaluated, vis-à-vis the conditions prevalent in each country and the cultural practices most commonly used by farmers. *Bacillus thuringiensis*, *Beauveria bassiana*, polyhedrosis viruses, and extract of neem were tested. These products are being evaluated on plantations where pepper is grown in association with corn. The evaluation consisted of counting the number of diseased fruit, versus the results obtained with insecticides commonly used by farmers.

Alternative ways to manage larvae in tomato

Alternatives for managing *Heliothis* and *Spodoptera* were studied in Guatemala, including the use of *Bacillus thuringiensis,* polyhedrosis viruses, and neem. Results suggest that these biological control agents could be effective when applied at the right time, with the correct frequency, and in the proper dosage. More study is needed before a recommendation can be made. In the Dominican Republic, biological control agents were found to reduce pest attack by as much as 18% compared to the control treatment. Economic analysis is needed.

Other basic work in IPM

Work was carried out in Panama, Costa Rica, and the Dominican Republic with a view to learning more about the distribution and biology of pests. In Panama, studies were conducted to identify the species and biotypes of whiteflies, while in Costa Rica the principal insect pests of summer squash, and their natural enemies, were identified.

These studies contributed to a clearer understanding of important aspects of the specific problems affecting priority vegetables in the region. In Panama, it was determined that the B biotype of whitefly is the most abundant. In Costa Rica, it was determined that *Acalymma* sp and *Diaphania hyalinata* are devastating to the cultivation of winter squash.

Future studies must focus on determining their capacity to transmit viruses and on identifying their natural enemies.

Project 10: Information exchange on tropical vegetables

Research is not complete until its results are made public. And, no development effort can succeed without effectively communicating its goals and delivering its technologies. Project 10 is about gathering, packaging, and sharing information critical to the progress of vegetable research and development. The work is divided into two subprojects, the first dedicated to packaging information and the second dedicated to making information available to AVRDC scientists and cooperators.

Multimedia, electronic, and print publications

Some of the publications in 1999 included *AVRDC Report 1998*; *All the right ingredients: Feeding hungry cities in the next century*, produced for International Centers Week; three issues of *Centerpoint* newsletter (the newsletter was increased to thrice yearly in 1999, and will be published quarterly in 2000); three technology pamphlets in the *Cooperators' Guide* series; a slide set and booklet on rearing eggplant fruit and shoot borer; and translations of the Center's popular field guide entitled *Insect pests of selected vegetables in tropical and subtropical Asia*. A new brochure was also published in English and Chinese and a new slide show for visitors to the Center was produced.

How information was published in 1999 is as noteworthy as *what* was published. For the first time, AVRDC's annual report was made available on the Center's WWW site in PDF format, as were two *Cooperators' Guide*s. The site had more than 14,000 visitors from 100 countries in 1999. It will be continually enriched with content of use to researchers and extensionists. Print publications will continue to be important, but where the Center can make use of new technology to gain efficiency and reach, it will do so, in pace with cooperators' rising access to new information technologies.

The Office of Publications and Communications mailed more than 20,000 publications in 1999. The Center's mailing list was regularly updated and now contains 2969 entries, including 655 libraries in 144 countries. The office printed more than a quarter of a million pages and handled more than 350 art requests from Center scientists. More than 9700 photos were shot and processed.

Collecting and sharing tropical vegetable information

This subproject is handled principally by the Center's library. In 1999 the library delivered more than 1200 documents, loaned more than 4200 titles, and collected and catalogued hundreds of new acquisitions. Literature of use to vegetable researchers was searched and the findings were added to the library's collection databases, which can be searched by Center scientists via the Internet. AVRDC library staff also conducted 40 searches of CD-ROM databases and 33 searches of the library collection on behalf of Center scientists and cooperators.

The library conducts regular searches of literature of interest to vegetable researchers. The results of these searches are published as Selective Dissemination of Information bulletins. In 1998, the Center began publishing these on its website, and in 1999 a listserver was set up to allow people to sign up to receive these SDI bulletins regularly by email.

Contact: D G Abbass

Project 11: Training for research and development

The goal of this project is to increase skills among vegetable researchers in developing countries to conduct problem-solving research. In 1999, 89 scholars from 28 countries received training at AVRDC (Table 110).

Research internships

Eight research interns from Bangladesh, Bhutan, Korea, and Vietnam completed training programs (lasting two–six months) on entomology, mycology, pepper breeding, soybean breeding, socioeconomics, and genetic resource management. A research scholar from Japan undertook training on onion breeding, and two research fellows from the Philippines received training on olericulture and socioeconomics.

Special-purpose training

The International Cooperation and Development Fund (ICDF) of the Republic of China (ROC) continued to support AVRDC's training activities in 1999. ICDF funded a three-week course on vegetable cultivation and seed production in November for 18 participants from 17 countries. The course covered:

- principles and practices of crop management and protection
- seed production technologies
- practices applied by Taiwanese farmers
- organization of agricultural research and farmers' associations in Taiwan

Eight participants from Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka—the member countries of the South Asia Vegetable Research Network (SAVERNET), funded by the Asian Development Bank—attended one of two four-week training courses, held in June and September, on rearing of eggplant fruit and shoot borer. The program covered:

- eggplant fruit and shoot borer rearing: collection, feeding, adult maintenance
- use of sex pheromones
- management of crops: seedling raising, construction of barrier nets, timely cutting of damaged shoots
- visits to Taiwanese agricultural research and development centers

Graduate student training

AVRDC collaborates with National Pingtung University of Science and Technology (NPUST) in Taiwan and the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) to make its facilities and expertise available to graduate students doing thesis research on tropical vegetables. In 1999 three students were working at AVRDC under this program: an NPUST MS student from The Gambia working on the effects of vesicular arbuscular mycorrhizal inoculation and grafting on the production of summer tomato, and two BSMRAU PhD students from Bangladesh, one working on genetics of heat tolerance in tomato, the other on nutrient management in vegetable soybean.

Short-term training and summer interns

Four technicians from ROC agricultural technical missions in The Gambia, Palau, Nicaragua, and Fiji were supported by ICDF to undertake three–six day training programs at AVRDC.

An overseas Chinese technician from a private company in Argentina received eight days of individual training on vegetable production.

For the 25th consecutive year, AVRDC hosted undergraduate trainees from universities in Taiwan: there were 30 interns from 10 universities in 1999.

Eight undergraduate students from the University of the Philippines at Los Baños worked at AVRDC during the summer on parts of their thesis research on germplasm management, bacteriology, and molecular marker development.

Training materials

During the year, 54 slide sets with scripts and 13 videos were distributed to 20 training scholars from various countries.

Contact: T Kalb

Table 110. *Training scholars at AVRDC headquarters, by country and by category in 1999*

Country	PF	RF	RS	RI	SPT	VS	GS	UST	Total
Angola					1				1
Bahrain					1				1
Bangladesh				2	1		2		5
Belize					1				1
Bhutan				2	1				3
Dominica					1				1
Dominican Republic					1				1
Fiji					1				1
The Gambia							1		1
India	1				4				5
Japan			1						1
Korea				1					1
Malawi					1				1
Malaysia					1				1
Mali					1				1
Marshall Islands					1				1
Nepal					1				1
Pakistan					1				1
Paraguay					2				2
Philippines		2			2	2		8	14
São Tomé e Príncipe					1				1
Solomon Islands					1				1
Sri Lanka					1				1
St Christopher					1				1
Swaziland					1				1
Taiwan					2			30	32
Thailand					3				3
Vietnam				4	1				5
Total	1	2	1	9	33	2	3	38	89

PF = Postdoctoral Fellow; RI = Research Intern; RF = Research Fellow; SPT = Special Purpose Trainee; RS = Research Scholar; UST = Undergraduate Student Trainee.

Project 12: Technical services

The objectives of this project are to:

- enhance the capacity of local agribusinesses and public corporations to better serve vegetable producers
- create employment
- spur socioeconomic development

AVRDC is conducting research to better understand the functions and constraints of vegetable-related agribusinesses, and also to develop a mechanism to make available the Center's expertise and infrastructure.

Constraints of vegetable-related agribusinesses in Taiwan

A simple questionnaire survey was conducted in October 1999. Questionnaires were distributed to 58 vegetable-related companies in Taiwan—24 food-processors and 34 seed and seedling companies. By the end of the year, 33 completed questionnaires (56.9%) had been returned, 16 of 24 sent to the food sector and 17 of 34 sent to the seed and seedling companies. Survey results are summarized here.

Table 111. *Major products of food and seed companies in Taiwan*

Product	Food companies (respondents)		Seed companies (respondents)	
	(no.)	(%)	(no.)	(%)
Seeds	1	6	17	100
Seedlings	0	0	8	47
Frozen vegetables	14	88	-	-
Dehydrated vegetables	4	25	-	-
Pickled vegetables	3	19	-	-
Others[1]	2	13	2	12

[1] Others includes vegetable juices, stored vegetables, fresh vegetables.

Table 112. *Relative importance of vegetable crops in food and seed industries in Taiwan*

Product	Food companies (respondents) (%)[1]	Seed companies (respondents) (%)[1]
Cucurbits	6	82
Solanaceous crops	25	77
Legumes	81	41
Root and stem crops	69	71
Leafy vegetables	56	77
Others[2]	6	29

[1] Percent that reported the crop is important.

[2] Others includes sweet corn, ornamental crops, and turf grasses.

Major products

The major products of the food and seed companies are listed in Table 111. The main vegetable crops handled by the companies are listed in Table 112. Legumes are the most common vegetables, particularly for frozen foods.

Research and development in food and seed industries

Some 44% of food companies and 71% of seed companies have established research and development departments. Among the food companies, the research and development budget is generally less than 10% of the total budget; main activities are the development of local and international markets. Most of the seed companies devote 10–20% of their total budget to research and development, and spend these funds mainly on developing new varieties and products.

Table 113. *Relative importance of technical services required by food and seed companies as perceived by survey respondents*

Service item	Food companies (respondents) (%)[1]	Seed companies (respondents) (%)[1]
Seed production	25	18
Disease identification	69	94
Evaluation of disease/insect resistance	6	53
Identification of vegetable varieties	38	47
Purity tests of vegetable varieties	0	35
Plant/food nutrient analysis	56	18
Molecular tools	6	41
Development of analytical methods	6	24
Others	13	47

[1] Percent that reported the service item is important.

Major constraints

Food and seed companies both report that weakness in research and development, in coming up with new products/varieties, is an important constraint (Figure 21). Shortages of raw materials and labor are the next serious constraints in the food industry. Seed companies consider human resources to be the most serious constraint. The cost of introducing or developing new technologies and the cost of seed production are also important constraints in the seed industry.

About 82% of seed companies and 44% of food companies have established branches or substations in foreign countries. All the food companies have branches in China, where labor cost is much lower than in Taiwan. For the same reason, most seed companies have set up branches or substations in China or Thailand. Food and seed companies are also increasingly establishing branches in Vietnam (apparently, production of vegetable hybrid seed is moving from Thailand to Vietnam).

Technical services needed by vegetable-related food and seed companies

The questionnaire listed several technical services that AVRDC could offer to the private sector, and respondents were asked to make choices based on their needs. The results are given in Table 113.

The companies suggested other technical services that would be of value, but which are as yet not offered by AVRDC: collaborative research on the development of disease/insect resistant varieties, production of disease inoculum and inoculation methodology, disease resistant germplasm materials, training courses related to cucurbits and solanaceous vegetables, tissue culture techniques, seed viability tests, gene transformation, and radioactivity treatment.

Most (94%) of the food companies and all of the seed companies indicated that a reasonable service charge would be acceptable.

Contract research projects

In 1998–99, AVRDC was granted 21 contract research projects from the Council of Agriculture and the National Science Council, ROC. In addition, the AVRDC pepper and tomato units conducted three contract research and development projects under agreements with two private companies (Seminis Vegetable Seeds and Kagome) and a public corporation (Taiwan Sugar Research Institute).

Contact: N C Chen

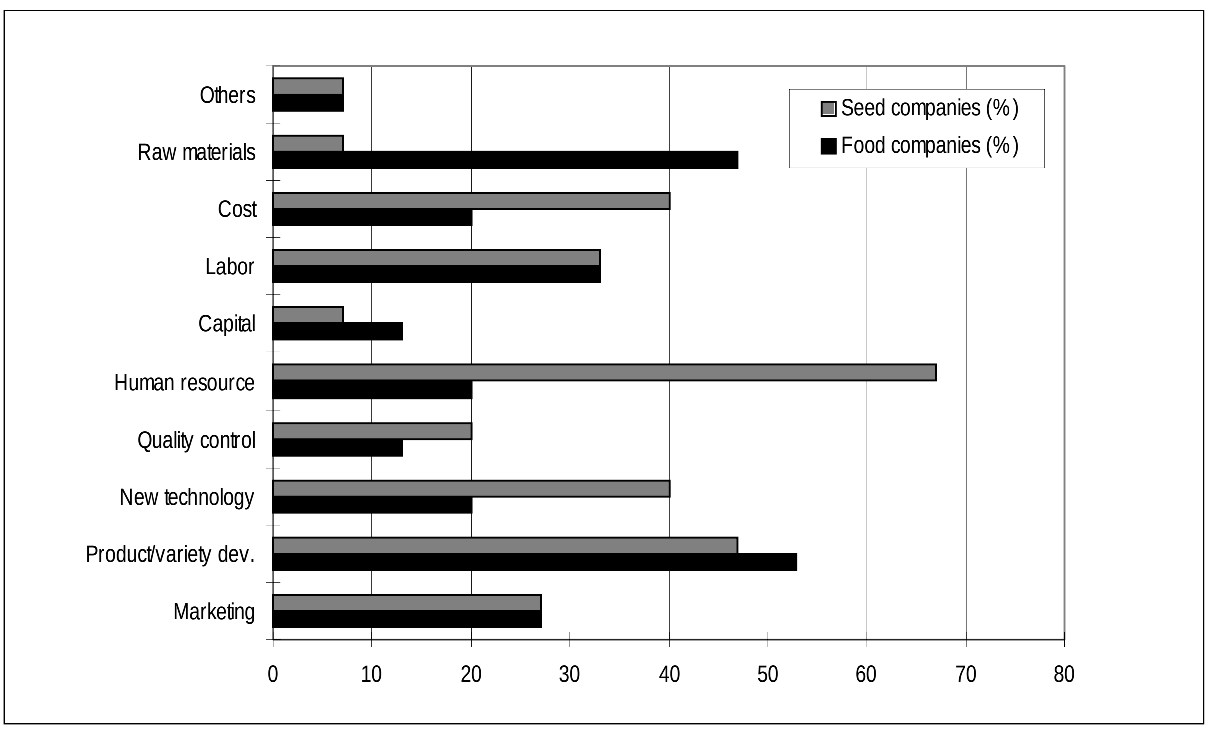

Figure 21. *Relative importance of constraints in food and seed companies as perceived by survey respondents.*